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ANÆSTHETICS

AND THEIR

ADMINISTRATION

A TEXT-BOOK FOR MEDICAL AND DENTAL PRACTITIONERS AND STUDENTS

BY

SIR FREDERIC W. HEWITT, M.V.O.
M.A., M.D. CANTAB.
ANÆSTHETIST TO HIS MAJESTY THE KING
LATE ANÆSTHETIST TO HIS MAJESTY KING EDWARD VII.
PHYSICIAN-ANÆSTHETIST TO ST. GEORGE'S HOSPITAL
CONSULTING ANÆSTHETIST AND EMERITUS LECTURER ON ANÆSTHETICS AT THE LONDON HOSPITAL
LATE ANÆSTHETIST AT THE LONDON HOSPITAL, CHARING CROSS HOSPITAL
AND THE ROYAL DENTAL HOSPITAL OF LONDON

FOURTH EDITION

PREPARED WITH THE ASSISTANCE OF

HENRY ROBINSON, M.A., M.D., B.C. CANTAB.
ANÆSTHETIST TO THE SAMARITAN HOSPITAL AND TO THE CANCER HOSPITAL

WITH ILLUSTRATIONS

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PREFACE TO THE FOURTH EDITION

THE present edition differs from its predecessors in several respects. In the first place its publication has been rendered imperatively necessary by the extraordinary changes that have recently taken place in the practice of anæsthesia—changes so revolutionary in their character that large sections of the book have had to be completely rewritten. In the second place it contains two wholly new chapters—added after much deliberation—one on local and regional anæsthesia, and the other on the medico-legal aspects of surgical anæsthesia in general. And in the third place it is, to some extent at least, a joint product, for in view of the extensive revision which was needed to bring the work thoroughly up to date in a comparatively short space of time, and of the special knowledge required for the adequate treatment of the medico-legal side of the subject, I was obliged to obtain no small measure of assistance.

Whilst in a state of some perplexity as to whom to entrust with the work of generally revising the book, I was struck by the force and lucidity of certain anonymous articles on surgical anæsthesia which appeared in one of our medical journals; and hearing, quite accidentally, that they had been written by Dr. Henry Robinson, I decided to try to secure his co-operation. Fortunately I was successful, and I take this early opportunity of expressing to him my sincere gratitude for the time and labour he has ungrudgingly expended in helping me to present to the reader, in true perspective, all that is worthy of record in this rapidly developing subject. I cannot help feeling that the book has greatly benefited by the independent opinion often expressed by Dr. Robinson on various technical points.

As will be seen by reference to the last chapter, the medico-legal aspects of surgical anæsthesia have received that masterly treatment at the hands of Mr. Digby Cotes-Preedy which, from the name and position he has made for himself at the bar, we might be certain they would receive. I here tender him my very best thanks for his valuable contribution. I had hoped that before going to press Mr. Cotes-Preedy would have been able to chronicle, in his article, the passage of an Anæsthetics Act protecting the public against the use of anæsthetics by unqualified persons. It is a deplorable fact, however, that in spite of the representations of the Home Office Departmental Committee, which was appointed to inquire into the question, of the General Medical Council, and of practically every academic and professional body whose opinions were ascertained, no steps have yet been taken by the Government to pass into law the draft Bill which has now been before them for the past year. That the second decade of the twentieth century should have opened whilst it is still legally permissible for the most ignorant and untrained person to administer an anæsthetic is, I venture to submit, a reproach to our country, and one which I trust will be removed at no distant date.

To my friend Professor A. D. Waller, F.R.S., I am again deeply indebted, not only for his kindness in looking over the proofs of the two chapters dealing—I fear very inadequately—with the physiology of anæsthesia, but for the courtesy and consideration he has invariably shown me whilst I have enjoyed the privilege of being associated with him on the Anæsthetics Committee of the British Association for the Advancement of Science. His fearless attempts to arrive at the truth of every problem with which he deals have appealed to me in no small degree, and I here gladly bear testimony as a clinical worker to the great value of the many physiological contributions he has made to the subject in which we are jointly interested.

FREDERIC W. HEWITT.

QUEEN ANNE STREET, W.,
May 1912.

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CHAPTER I

THE EVOLUTION OF SURGICAL ANÆSTHESIA

It is quite impossible to say at what period in the world's history attempts were first made to prevent or relieve physical pain, nor can we do more than speculate with the uncertainty of ignorance as to the precise means which were first adopted for the mitigation of human suffering. That the ancient Egyptians, Assyrians, and Chinese were familiar with many vegetable substances capable of producing pleasurable, sedative, and anodyne effects [1] all writers upon this subject are agreed, and there can be no reasonable doubt that they took advantage of these effects when practising the rudimentary surgery of the time. The earliest record of the use of a nepenthe or narcotic is to be found in the following passage from Homer's *Odyssey* :[2]—

> Presently she (Helen) cast a drug into the wine whereof they drank, a drug to lull all pain and anger and bring forgetfulness of every sorrow. Whoso should drink a draught thereof, when it is mingled in the bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face, and his own eyes beheld it.

The Bible and the Talmud also contain references to the ancient practice of inducing torpor or deep sleep by artificial means; whilst Herodotus specially makes mention of the

[1] For additional information respecting the early history of anæsthesia I would refer the reader to those writers from whose works I have myself collected much valuable information, viz. *Chloroform and other Anæsthetics*, by John Snow, M.D., 1858; *Leçons sur les Anesthésiques et sur l'Asphyxie*, by Claude Bernard, 1875; *Artificial Anæsthesia and Anæsthetics*, by Henry M. Lyman, 1883; and *Les Anesthésiques*, by Dastre, 1890.

[2] *Odyssey*, iv. 220. Butcher and Lang's translation.

custom of the Scythians of inhaling the fumes of a certain kind of hemp, the effect of which was to produce an exalted mental state followed by sleep.

The earliest allusion to the employment of narcotics for the relief of pain during surgical operations appears in the writings of Dioscorides,[1] who lived at the beginning of the Christian era. He refers to the practice of boiling in wine the root of the *Atropa Mandragora* and of administering a certain quantity of the decoction

> before operations with the knife or actual cautery, that they may not be felt.

Pliny,[2] too, who was contemporary with Dioscorides, makes similar statements as to the powers of the mandrake, and in addition informs us that the seeds of the Rocket plant (*Eruca*) were sometimes infused in wine and taken by criminals about to undergo the lash in order to

> produce a certain callousness or hardihood of feeling.

In the second century Galen [3] makes mention of the

> power of mandragora to paralyse sensation and motion ;

and about the same time Lucian,[4] a Grecian historian, wrote :—

> He (Demosthenes) rouses his fellow-citizens, unwilling as if put to sleep by mandragora, employing his outspokenness as a sort of cutting and cauterisation of their apathy.

According to a French author,[5] there flourished in the third century a certain Chinese surgeon named Hoa-tho, who was in the habit of stupefying his patients, and possibly rendering them unconscious during surgical operations (incisions, acupuncture, amputations, etc.), by administering to them a preparation of hemp.

Coming to more recent times, we have evidence that in the thirteenth century of our era Hugo de Lucca, a Tuscan physician, prepared a certain oil with which he claimed

> that by means of smelling alone he could put patients to sleep on occasions of painful operations ;

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1 *De Med. Mat.* bk. iv. § 76.

2 Lib. xxxv. cap. 94.

3 Lib. vii. p. 207.

4 *Demosthenes' Encomium*, p. 36.

5 See *On Chloroform and other Anæsthetics*, by John Snow, M.D., p. 4.

but according to the testimony of Theodoric, his assistant, the vaunted preparation left much to be desired, for the patients had to be tied or held down by strong men. There can be no doubt, however, that it was the practice of many surgeons of the Middle Ages to produce some degree of stupefaction or insensibility during surgical operations, as is evident by the following extract from Du Bartas, a poet who lived in the middle of the sixteenth century :—

> Even as a surgeon minding off to cut
> Some cureless limb, before in use he put
> His violent engines on the vicious member,
> Bringeth his patient in a senseless slumber,
> And griefless then, guided by use and art
> To save the whole, cuts off the affected part.

In the year 1540, Valerius Cordus discovered sulphuric ether, but its narcotic properties were not recognised until three centuries later.

We are informed that in 1589 Giaubattista Porta, a surgeon who practised in Naples, used an essence made from hyoscyamus, solanum, poppy, and belladonna, enclosed in a leaden vessel, and

> the lid being opened, the patient would draw in by breathing the most subtle strength of the vapour, so that thereby he would be buried in a most profound sleep, nor be aware of what had been done to him.

Early in the seventeenth century, Shakespeare [1] makes Cornelius, a court physician, prescribe a drug which

> Will stupify and dull the sense awhile ;
> . . . but there is
> No danger in what show of death it makes,
> More than the locking-up the spirits a time,
> To be more fresh, reviving.

It was about this time that attempts were made in Italy, and particularly by Valverdi, to obtain unconsciousness by compression of the vessels of the neck—a procedure which is said to have been employed by the ancient Assyrians when circumcising children.[2]

In 1661 Greatrakes produced "magnetic sleep" by means

[1] *Cymbeline,* Act. i. sc. 5. [2] Claude Bernard, *op. cit.*

of stroking and making passes over the patient's body. A century later, in 1766, Anthony Mesmer evolved his theory of "animal magnetism" in a work on *The Influence of the Planets in the Cure of Disease.* After an almost equal lapse of time, James Braid of Manchester, in 1843, inaugurated modern hypnotism by the publication of his treatise on *Neurypnology, or the Rationale of Nervous Sleep.*[1] A few years later, while practising in India, Esdaile successfully induced hypnotic anæsthesia in a large number of native subjects, performing upon them a variety of surgical operations, many of which were, as the interesting records show,[2] of a severe character. From time to time, since the days of Esdaile, hypnotism has been similarly applied; but as success is only attainable with certain subjects, and as there are numerous moral objections to the system, hypnotic anæsthesia is now generally regarded as possessing scientific interest rather than any real practical value.

It was not until the very close of the eighteenth century that our modern system of anæsthesia began to be foreshadowed. Up to this time the various means which had been adopted for the prevention of pain during surgical operations had been utterly unreliable—in other words, true anæsthesia, in the modern sense of the term, had never been attained. But the discovery of hydrogen by Cavendish (1766), of nitrogen by Rutherford (1772), of oxygen by Priestley (1774), and of nitrous oxide by the last-named observer (about the same date), marked the commencement of a new era in chemical physics, and paved the way for the introduction into medical practice of a new, precise, and reliable system of inducing the most complete unconsciousness, and of maintaining this state for any reasonable time without injurious consequences. The medical world gladly welcomed the idea of the therapeutic employment of vapours and gases. Thus in 1795 we find Dr. Pearson of Birmingham employing ether as an inhalation for the relief of asthma. In 1798 a "Pneumatic Institute" was inaugurated at Clifton by Dr. Beddoes, and in this Institute he proposed to treat phthisis and many other diseases by the

[1] See *Braid on Hypnotism.* New edition, 1899.

[2] *Natural and Mesmeric Clairvoyance, with the Practical Applications of Mesmerism in Surgery and Medicine,* by James Esdaile, M.D., 1852.

inhalation of gaseous and vaporised substances. Mr. (afterwards Sir) Humphry Davy was then Dr. Beddoes's assistant, and carefully studied the action of nitrous oxide. On one occasion, when suffering from the pain of cutting a wisdom tooth, he inhaled this gas, and found the pain was thereby considerably mitigated. In the year 1800 he wrote:—

> As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place.

Curiously enough, as we shall presently see, this important suggestion was not turned to practical account in surgery till nearly half a century later.

According to a recent writer,[1] to whom our thanks are due for the interesting information he gives us, Henry Hill Hickman, a young English surgeon, who commenced practice in Ludlow, Shropshire, in the year 1820, vainly endeavoured to direct the attention of the profession, both in England and in France, to the possibility of preventing pain during surgical operations by certain inhalation methods which he had applied experimentally to lower animals, and which he was willing and anxious to demonstrate. In some of his experiments Hickman destroyed consciousness by the simple exclusion of atmospheric air, or by causing the animal to breathe his (the experimenter's) expired air, whilst in other cases he used carbonic acid gas or nitrous oxide gas for the purpose. Having failed to overcome the scepticism and condemnation with which his proposals were received in his own country, he appealed to King Charles X. of France for a full inquiry by leading French physicians and surgeons into the experiments he had conducted. In the autumn of 1828 his letter to the King was referred to the Royal Academy of Medicine, but although a committee of inquiry was appointed, Hickman was never summoned to demonstrate his methods. He died in the following year at the early age of 29.

As the effects produced by different gases and vapours became more generally known, distinct points of similarity began to appear between nitrous oxide and ether. The

[1] "Henry Hill Hickman: A Forgotten Pioneer of Anæsthesia," *Brit. Med. Journ.*, April 13, 1912, p. 843.

exhilaration and hilarity produced by the former led to the term "laughing gas." In 1818 an article, believed to have been written by Faraday, appeared in the *English Quarterly Journal of Science and Arts*,[1] containing the following interesting passage:—

> When the vapour of ether mixed with common air is inhaled, it produces effects very similar to those occasioned by nitrous oxide. . . . It is necessary to use caution in making experiments of this kind. By the imprudent inspiration of ether a gentleman was thrown into a very lethargic state, which continued with occasional periods of intermission for more than thirty hours. . . .

It was not an uncommon event, about this time, for lecturers upon scientific subjects to demonstrate practically the intoxicating properties of ether; and owing to the exhilarating and pleasurable sensations which the vapour produced, it became customary, particularly in certain country districts in the United States, for young people to engage in so-called "ether frolics." It is, indeed, to this latter circumstance that the discovery of surgical anæsthesia may be traced,[2] although it is difficult or impossible to decide to whom the chief credit of the discovery should be assigned.

There seems to be no reasonable doubt that in 1842 Dr. Crawford W. Long, a country practitioner, of Jefferson, Jackson County, Georgia, U.S.A., administered ether vapour with the distinct object and fortunate result of producing insensibility to pain during a surgical operation which he performed, and that he subsequently employed the same means with equal success. Long and his assistants had been in the habit of occasionally inhaling ether for amusement, and noticing that bruises had been unconsciously sustained not only by himself but by his assistants whilst in a state of ether intoxication, Long decided to test the anæsthetic effects of the vapour in surgical practice. He appears, however, to have taken no steps to make his important results known beyond the immediate circle in which he lived; indeed, it was not

[1] I am indebted to Lyman for this and other references.

[2] See an interesting pamphlet by Dr. Marion Sims, *The Discovery of Anæsthesia*. Dr. Sims and Dr. Lyman, who have carefully sifted the conflicting evidence in the controversy as to the discovery of anæsthesia, agree in their views, and it is surprising that more attention has not been paid to the facts which they have collected.

until some years later, when the rival claims of others were being hotly contested, that his own claims were brought forward and substantiated.[1]

The next step in the evolution of anæsthesia took place in 1844, when Davy's predictions regarding the future of nitrous oxide in surgery became for the first time realised. In this year, Mr. Horace Wells, a dentist of Hartford, Conn., was present at a popular entertainment given by Mr. Colton, a lecturer on chemistry, and noticing, as Long had done in the case of ether, that one of the audience who had inhaled "laughing gas" had unconsciously sustained injuries whilst under its influence, he determined to test its merits as an anæsthetic in dentistry. He accordingly inhaled some of the gas, and a friend of his extracted a tooth for him without the slightest pain being experienced. The result was so marvellous that Wells immediately began to employ nitrous oxide in his own practice, and so convinced was he of the importance of his discovery that he soon gave a public demonstration in the surgical theatre of the Harvard Medical School. Owing, however, to the want of knowledge which necessarily prevailed as to the principles upon which the administration should be conducted, the demonstration proved a fiasco, and both Wells and his anæsthetic fell into undeserved discredit. For some time, however, Wells continued to employ nitrous oxide in his practice, and with considerable success; but so keenly did he feel the contumely of his fellows and the failure of his hopes and schemes, that, on 14th January 1848, he destroyed his life. It is stated[2] that he opened a vein whilst in his bath, at the same time securing euthanasia by the inhalation of ether vapour.

The year 1846 is memorable as having witnessed the next advance, viz. the recognition and dissemination of the fact that by the inhalation of ether vapour complete surgical anæsthesia could be produced. In this year Mr. Wm. T. G. Morton, a former pupil and partner of Horace Wells, consulted the latter as to the manufacture of nitrous oxide. Wells referred Morton to a well-known chemist, Dr. Charles Jackson,

[1] A full account of Long's work is given by Dr. Buxton, *Lancet*, March 9 and 23, 1912.

[2] Dastre, *Les Anesthésiques*, 1890.

who suggested that instead of employing nitrous oxide, Morton should try sulphuric ether, which was far easier to obtain. Acting upon Jackson's suggestion, and unaware of Long's results, Morton administered ether vapour in two or three dental cases, and with such success that he gave a public demonstration of his discovery in the General Hospital of Massachusetts on 17th October 1846, whilst Dr. Warren operated. This time the anæsthesia left little or nothing to be desired. It is regrettable that Morton tried to keep the nature of his anæsthetic a secret, securing a patent for it, and calling it by the name of "Letheon." Secrecy, however, was out of the question, owing to the characteristic odour of ether vapour; Dr. Bigelow soon detected the nature of Morton's anæsthetic, and at once sent the news to London, from which centre it is needless to say it rapidly spread throughout the civilised world.

From these facts it will be seen that the credit of the discovery of surgical anæsthesia, in the modern sense of the term, can hardly be ascribed to any one individual. Long, Wells, Morton, and Jackson, of whom America may justly be proud, were one and all instrumental in the great work. Although it is true that Long took no steps towards enlightening and benefiting the world at large by the remarkable discovery he had made, and that had it not been for the labours of his more enterprising countrymen, Wells and Morton, the blessings of anæsthesia might for many years have remained unknown, his well-conceived and fearless line of action deserves no small degree of admiration and respect. To Horace Wells belongs the honour of first intentionally producing surgical anæsthesia by means of nitrous oxide, and of attempting to establish by a public demonstration that system of inducing insensibility to pain which has since spread into all countries. And to Morton our thanks are due as being the first to introduce ether into surgical practice, and to make known the possibility of maintaining continuous anæsthesia during surgical operations. It is a remarkable and deplorable fact that, with the exception of Long, all these pioneers in the hitherto untrodden field of practical anæsthesia ended their days with symptoms of mental aberration or actual insanity. The legacy, however, which they left behind them has proved to be, and will for ever remain, of incalculable value to humanity.

The first operation performed in England under a general anæsthetic took place at the house of Dr. Boott in Gower Street, London, on 19th December 1846. Dr. Boott had received from Dr. Bigelow the news of the discovery of ether anæsthesia, and he communicated this news to Mr. Robinson, a neighbouring dentist, who, having devised an inhaler for the administration, extracted a tooth from a patient without inflicting the slightest pain. Two days later Mr. Squire administered ether to two patients at University College Hospital; Mr. Liston amputated a thigh in the one case and removed an in-growing toe-nail in the other.[1] On the 19th of January 1847, Dr. (subsequently Sir) J. Y. Simpson employed ether for the first time in midwifery practice, and found that the pains of labour may be wholly abolished without interfering with uterine contractions.

On 8th March 1847, Flourens announced to the Académie des Sciences[2] that chloroform exerts on the lower animals an anæsthetic action analogous to that of ether; but, curiously enough, little or no notice appears to have been taken of this observation. Later in the year, Simpson, who had for some time been endeavouring to find a less irritating and more convenient anæsthetic than ether, happened to consult Mr. Waldie, a scientific chemist of Liverpool, who suggested that chloroform, one of the constituents of "chloric ether," which was then therapeutically employed as a carminative, and contained chloroform mixed in varying proportions with rectified spirit, might be tried with advantage. Attempts had already been made to induce anæsthesia by means of the vapour of "chloric ether"; but such attempts had, for obvious reasons, failed. Simpson soon satisfied himself that the vapour of chloroform, the more active ingredient of "chloric ether," is capable of producing anæsthesia, and he lost no time in benefiting others by the discovery he had thus made. On 10th November 1847 he read a paper entitled "Notice of a New Anæsthetic

[1] A most interesting account of this great event is published in the *University College Hospital Magazine*, February 1911.
[2] *Comptes rendus*, t. xxiv. p. 342, 1847.

Agent as a Substitute for Ether in Surgery and Midwifery"; and as a result of this paper, and of Simpson's subsequent writings, chloroform rapidly began to supplant ether in general surgery. This is not surprising, for its vapour is more agreeable, it less frequently induces struggling and intoxication, its action is more speedy, and it is altogether more convenient and manageable. It was for a while believed to be absolutely safe, but the death of a young woman named Hannah Greener, on 28th January 1848, soon dispelled this idea. From time to time similar casualties occurred, and it soon became apparent that whatever might be the advantages of the new agent, the administration of chloroform was by no means without its grave risks to life. As death after death was reported, all kinds of theories were advanced to explain them. The greatest ignorance, however, prevailed, and several years passed by without any definite light being thrown upon the causation of these melancholy accidents.

In 1847 Flourens also drew attention to the anæsthetic properties of ethyl chloride, and in the following year Heyfelder first administered the vapour of this substance for a surgical operation. Although Heyfelder's administrations were successful it was not until the year 1895 that ethyl chloride became a recognised general anæsthetic.

The first attempts to place the administration of chloroform and ether upon a sound and scientific basis were made by Dr. John Snow, whose classical work *On Chloroform and other Anæsthetics* was published in 1858. Snow investigated the physical properties of the vapours of various anæsthetics; he performed a large number of experiments upon lower animals, with the object of determining the physiological effects which these agents produced; and he collected all the clinical and experimental evidence which was then available, in order to ascertain the precise way in which death occurs under chloroform, ether, and other gaseous or volatile substances. He was the first to describe the effects produced by the inhalation of definite percentages of chloroform vapour and air. He came to the conclusion that, in the case of chloroform, fatalities usually arise from primary cardiac paralysis, due to the inhalation of too concentrated a vapour; and working on this assumption, he devised and used the first chloroform inhaler by which the percentage of vapour could be regulated. Subsequent research has tended to show that some primary interference with respiration is generally present in chloroform casualties, although there can be no doubt that chloroform is, as Snow maintained, a direct cardiac depressant. Among the substances investigated by Snow, reference must be made to amylene—an anæsthetic which he was the first to administer, and one which he used in a considerable number of cases. The biography of Snow, written by his friend the late Sir B. W. Richardson, is full of interest, as showing the scientific enthusiasm with which Snow worked. To quote his biographer:

> His greatest deduction . . . and the proofs on which it is based, are to be found in his observations, where he explains that the action of the volatile narcotics is that of arresting or limiting those combinations between the oxygen of the arterial blood and the tissues of the body which are essential to sensation, volition, and all the animal functions. He demonstrated that these substances modify, and in large quantities arrest, the animal functions in the same way and by the same power as that by which they modify and arrest combustion, the slow oxidation of phosphorus and other kinds of oxidation unconnected with the living body when they (the narcotics) are mixed with atmospheric air.

By the death of Snow the advance of the subject suffered a distinct check. One of the results of his indefatigable labours was to direct attention to the hitherto unrecognised fact that by care and attention to detail deaths during anæsthesia could, to a very large extent, be avoided. Snow had not only shown himself to be an ardent seeker after truth, but a successful and skilful anæsthetist: not only had he investigated the subject from its scientific side, but he had silently demonstrated the importance of what may be called the personal factor in anæsthetising. Of those who continued the work which he had commenced there is no one to whom we are so much indebted as the late Mr. J. T. Clover, whose ingenuity and mechanical ability found such a happy sphere of activity in this department of practice. Snow's mantle, indeed, fell upon a successor who was conspicuously fitted to carry on work so ably begun. The first step taken by Clover was to perfect the principle of chloroform administration upon which Snow had laid such stress; and in 1862 he published an account of his chloroform inhaler, by which the administrator could adjust, more accurately than had hitherto been possible, the percentages of chloroform vapour and air. With this apparatus Clover anæsthetised a large number of patients, but not without becoming convinced that, so far as safety was concerned, chloroform was a less satisfactory anæsthetic than ether. He therefore set himself to the task of rendering ether anæsthesia as practicable as that of chloroform, and, as we shall subsequently see, this task he successfully accomplished.

The physiology of anæsthesia next began to attract attention not only in this country, but throughout the world. In 1864 a committee of the Royal Medical and Chirurgical Society, which had been appointed "to inquire into the uses and the physiological, therapeutical, and toxical effects of chloroform," issued an important Report (see p. 115). They agreed, in the main, with Snow's conclusions as to the danger of concentrated chloroform vapour, and strongly recommended as a substitute for this anæsthetic a certain mixture of alcohol, chloroform, and ether, which had been originally proposed and used by Dr. George Harley, and which has since been extensively employed under the name of the A.C.E. mixture. Elaborate investigations into numerous physiological questions were also made at about this time by Claude Bernard, Benjamin Richardson, and others.

In 1867 Richardson introduced to the notice of the profession a new agent for producing general anæsthesia, to which he gave the name "bichloride of methylene"; and for some time this substance, which was considered to possess many advantages over chloroform, was favourably received by surgeons. For reasons, however, which will appear in subsequent pages "bichloride of methylene" enjoyed but a brief reign.

In the same year, Dr. Junker described[1] his ingenious apparatus for administering chloroform—an apparatus which has proved to be of great value, more particularly in the surgery of the mouth, throat, and nose.

It was about this time that nitrous oxide began to regain the footing it had lost by Wells' untimely end and by the

[1] *Medical Times and Gazette*, 30th November 1867, vol. ii. p. 590, and 1868, vol. i. p. 171.

failures which had attended his earlier administrations. Its revival is attributable to the energetic advocacy of Colton, the lecturer at whose demonstration Horace Wells had, about twenty years before, conceived the idea of painless tooth extraction. In 1863 Colton formed an association in New York for the performance of dental operations under the influence of "laughing gas"; and the reports of his cases were so satisfactory that dentists began to give the matter their serious consideration. In 1864 Mr. Rymer, a London dentist, recorded several successful cases in which he had secured anæsthesia by means of nitrous oxide. It was not, however, till 1867, when Colton himself visited Paris and demonstrated before Dr. Evans, an English dentist practising in that capital, his methods of procedure, that the revived anæsthetic began to find widespread favour. On 31st March 1868 Evans came to England and gave a demonstration at the Dental Hospital of London (then in Soho Square); and on 7th December of the same year a joint committee of the Odontological Society and of the Dental Hospital issued a Report which was so favourable to nitrous oxide that from that time onwards this gas has occupied the foremost place amongst the general anæsthetics of modern dentistry.

So many chloroform accidents occurred during the twenty years that succeeded Simpson's discovery that many surgeons began to discard this anæsthetic and to return to ether. In the United States ether held its own from the first; but in all other parts of the world, and more particularly in its native country, chloroform had to a very large extent supplanted its rival. The opportune discovery by Clover of the "close" system of ether administration greatly strengthened the position of the latter anæsthetic. Clover adopted the system of air limitation during etherisation; he improved the methods for administering nitrous oxide, both alone and as a preliminary to ether. In 1876 he published an account of his ingenious apparatus by which nitrous oxide and ether could be administered either separately or in succession; and in the following year he described his "portable regulating ether inhaler," which has since deservedly enjoyed a wide reputation.

The next point which occupied the attention of those interested in the progress of anæsthesia was the precise action of chloroform, and, more particularly, of lethal quantities of chloroform upon the mammalian organism. The first purely physiological research upon this subject was conducted by the "Glasgow" Committee of the British Medical Association, whose Report appeared in 1879. The Committee found that blood-pressure and cardiac action under chloroform are distinctly lowered, and whilst admitting that, in deaths from this anæsthetic, respiration generally ceases before cardiac action; they contended that the reverse may occur, that is to say, that the heart may be primarily paralysed. This view was in harmony with that advanced by Snow, but it was opposed to the principles laid down by Syme and the Edinburgh school. The famous Scotch surgeon had taught that chloroform never produces primary depression of the heart, and that, provided the respiration is carefully watched and the pulse disregarded, it is a perfectly safe anæsthetic. In order that this disputed point might be settled, the Nizam of Hyderabad, at the suggestion of Surgeon-Major Lawrie, who had for many years strenuously upheld the teaching of Syme, very generously granted a sum of money for still further prosecuting scientific research, and, as the result, the First Hyderabad Chloroform Commission was appointed. Numerous experiments upon lower animals were made, and the conclusions at which the Commission arrived were in complete harmony with the teaching of the Edinburgh school. The medical profession, however, hesitated to accept these conclusions, and it was accordingly proposed to institute a Second Commission to carry out further physiological experiments upon a large scale. The Nizam again most liberally aided the project by supplying funds, and Dr. (now Sir) T. Lauder Brunton, who had been nominated by the *Lancet*, left England for Hyderabad in order to take part in the work. The voluminous Report of this Commission appeared in 1891, and in all essential details it corroborated the conclusions at which the First Commission had arrived. Finality, however, had not yet been attained; for not only was it soon shown by eminent physiologists that there were numerous fallacies in the technical work of the Commission, but that many of the tracings upon which criticism had been invited were capable of interpretations differing from those assigned to them.

Amongst the numerous independent physiological researches which have been undertaken with the object of settling the chloroform question, mention must be made of the investigations of Bert, MacWilliam, Gaskell, Shore, Leonard Hill, Embley, Sherrington, Schafer, Waller, Buckmaster and Gardner. Bert's researches, which will be found described in subsequent pages, were in reality little more than a repetition of those conducted by Snow many years previously, and the results at which the French observer arrived were in the main identical with those of Snow. MacWilliam, Gaskell, Shore, and Leonard Hill have successfully accomplished the difficult task of harmonising the more important of the conflicting facts with which the subject was surrounded when they entered the controversial field. It has been conclusively shown by them, and may be accepted as proved, that when chloroform is administered to the full surgical degree, it undoubtedly acts as a cardiac depressant. The subsequent researches of Sherrington and Sowton corroborate this view. In summing up the matter, therefore, it may be said that although there are some who still adhere to the Hyderabad doctrine, and regard chloroform as a drug which reduces arterial tension and depresses respiration, without interfering with cardiac action, the balance of present evidence is opposed to this view, and is in favour of the rival and more reasonable proposition, viz. that the fall of arterial tension which occurs is largely due to a direct effect of the anæsthetic upon the heart substance; and that whilst it is perfectly true that respiration usually ceases before the heart fails, it is the effect of the anæsthetic upon the circulation, and not its influence upon the respiration, which is the characteristic and principal element in chloroform syncope. For further details on this point the reader is referred to Chapter IV.

Since the days of Clover much labour has been expended in efforts to diminish the dangers and inconveniences of general anæsthesia. Amongst these labours a foremost place must be given to those which have had as their object the prevention or correction of the natural tendency of all anæsthetics to bring about intercurrent asphyxial conditions. There can be no doubt that if there is one principle which is more important than any other in administering all general anæsthetics, it is that a free and unobstructed airway is absolutely essential to safe anæsthetisation. Whilst it may, perhaps, be going too far to say that obstructed breathing is a more frequent cause of death than simple overdosage, it may unhesitatingly be affirmed that it is just as important to guard against the one as to guard against the other. Clinical researches, concerning the effects of administering different percentages of air and of oxygen with nitrous oxide, led to the establishment of that system of administering nitrous oxide and oxygen which is now in common use, and which is unequalled so far as actual safety to life is concerned. It may be said, indeed, that the loss of consciousness which can be secured by a non-asphyxial nitrous oxide anæsthesia is practically free from risk to life. Oxygen has also gradually come into favour as a substitute for atmospheric air during the administration of chloroform; but it is questionable, in the light of more recent observations, whether such a substitution is necessary except in patients suffering from grave respiratory or cardiac conditions.

The mechanical problems of anæsthesia to which Snow and Clover had devoted such fruitful attention became a conspicuous feature in the development of this subject during the close of the nineteenth and the beginning of the present century. Those interested in anæsthetics began to vie with one another in their efforts to secure ideal results by mechanical means, and the most varied and complex inhalers were devised. An increase in the calibre of the inhalers used for nitrous oxide, and for ether, greatly improved the effects obtainable by these two anæsthetics, and led to the use, upon a large scale, of numerous comparatively complicated sequences in which nitrous oxide and ether played an important part. But of all the mechanical devices for anæsthetisation, those which had for their object the administration of chloroform by the percentage system deserve special notice. Snow, Clover, and Paul Bert had one and all found that the chief risk of chloroform lay in undue vapour concentration, and various attempts were made to devise regulating inhalers capable of delivering, with precision, known chloroform atmospheres sufficiently dilute to secure anæsthesia without prejudicially affecting the respiratory and circulatory functions. The first scientifically accurate apparatus seems to have been that of Dubois, which is still used in this country, and to a greater extent upon the Continent. Of those whose physiological researches and mechanical ingenuity have combined to establish the principles upon which chloroform can safely be administered, no one is entitled to greater credit than Professor A. D. Waller, whose "chloroform balance" will be found fully described in a subsequent chapter (p. 103). Amongst the more portable but somewhat less accurate instruments for the percentage administration of chloroform mention must be made of the Vernon-Harcourt inhaler, which has proved itself to be exceedingly valuable in practice. The Roth-Dræger instrument for administering definite percentages of chloroform with oxygen is also worthy of notice. Whatever the drawbacks of these mechanical contrivances may be, in actual practice they undoubtedly render chloroform far safer, *cæteris paribus*, than when administered from some absorbent fabric irregularly moistened with liquid anæsthetic; and they possess considerable educational value in that they are capable of indicating the ideal to be aimed at when no such mechanical contrivances are at hand.

In spite of this great development in chloroform anæsthesia there is, at the time of writing (1912), a distinct tendency towards simpler methods. Slow inductions, by open masks, are gradually replacing rapid inductions by complex and closely fitting inhalers; and mixtures of chloroform with ether—the proportions varying according to the circumstances present—and ether itself, administered by the so-called "open-method," are being used upon an increasing scale in preference to chloroform. It would seem, in fact, that the very steps that have to be taken to render chloroform a safe anæsthetic for routine use are proving themselves in practice to be so irksome that the more widespread employment of this agent, which was predicted by many of its advocates, is very doubtful.

Although there is still much work to be done in the strictly clinical side of this subject, it may be said that our knowledge is much more complete than formerly as to the particular anæsthetics and methods which should be employed in particular cases. Errors in regard to the choice of anæsthetic, although frequently committed, particularly by those who from hurry or other causes have not thoroughly studied their cases, are becoming less and less common. This is doubtless owing to the fortunate circumstance that much more attention is now paid to the factor of the anæsthetic in surgical practice. Simplicity in procedure is becoming the order of the day, and the principles which should be followed in selecting different mixtures and sequences of the two cardinal anæsthetics—ether and chloroform—and of various adjuvant drugs, such as those referred to in Chapter IX., are thus undergoing legitimate and fruitful extension. Moreover, a very important step has been taken during the past few years in preventing, by various means, the occurrence of surgical shock during operations under general anæsthetics. By the preliminary use of atropine, by the more frequent employment of the Trendelenburg posture—which as we now know raises blood-pressure—by subcutaneous saline infusion during anæsthesia, and by the use of mixtures of chloroform and ether, or of ether itself rather than of chloroform, in cases liable to surgical shock, this condition is now rarely met with save in desperately bad subjects, and in operations attended by considerable hæmorrhage. Furthermore, even in those cases in which severe shock is present beforehand, as well as in those in which it occurs from unavoidable causes during anæsthesia, we have, in the recently introduced pituitary extract, an agent which is of the greatest possible remedial value.

It is satisfactory to observe that within recent years more thought has been bestowed than formerly upon what may be termed the *entourage* of general anæsthesia. The patient is more carefully prepared; he is often examined prior to operation, with the special object of deciding upon the most appropriate means of producing anæsthesia; he is spared, as far as possible, all visual and aural distress immediately prior to and during anæsthetisation; special means are employed to conserve the bodily heat during unconsciousness, and precautions are frequently taken to reduce the after-effects of the anæsthetic.

Finally, for cases which for one or more reasons are regarded as unsuitable for inhalation anæsthesia, we have in infusion anæsthesia (p. 357) and in intraspinal analgesia (p. 521) methods which have now been tried with sufficient frequency to deserve consideration. Whilst there can be no doubt that by special care and skill general anæsthesia by inhalation may safely be induced in the vast majority of surgical operations, and that even in many cases which are regarded as unsuitable for this form of anæsthesia, a skilled anæsthetist can safely maintain unconsciousness, there undoubtedly remain a few highly exceptional cases in which one or other of these means should be chosen to secure painless surgery.

CHAPTER II

THE PROPERTIES AND IMPURITIES OF THE CHIEF AGENTS CAPABLE OF PRODUCING GENERAL SURGICAL ANÆSTHESIA

A. NITROUS OXIDE

NITROGEN monoxide (otherwise known as protoxide of nitrogen, nitrous oxide, or "laughing gas") has the chemical formula N_2O. It was first prepared by Priestley towards the close of the eighteenth century.[1]

Properties.—Under ordinary conditions nitrous oxide is a colourless, transparent, feebly refractive gas, with a peculiar sweetish odour and taste. It may be respired without discomfort when the apparatus for its administration is properly constructed. When pure it is wholly devoid of irritant properties, so that it is particularly useful in cases in which other anæsthetics excite cough, swallowing, etc. Water at 0° C. dissolves a little more than its own volume, but the solubility diminishes as the temperature of the water is raised. Liquefaction takes place under a pressure of 30 atmospheres at 0° C., or 50 atmospheres at 7° C. Liquefied nitrous oxide is a colourless, very mobile body, having a sp. gr. of ·9369 at 0° C. (Andreef). It boils at − 92° C., and melts at − 99° C The steel and iron cylinders in which nitrous oxide is supplied by the manufacturers contain the agent in this liquid form. Roughly speaking, 15 oz. by weight of liquefied nitrous oxide will furnish 50 gallons of the gas. Solid nitrous oxide, in

[1] Roscoe and Schorlemmer (*A Treatise on Chemistry*, 1884) give the date 1772; Watts (*A Dictionary of Chemistry*), 1776. The truth seems to be that the first preparation was in 1772, and the full recognition in 1776. See *Experiments and Observations on Different Kinds of Air*, by Joseph Priestley, vol. i. p. 118, and vol. ii. p. 175.

the form of compact snow, has been prepared by Wills.[1] Sheppard pointed out[2] that the faulty working of nitrous oxide cylinders is often due to superficial solidification produced by the intense cold which results from the conversion of the liquid nitrous oxide into gas. Nitrous oxide is not easily decomposed, a considerable elevation of temperature being necessary to split it up into its constituent gases. When a burning body is placed in the gas, the latter is decomposed, and combustion is supported.

Impurities.—The nitrous oxide supplied for anæsthetic purposes is usually free from impurities.[3] It is stated, however, that the gas has sometimes been found to contain **other oxides of nitrogen**, and **chlorine.** These gases would give the nitrous oxide an irritating odour and would induce coughing. The former impurities would be best detected by passing a slow stream of the nitrous oxide through a cold solution of ferrous sulphate, acidulated with sulphuric acid; should the solution darken, the presence of other oxides of nitrogen would be indicated. Chlorine would be detected by its characteristic odour, and by its precipitating the chloride from a solution of argentic nitrate.

Liquefied nitrous oxide may be preserved for an almost indefinite time in iron or steel cylinders. Some administrators[4] have drawn attention to differences between the gas obtained from liquid nitrous oxide and that which has never been subjected to liquefaction. Such differences probably depend upon the absence of all traces of atmospheric air in the nitrous oxide which issues from the cylinders. If nitrous oxide be kept in a gaseous form, even for a few days, admixture with **air** will be liable to occur.

B. ETHER

Ethyl oxide (otherwise known as ethylic ether, vinous ether, sulphuric ether, or simply ether) has the chemical formula

[1] *Chemical Society's Journal*, II. xii. 21.

[2] See footnote, p. 284.

[3] Some years ago I had the nitrous oxide supplied to the Dental Hospital analysed by an eminent chemist. That obtained from one manufacturer was absolutely pure; that from another contained 1·2 per cent of oxygen.

[4] See *Brit. Journ. Dent. Science*, 15th Dec. 1884 ("Anæsthetics and their Administration," by J. W. Roberts, L.D.S.).

$C_4H_{10}O$, or $(C_2H_5)_2O$. According to Watts[1] it was first prepared by Valerius Cordus in 1540.

Properties.—Ether is a transparent, colourless, very mobile, and highly volatile liquid, possessing a characteristic pungent odour and burning taste. It is perfectly neutral to test-paper. It refracts light strongly. The sp. gr. of pure ether is ·723 at 12·5° C. (Watts), or ·720 at 15·5° C. (Fownes). At 0° C. it is said to have a sp. gr. of ·7356 (Roscoe and Schorlemmer). According to Watts and Fownes it boils at 35·6° C. (96° F.) under the ordinary atmospheric pressure; but other observers (Kopp and Andrews) give the boiling-point as 34·9° C. Its vapour density, as compared to air, is 2·586 (Gay-Lussac), 2·565 (Snow); as compared to hydrogen, 37. Owing to its possessing such a high sp. gr., ether vapour may be poured from one vessel to another, and the process actually watched in bright sunlight. Olszewsky solidified ether, and found the melting-point to be − 117° C. Ether is freely miscible with alcohol, chloroform, and almost all other hydrocarbon compounds. Ether is soluble to a certain extent in water, 1 part dissolving in 10 at 11° C. One part of water, moreover, dissolves in about 34 parts of ether. Ether vapour is highly inflammable, and when mixed with air detonates violently on the approach of a burning body. It burns with a white luminous flame. These facts should be borne in mind, not only when administering in the neighbourhood of a naked flame, but when pouring the liquid from one bottle to another. The actual cautery should never be used about the mouth or nose when the patient is under the full influence of ether.[2]

Impurities.—Pure ethylic ether should be perfectly neutral to test-paper, and should evaporate without leaving any residue whatever. It should, moreover, form a clear mixture in all proportions with oil of copaiba. Ether containing **water** or **alcohol** forms an emulsion with considerable quantities

[1] Watts's *Dictionary of Chemistry* (new ed.), vol. ii. 464.

[2] Kappeler (*Anæsthetica*, p. 173) refers to a case at Lyons, in which, during the use of the cautery in the mouth, the ether vapour ignited. The face of the patient and the bag of the ether inhaler caught fire, and deep burns upon the face resulted. The case is also referred to in the *Brit. Med. Journ.*, 1879, vol. ii. p. 2826. Mr. Marmaduke Sheild records a similar case (*Proc. Med. Soc.*, 1887, vol. x. p. 144), and states that he has also known the expirations of a patient under ether to become ignited by an adjacent lamp. See also two cases reported in *Surgical Observations* by Dr. Warner.

of the oil (Watts). The presence of water may also be detected by means of potassium phosphate, which is insoluble in anhydrous ether, but dissolves partially in ether containing water, a brown residue being left.[1] Tannic acid, which is insoluble in ether but soluble in water, is also used as a test for the latter. Wet ether gives turbidity with carbon bisulphide, and the Pharmacopœia (1898) includes among the tests of Æther Purificatus the following: "It should dissolve in an equal volume of carbon bisulphide (absence of excess of water)." Alcohol is best detected by shaking the ether with water, which removes the alcohol; the aqueous extract is then gently warmed, a few crystals of iodine added, and then so much caustic potash that the solution just becomes colourless; after standing for a few hours, or at most a night, a bright yellow precipitate of iodoform will be thrown down, and the characteristic six-sided tablets or six-sided stellar groups may be examined microscopically.[2] By this test 1 part of alcohol in 2000 parts of water may be detected. When ether is kept in an imperfectly stoppered bottle it is said to absorb oxygen, and to become acid from the presence of **acetic acid.** It is difficult, however, to understand this, for, owing to its extreme volatility, the contents of the bottle would soon altogether disappear. Should acetic acid be present, the ether would, of course, redden blue litmus paper, and an aqueous extract of it would give the reactions for acetic acid. A dark-red coloration with ferric chloride is not characteristic of the presence of acetic acid, as formates and other bodies give this reaction as well. Roscoe and Schorlemmer state that the most characteristic test is the conversion of acetic acid into cacodyl oxide: "For this purpose the acid is saturated with caustic potash, evaporated with a small quantity of powdered arsenic trioxide, and the mixture heated in a test-tube, when the characteristic smell is perceived." Should the aqueous extract contain **sulphuric acid,** it may be detected by the white precipitate (insoluble in hydrochloric acid), which it gives with baric chloride. The Pharmacopœia (1898) includes among the tests to which "purified ether"

[1] Romei, *Zeitschr. anal. Chem.*, 1869, p. 390.

[2] See Roscoe and Schorlemmer, vol. iii. part i. p. 318. See also Watts's *Dictionary of Chemistry*, 2nd Supplement, 1875, art. "Ethyl Oxide."

must conform the following: "On shaking with half its bulk of a dilute solution of potassium bichromate acidulated with sulphuric acid, and setting aside, the supernatant ether should have no blue colour (absence of hydrogen peroxide)." This apparently supersedes the starch test of the older editions, and indicates the official conclusion of the vexed questions to which that test gave rise.[1]

According to Martindale[2] the following kinds of ether are obtainable:—

(1) *From Pure Rectified Spirit*

(i.) *Æther* (Off.). Sp. gr. ·735. Ordinary medicinal ether. Contains a little spirit and water. Not so suitable for inhalation as—

(ii.) *Æther Purificatus* (Off.). Sp. gr. not exceeding ·722, and not below ·720.

(2) *From Methylated Spirit*

(i.) *Absolute Ether—Methylated.* Sp. gr. ·717-·719. Contains a little methylic ether, and is specially adapted for producing local anæsthesia, as it boils under 80°. Not adapted for producing general anæsthesia.

(ii.) *Rectified Ether.* From methylated spirit. Sp. gr. ·720. Well washed to free it from methylic ether, purified, and re-distilled. Well adapted for producing general anæsthesia.

(iii.) *Methylated Ether.* Sp. gr. ·730. For common purposes.

Putting on one side the first and third of the methylated ethers in the above list, which are used either for producing local anæsthesia or for common purposes, and which should never be employed for inhalation,[3] and putting on one side also the ether standing first of all on the list, which is rarely used for inhalation, we are left with "Æther Purificatus" of the British Pharmacopœia, 1898, and "rectified ether from methylated spirit," or, as it is sometimes termed, "pure methylated ether." Opinions are still divided as to the relative merits of these two ethers. The matter is of some practical importance, inasmuch as the Æther Purificatus costs about three times as much as the Methylated Ether, owing to

[1] Prof. Dunstan and Mr. Dymond came to the conclusion that impure ether sometimes contains hydrogen peroxide, though they failed to produce it in pure ether by the prolonged action of oxygen.

[2] *Extra Pharmacopœia*, 1892.

[3] A fatal result has been known to follow the administration of "local anæsthetic ether" (see *Lancet*, 7th August 1875). These impure ethers, when inhaled, produce much irritation, respiratory difficulty, cough, salivation, etc.

the fact that the spirit from which the former is made has to pay a heavy duty. The inexpediency of taxing such drugs as ether and chloroform to the extent of 200 per cent of their value has been represented to the Chancellor of the Exchequer, but so far in vain. In the case of hospitals the difference in price of the two products amounts to a very considerable sum during the year; and it is unjustifiable to use the rectified spirit ether unless it can be shewn to have some definite superiority. To test the feelings of London anæsthetists on this point, one of us (H. R.) has circularised every one who at a certain date held a hospital appointment as an anæsthetist in the metropolis. Out of 53 anæsthetists who were kind enough to answer the form of questions sent to them, 14 use Æther Purificatus only, 28 use Methylated Ether only, and 11 use both. Both the writers (F. W. H. and H. R.) use methylated ether, and they are convinced that when properly prepared its action and its after-effects are indistinguishable from those of ether prepared from dutiable spirit.

C. CHLOROFORM

Trichlormethane, dichlorinated chloride of methyl, perchloride of formyl, commonly known as chloroform, has the chemical formula $CHCl_3$. Liebig, Soubeiran, and Guthrie appear to have independently discovered chloroform[1] in the year 1831; but its real chemical composition was not ascertained till 1834, when Dumas[2] determined its true formula.

Properties. — Chloroform is a colourless, transparent, mobile, and volatile liquid, possessing a pleasant, penetrating odour, and sweet fiery taste. Its sp. gr. at 17° C. is 1·491 (Regnault); at 0° C. 1·52523 (Pierre). Chloroform obtained

[1] According to Roscoe and Schorlemmer, chloroform was discovered in 1831 by Liebig (*Pogg. Ann.* xxiii. 444; *Ann. Pharm.* i. 31, 198), and about the same time, but independently, by Soubeiran (*Ann. Chim. Phys.* [2], xlviii. 131; *Ann. Pharm.* i. 272). The former considered it to be a chloride of carbon; the latter gave it the name "éther bichlorique." According to Watts (*Dictionary of Chemistry*), Liebig's discovery was in 1832; but as Liebig strongly put forward his claims to priority (*Ann. Chem. Pharm.* clxii. 161) it seems certain that, so far as he and Soubeiran were concerned, the discovery was almost simultaneous. Dr. Buxton (*Anæsthetics*, 4th ed. p. 19) points out that Guthrie, an American chemist, manufactured chloroform six months before Soubeiran.

[2] *Ann. Chim. Phys.* lvi. 115; *Ann. Pharm.* xvi. 164.

by crystallisation at an extremely low temperature (Pictet's process) is stated to have a sp. gr. of 1·5002 at 15° C.[1] Wade and Finnemore,[2] who have carefully investigated the subject, state that pure chloroform boils at 61·15° with the barometer at 760 mm. Its vapour density as compared to air is, according to Dumas, 4·199; according to Regnault, 4·230. If the density of hydrogen be taken as 1, that of chloroform vapour is 59·75. Chloroform remains liquid and transparent at −16° C. (Pierre), but may be solidified by the cold produced by its own evaporation. Snow found that chloroform dissolves in about 288 times its volume of water. It is miscible in all proportions with alcohol, ether, and other organic liquids. It is not inflammable, but its vapour is decomposed when passed into a lighted spirit-lamp, and burns with a smoky flame, emitting fumes of hydrochloric acid.

According to Waller and Wells[3] a drop of chloroform from an average pipette weighs 20 mgm., and from a stoppered bottle 25 mgm., whilst the vapour of a drop when inhaled with an ordinary inspiration of from 400 to 500 c.c. of air, supplies a 1 per cent mixture of chloroform and air.

The **percentage composition** of mixtures of chloroform vapour and air containing between 3 and 12 per cent of the former may be rapidly estimated by the absorption of the chloroform vapour by olive oil.[4] For mixtures containing less than 3 per cent of vapour the simple and ingenious densimetric method introduced by Waller and Geets[5] should be employed.

This method consists in the direct weighing on a chemical balance of a flask of known capacity (circa 500 c.cm.), (*a*) filled with air, (*b*) filled with the mixture of chloroform and air. . . . 500 c.cm. of a 1 to 10 per 100 mixture of chloroform and air implies 5 to 50 c.cm. of $CHCl_3$ vapour weighing (on the assumption that 1 gram of liquid $CHCl_3 = 200$ c.cm. $CHCl_3$ vapour) 25 to 250 mg.—the weight of the volume of air displaced by the $CHCl_3$ vapour.

The weight of a litre of $CHCl_3$ vapour at 0° C =

[1] Martindale's *Extra Pharmacopœia*.
[2] *Trans. Chem. Soc.*, 1904, vol. 85.
[3] *Lancet*, 9th July 1904, p. 76.
[4] See *Brit. Med. Journal*, 12th July 1902.
[5] *Ibidem*, 20th June 1903, p. 1421.

$$\frac{12 + 1 + 106}{2} \times 0{\cdot}0895 = 5{\cdot}325 \text{ grams.}$$

The weight of a litre of air = 1·293 grams.

So that a litre of chloroform vapour is 4·032 grams heavier than a litre of air. Or each c.cm. of chloroform vapour replacing 1 c.cm. of air gives an increased weight of 4·032 mg. Taking, then, 4 mg. as the additional weight due to the presence of each 1 c.cm. $CHCl_3$ in the mixture of air and chloroform (corrections for temperature and pressure not included) we have: In a 500 c.cm. flask each 1 per cent (= 5 c.cm.) giving an increment of 0·020 gm.; and in a 250 c.cm. flask each 1 per cent (= 2·5 c.cm.) giving an increment of 0·010 gram. For practical purposes we can avoid calculation and estimate the percentage of chloroform vapour by a direct reading of the difference of weight of a 250 c.cm. flask, (*a*) filled with air, (*b*) filled with the mixture of chloroform and air to be titrated. The excess of the latter counted in centigrams, gives the percentage of the mixture: thus

an excess of		0·010	gram	= 1·0	per 100
„	„	0·050	„	= 5·0	„
„	„	0·027	„	= 2·7	„

Collingwood[1] has also introduced an ingenious "tonometer" for estimating the percentage composition of atmospheres containing chloroform or other anæsthetics: his method is applicable for the estimation of chloroform percentages even when CO_2 is present.

It has been found that chloroform is less liable to decomposition when it contains a very small percentage of absolute ethylic alcohol. One-tenth per cent of alcohol is stated to be sufficient for this purpose.[2] The British Pharmacopœia (1898) therefore prescribes that chloroform shall contain sufficient absolute alcohol to produce a liquid having a specific gravity of not less than 1·490 and not more than 1·495. In chloroform made from alcohol there is also present[3] a small amount of ethyl chloride; and chloroform which contains this impurity is said to give better results clinically than that which does not. In acetone chloroform there is no ethyl chloride; but the addition of 0·25 per cent of the latter renders it physiologically identical with alcohol chloroform.[4]

[1] *Proceedings of the Phys. Soc.*, 12th November 1904, and 25th February 1905.

[2] Dott, *Pharmaceutical Journal*, 1882, p. 769.

[3] Wade and Finnemore, *Journal of the Chemical Society*, 1904.

[4] *Transactions of the Society of Anæsthetists*, vol. vii. p. 89.

There is still a good deal of difference of opinion among anæsthetists as to the advantages of chloroform prepared from methylated spirit, acetone, and rectified spirit respectively. The disparity in price of these three products is as great as in the case of ether (*vide* p. 25). Acetone chloroform costs a little less than methylated; and ethyl alcohol chloroform costs about three times as much as either, owing to the duty on rectified spirit. This difference involves a heavy extra expense on hospitals where the rectified spirit chloroform is in use. Among the 53 London anæsthetists who answered the circular referred to on p. 25, 18 use ethyl alcohol chloroform exclusively in their hospital work; 14 use methylated chloroform only; 4 use acetone chloroform only; 3 use both ethylated and methylated chloroform; 3 use methylated and acetone; 3 use ethylated and acetone; and 3 use all three products. In private work 29 out of the 53 use rectified spirit chloroform solely. The opinions expressed vary widely: several anæsthetists feel convinced that ethylated chloroform is followed by less vomiting, headache, and unpleasant after-effects generally than are the other kinds; but two or three hold exactly the opposite view, that ethylated chloroform is the worst in this respect. Several think that a smaller quantity of ethylated chloroform is required to produce anæsthesia; the teaching of Dr. Edkins, physiologist at St. Bartholomew's Hospital, is quoted by two to this effect. Several anæsthetists believe that acetone chloroform is distinctly inferior to the varieties made from alcohol; two consider it as equal to ethylated chloroform, and regard both as superior to the methylated kind. Two think methylated chloroform keeps better than the others. A few frankly use ethylated chloroform because some of the coroners appear to believe in its superiority. Finally, some anæsthetists use ethylated chloroform when giving it alone, but consider methylated good enough to use in mixtures. We adhere to the belief that, when properly prepared and purified, the actions and after-effects of these three kinds of chloroform are indistinguishable. Sir T. E. Thorpe vouches for the fact that no chemical test will enable an analyst to detect the source from which a properly purified specimen of chloroform has been prepared.[1]

Impurities.—A great deal of discussion has from time to time taken place concerning the nature of the impurities of chloroform, and the responsibility of such impurities for dangerous or fatal symptoms during chloroformisation. Whilst impurities and decomposition products have undoubtedly been found in chloroform which has produced dangerous symptoms, such symptoms have often appeared under the influence of chloroform which has stood with credit the recognised tests of purity. In the present unsettled state of the subject it will therefore be best that we should confine ourselves to indisputable facts.

The chloroform used for anæsthetic purposes should conform to the following tests:—

1. It should possess a sp. gr. and boiling-point such as have been already mentioned.
2. It should be perfectly transparent and colourless.
3. It should be absolutely neutral to test-paper.
4. It should possess an agreeable, bland, and non-irritating odour.
5. When a portion is allowed to evaporate spontaneously from a watch-glass it should leave no residue, either of water or of any substance possessing a strong smell.
6. When shaken with concentrated sulphuric acid no brownish coloration, or only the faintest, should result.
7. It should form no precipitate with a solution of argentic nitrate.
8. It should not acquire a brown colour when heated to the boiling-point with caustic potash.

When protected by a small percentage of alcohol, as above mentioned, chloroform is not easily decomposed. It has been stated by Sir W. Ramsay that exposure to sunlight and air will, in the course of a short time, lead to the formation of carbonyl chloride. This may be detected, on adding baryta

[1] While these pages have been in the press, the Royal Society of Medicine (Anæsthetic Section) has decided to recommend that methylated and acetone chloroforms be made officinal in the next issue of the *British Pharmacopœia*. A new process for manufacturing acetone is also being described, whereby the price of this raw material of chloroform will be very greatly reduced.

solution to the chloroform, by the formation of a white film at the junction of the two liquids. Hydrochloric acid and free chlorine have for several years been known to be present in chloroform which has undergone decomposition, and are to be detected by the chloroform reddening blue litmus paper, forming a precipitate with argentic nitrate, and liberating iodine from a solution of potassium iodide. **Acetic acid, formic acid**, and **aldehyde** are also stated by Kappeler to be producėd by the decomposition of chloroform. The detection of **alcohol** is best effected by making a watery extract of the chloroform, and obtaining the iodoform reaction. According to Kappeler, alcohol may also be conveniently recognised by the turbidity which results when equal parts of oil of almonds and chloroform are shaken together, or by the coagulation which takes place in white of egg when a few drops of the chloroform are added, or by the milky appearance which drops of chloroform assume when allowed to fall through distilled water.[1] When alcohol is present in excess of that quantity which is customarily added, the sp. gr. of the chloroform will, as already mentioned, be lower than 1·49. Alcohol, as well as other easily oxidisable substances, will, if present in chloroform, cause a cold solution of potassium bichromate acidulated with dilute sulphuric acid to turn green. Should **ether** be present it would, like alcohol, lower the sp. gr. of the chloroform. It may, moreover, be detected by dropping a watery solution of iodine into the chloroform. Should the drops remain of an amethyst colour and transparent, the chloroform is pure, but should the drops assume a dark-red colour, ether is present. Crystals of nitrosodic sulphide of iron are insoluble in pure chloroform, but dissolve in the presence of ether or alcohol. Should **methyl compounds** be present they may be detected by the chloroform becoming dark-coloured or black when treated with concentrated sulphuric acid, or by a black oily layer forming when the chloroform is treated with chloride of zinc (Kappeler). According to Roussin,[2] pure chloroform shaken with di-nitrosulphide of iron remains colourless; but if it contain alcohol, ether, or wood spirit, it will acquire a dark colour. Kappeler,[3]

[1] Kappeler, *op. cit.*
[2] Watts's *Dictionary of Chemistry*, "Chloroform."
[3] *Op. cit.*

referring to this test, also states that the reaction is not only caused by the presence of ethylic alcohol and ether, but by aldehyde and amylic alcohol. According to Roscoe and Schorlemmer, pure chloroform does not attack bright metallic sodium, even at the boiling-point. Should the metal become coated with a white coating of chloride, the presence of chlorine compounds, such as **dichlorethane** or **ethylene dichloride**, may be assumed. As a corroborative test of the presence of these impurities, these authors state that the chloroform when heated with alcoholic potash evolves the combustible gas ethylene. In one of the 101 fatal chloroform administrations collected by Kappeler, **allyl chloride** was discovered in the chloroform, but the same chloroform had been used without bad effects in other cases. In another of these cases "higher combinations of chlorine" were found in the chloroform. But in nine of the fatal cases in which the chloroform used was examined no impurity was detected.

Chloroform should always be kept in a cool, dark place, and in accurately stoppered bottles. As it is now an accepted fact that exposure to light and air is liable to set up decomposition, the drug should be obtained in small rather than large bottles.

Chloroform vapour is **decomposed by contact with a naked flame**, phosgene and hydrochloric acid gases being formed, and the phosgene again splitting up, as indicated by the following equations: $2CHCl_3 + O_2 = 2COCl_2 + 2HCl$; and $COCl_2 + H_2O = 2HCl + CO_2$. When chloroform is administered in a small, badly-ventilated room, in which there is an oil or gas stove for heating purposes, or a gas burner or oil lamp for illuminating purposes, all occupants of the room, including the patient, will be liable to be affected by the irritant products of decomposition. Smarting of the eyes, burning sensations about the upper air-passages, dry spasmodic cough, and a feeling of oppression and tightness about the chest, may be experienced by those engaged in the operation. The smaller the room, the greater the number of naked flames, and the longer the administration, the more marked will be the symptoms. The author has frequently experienced these sensations in a minor degree; and, curiously enough, has sometimes found the pungent odour more noticeable on leaving the room in which the operation has been performed than in the room itself. It is stated that occupants of operation rooms may suffer from persistent bronchial irritation, bronchitis, and even broncho-pneumonia after exposure to the fumes of the decomposed chloroform; and some observers have gone so far as to allege that patients undergoing operations may display such asphyxial symptoms from this cause as to render remedial measures necessary.[1]

D. ETHYL CHLORIDE

Ethyl chloride has the chemical formula C_2H_5Cl. Colin and Roubiquet[2] were the first to point out its true composition. It is a colourless, very volatile liquid with a sweetish taste and an aromatic, faintly pungent odour. Its specific gravity is 0·9214 at 0° C. (Pierre). The density of its vapour is 2·219 (Thènard), taking air as unity, and its boiling-point is 12·5° C. (Regnault). It is very combustible, burning with a green flame with liberation of free hydrochloric acid. It is very soluble in alcohol. When thus dissolved the solution may be kept in well-stoppered bottles, and the ethyl chloride obtained by gently heating. Ethyl chloride vapour is soluble to the extent of 253·36 per cent by volume (0·678 per cent by weight) in water at 21° C. and 760 mm. pressure. Blood at 38° C. takes up more than twice as much as this, the exact amount being impossible to determine.[3]

The **purity** of ethyl chloride may be roughly determined by its odour, by its leaving no residue when vaporised, and by its not reddening litmus paper. As there are now several

[1] It is difficult to say who first drew attention to the decomposition of chloroform by naked flame. The earliest reference I can find is in the *China Medical Missionary Journal* for December 1888, p. 160; but the anonymous writer of the short article therein refers to observations on the subject by "a contributor to a prominent medical journal." Iterson, Fischer, and Zweifel drew attention to the phenomenon in 1889; and in that year an article by Dr. Patterson, containing interesting personal experiences, appeared in the *Practitioner*, vol. xlii. p. 418. Zweifel reported a fatal case of bronchitis and pneumonia. See also *Lancet*, 12th March 1898, containing an interesting letter from Dr. J. J. Waddelow. See also *Birmingham Medical Review*, August 1892, containing an article by Dr. Charles Martin. The subject has attracted much attention on the Continent. According to Bréaudat (*Dict. de Physiologie*), the combustion of chloroform vapour gives rise to hydrochloric acid, and an acrid and acid oil containing several organic bodies; but he failed to find any $COCl_2$.

[2] Roscoe and Schorlemmer's *Organic Chemistry*.

[3] E. H. Embley, *Proceedings of Royal Society*, B. vol. lxxviii. 1906, p. 392.

reliable manufacturers of this anæsthetic, there is no difficulty in obtaining it in a state of perfect purity. The label upon the ethyl chloride tube should state that the contents are intended to produce *general* anæsthesia.

E. ETHYL BROMIDE

Ethyl bromide, bromide of ethyl, hydrobromic or bromhydric ether, C_2H_5Br, was first prepared by Serullas in 1827. It is a transparent, colourless, highly volatile liquid, of a strong sweetish ethereal odour and pungent taste. It has a sp. gr. of 1·4189 at 15° C. (Mendelejeff), and of 1·4733 at 0° C. (Pierre). Its vapour density, according to Marchland, is 3·754. It boils at 40·7° C., when the barometer stands at 757 mm. (Pierre). It is sparingly soluble in water, but mixes in all proportions with alcohol and ether. It burns, when ignited, with a green smokeless flame, bromine vapour being evolved. When exposed for some time to air, ethyl bromide decomposes and bromine is liberated.

The following are stated to be the common impurities of ethyl bromide, viz. free hydrobromic acid, free bromine, phosphoretted hydrogen, amyl and ethylene compounds, and sulphur compounds.[1]

According to Merck, ethyl bromide should stand the following tests: (1) when put on the hand it should evaporate quickly and absolutely, without residue, producing a marked feeling of cold; (2) the filtration with water should be neutral and should not change on the addition of nitrate of silver; (3) the addition of concentrated sulphuric acid should cause no discoloration.[2]

F. ETHIDENE DICHLORIDE

Ethylidene chloride, dichlorethane, or, as it is more commonly called, ethidene dichloride, was discovered by Regnault, who, from the mode of its preparation, gave it the name of monochlorinated chloride of ethyl. Snow was the first to use ethidene dichloride as a general anæsthetic.[3] It has the chemical formula $CH_3 . CHCl_2$, and is a metamer of ethylene dichloride, or Dutch liquid. Ethidene dichloride is a transparent colourless liquid, resembling chloroform in taste and odour. According to Watts, its sp. gr. is 1·189 at 4·3° C. (Geuther); according to Roscoe and Schorlemmer, 1·2044 at 0° C. (Thorpe.) The boiling-point of the purest samples has been found to be 60° C. (Beilstein and Krämer), four degrees lower than the boiling-point of the substance originally prepared and studied by Regnault. The vapour

[1] *Brit. Med. Journ.*, 30th August 1902, p. 587.

[2] In the second test, *washing* with water is probably meant, *i.e.* the washings should be neutral, etc.

[3] The reader is referred to Snow's interesting article on "Monochlorurretted Chloride of Ethyle" (*sic*), *op. cit.* p. 420.

density of ethidene dichloride is 49·54.[1] It is distinguished from ethylene dichloride by its boiling-point (ethylene dichloride boils between 83° C. and 84° C.) and by its behaviour with cold alcoholic potash, which decomposes Dutch liquid but has little or no effect upon ethidene dichloride. It is soluble in alcohol and ether, but is insoluble in water.

Clover found [2] that the ethidene dichloride supplied for anæsthetic purposes had not a uniform boiling-point, but could be divided, by fractional distillation, into two or more substances. That which he used had a sp. gr. of "1225," and a boiling-point of 46·1°, the temperature rising to 60°, at which point it boiled steadily till it was nearly all dissipated.

G. AMYLENE : PENTAL

Amylene, C_5H_{10}, was discovered by Balard in 1844, and first used as an anæsthetic by Snow. According to the latter authority, whose views have since been endorsed by all leading chemists, amylene is not a very definite compound, but a mixture of several isomeric bodies.[3]

Amylene is a colourless, thin, and very volatile liquid. Although not pungent when inhaled, its vapour has a disagreeable odour, somewhat resembling that of wood spirit. The liquid is almost without taste. The sp. gr. of amylene is stated to be ·66277 at 0° C., or ·6544 at 10° C. (Watts).[4] The sp. gr. of the amylene used by Snow was ·659 at 56° F. The boiling-point of amylene differs in different samples, and is not constant in the same sample. Balard placed it at 39° C., Frankland at 35° C., and Kékulé at 42° C. The vapour of amylene is inflammable.

At about the time of Snow's death, Duroy is said [5] to have carefully studied the boiling-point of amylene, and to have found that it varied widely—from 30° C. to 62° C. He found, moreover, that pure iso-amylene had a constant boiling-point of 38° C. (according to other observers, 35°). The name "pental" is applied to a pure form of amylene introduced into commerce by Mering.

H. HEDONAL

Hedonal,[6] or methyl-propyl-carbinol-urethane, which has a formula of $CH_3CH_2CH_2CH(CH_3)O.CO.NH_2(=C_6H_{13}O_2N)$, has recently been

[1] For further information see Watts's *Dictionary of Chemistry*, vol. vii. 2nd Supp. 1875, p. 490.

[2] *Brit. Med. Journ.*, 29th May 1880, p. 797.

[3] See Roscoe and Schorlemmer, vol. iii. pp. 240 and 283. Also Watts's *Dictionary of Chemistry*, 3rd Supp. vol. viii. pt. i. 1879, p. 79.

[4] See *Ann. Ch. Pharm.* 4th Supp. 143.

[5] See *Brit. Journ. Dent. Science*, 1st June 1892, in which an abstract of a paper on "Pental" from the *Vierteljahrsschrift für Zahnheilkunde* appears. The paper is by Dr. Julius Kossa and Herm. Neumann of Budapest.

[6] The author is indebted to Messrs. Allen and Hanbury for the information here given.

used for producing general surgical anæsthesia. It is prepared by heating the secondary methyl-propyl-carbinol with urea nitrate under pressure. It is a white crystalline powder having a faint aromatic odour and taste, melting at 74° C. (165·2° F.), and boiling at 215° C. (419° F.). It dissolves in 120 parts of water at 37° C. (98·6° F.), but is more soluble at higher temperatures, and is readily soluble in alcohol, ether, chloroform, and other organic solvents. Hedonal is said to be a perfectly innocuous soporific, to be completely oxidised in the system, to be eliminated in the form of water and CO_2, and, owing to its complete disintegration in the organism to be entirely devoid of cumulative action (p. 467).

For a full account of the physical properties of this substance the reader is referred to *The British Medical Journal*, 15th June, 1912, p. 1378.

CHAPTER III

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

A. TERMINOLOGY: DEFINITIONS

THE agents whose chemical and physical properties have just been considered constitute the more important members of the therapeutic group known as **general anæsthetics.** The remaining members of this group are comparatively unimportant, for they are, so far as our present knowledge goes, incapable of producing such satisfactory effects as those obtainable by nitrous oxide, ether, chloroform, and the other substances to which reference has been made. Considerable differences of opinion exist as to the agents which should or should not be thus grouped together; and the question naturally presents itself: What is a general anæsthetic? To say that it is a substance which has the power of destroying conscious sensibility throughout the organism is hardly sufficient; for such a definition would include many therapeutic bodies which possess, so to speak, merely incidental anæsthetic properties, and which are more fitly included under other groups, such as narcotics, soporifics, anodynes, convulsants, etc. According to our present conceptions a general anæsthetic must possess the following properties:—

(*a*) It must be able to produce universal insensibility;

(*b*) It must be capable of being readily introduced into the circulation without discomfort to the patient;

(*c*) It must produce its effects gradually and progressively, so that its action may be under control;

(*d*) It must bring about not only general sensory paralysis, but such a loss of motor power as to render practicable the performance of the most delicate surgical operation;

(*e*) Its action upon the sensory and motor systems must not be associated with greater excitement, convulsive movement, or interference with respiration, circulation, or other important vital processes than can be controlled or corrected by the anæsthetist;

(*f*) And lastly, it is essential that the agent employed shall be of such a kind that when it has been withdrawn the whole organism shall resume its functions, and return to that condition in which it existed immediately before the anæsthetic was applied.

All agents fulfilling these requirements may be allowed a place in the group of general anæsthetics; and the more completely any agent fulfils such requirements the higher will be its place in the group. Anæsthetics such as nitrous oxide, ether, and chloroform thus occupy high positions; whilst others, such as amylene, nitrogen, etc., have but a questionable right to be included in the list.

There are very wide chemical and physical differences between the various substances whose physiological action we are about to discuss. They belong to no special chemical family; nor do they possess any distinctive element or group of elements in their composition. They are, moreover, equally dissimilar in their physical properties, for whilst most of them are liquid at ordinary temperatures, many are gaseous. Thus, the indifferent gases, hydrogen and nitrogen, by the simple exclusion of oxygen, will render patients completely unconscious —anoxæmic anæsthesia (see pp. 81 and 465). Carbonic acid, too, when mixed with oxygen, has been shown to be possessed of anæsthetic properties (p. 131). Then, as we shall presently see, nitrous oxide (N_2O) has every claim to be regarded as a true anæsthetic. And other gaseous bodies, such as ethylene or olefiant gas (C_2H_4), methyl chloride (CH_3Cl), and methyl oxide ($(CH_3)_2O$), have been employed, with more or less success, for inducing general insensibility. As we pass from bodies which are gaseous at ordinary temperatures to those which are liquid, we find upon the borderland several highly volatile agents, derivatives of hydrocarbons, such as ethyl chloride (C_2H_5Cl), which boils at the body temperature, methyl bromide (CH_3Br), and aldehyde ($CH_3 . CHO$). Then, as instances of anæsthetics with somewhat higher boiling-points, we have ethyl oxide, or "ether" ($(C_2H_5)_2O$), ethyl bromide (C_2H_5Br), and amylene (C_5H_{10}), all of which have been referred to in the preceding chapter. The next body generally placed upon the list is bichloride of methylene (CH_2Cl_2); but, as we shall see, this substance is, strictly speaking, improperly included. With a somewhat higher boiling-point than that of the preceding agent comes carbon bisulphide (CS_2), whilst acetate of methyl ($CH_3 . CO . OCH_3$) and acetone ($CH_3 . CO . CH_3$) are included amongst general anæsthetics by some writers. Ethidene dichloride ($CH_3 . CHCl_2$), which has already been alluded to (p. 33), has a boiling-point (60° C.) almost identical with that of chloroform ($CHCl_3$). Amongst the less volatile bodies which possess general anæsthetic properties may be mentioned bichlorinated chloride of ethyl,[1] acetate of ethyl ($CH_3 . CO . OC_2H_5$), tetrachloride of carbon (CCl_4), ethylene chloride, or Dutch liquid ($CH_2Cl . CH_2Cl$), amyl hydride (C_5H_{12}), ethyl nitrate ($C_2H_5 . NO_3$), benzene (C_6H_6), and turpentine ($C_{10}H_{16}$). Alcohol ($C_2H_5 . OH$), as is well known, is capable of producing deep anæsthesia when administered in sufficiently large quantities. Finally, there are certain substances which are solid at normal temperatures, but which may, when administered in such a way as to enter the circulation, produce complete unconsciousness. Amongst these are: chloral ($CCl_3 . CHO$), acetal ($CH_3 . CH . (OC_2H_5)_2$), amyl chloride ($C_5H_{11}Cl$), ethyl benzoate or benzoic ether ($C_6H_5 . CO . OC_2H_5$), and hedonal ($C_6H_{13}O_2N$), to which special reference has been made in the preceding chapter (p. 34).

The term **general surgical anæsthesia** is commonly applied to that state of profound insensibility which is brought about by the action of a general anæsthetic, and which is of such a character as to allow of the painless performance of any surgical operation. In studying this state it is important to bear in mind that it may be either (*a*) simple or (*b*) complex.

(*a*) By **simple general surgical anæsthesia** is meant that

[1] Mr. Hugh Candy informs me that there are two compounds which may be described as bichlorinated chloride of ethyl: (1) $CH_2Cl . CHCl_2$, boiling at 114° C.; and (2) $CH_3 . CCl_3$, boiling at 76° C.

state or condition which is distinctive of the simple action of a general anæsthetic, and which is unattended by any intercurrent complication materially affecting the respiratory, the circulatory, the nervous, or the muscular system.

This is the state or condition usually obtained by the experimental physiologist who, having anæsthetised his subject, introduces a tracheal cannula and administers through it a regulated anæsthetic vapour, thus providing, not only for the free ingress and egress of that vapour, but for the maintenance of unembarrassed breathing. It is rarely possible to parallel this state in the human subject. Occasionally, however, such a subject may be said to have passed into simple general anæsthesia. Thus, it may happen that a normal or healthy human being becomes anæsthetised with as little embarrassment to breathing as would have arisen had he been inhaling through a tracheotomy tube, and that when anæsthetised he is subjected to no surgical or other stimulus. Or the circumstances may be such as to make the parallel closer, the patient, at the time of the administration, having a tracheotomy tube *in situ*, and no surgical operation to be performed. As a general rule, however, simple general surgical anæsthesia is not seen in practice.

(*b*) Under the term **complex general surgical anæsthesia** may be included all those states or conditions which are partly dependent upon the simple or normal action of a general anæsthetic, as just defined, and partly upon one or more intercurrent complications, due to other causes than the direct action of the anæsthetic and capable of materially affecting the respiratory, the circulatory, the nervous, or the muscular system.

The various states or conditions thus included under one term are far more common in human beings than in lower animals—in the operating theatre than in the physiological laboratory. This is mainly owing to the fact that in the case of man it is customary to introduce anæsthetic gases and vapours through the complex and changeable upper air-passages above the trachea, so that any altered position, spasm, or swelling of parts within or about those passages will be liable to introduce an asphyxial element into the anæsthesia, and thus to convert simple anæsthesia into the complex variety. The various causes of intercurrent asphyxia will be subsequently discussed (pp. 554, 566, and 577). In the case of lower animals, anæsthetics are usually introduced through the trachea, so that no such intercurrent asphyxial states can arise. There is also another reason for the comparatively greater frequency of complex surgical anæsthesia in man, namely, that during general anæsthesia, and especially during deep chloroform anæsthesia, many of the surgical procedures of the operating theatre are attended by special and conspicuous vaso-motor effects which, although they may be paralleled in the lower mammal, as will be seen below (p. 57), are generally absent during the observations of the physiologist. The complex form of anæsthesia is the rule and not the exception when human beings are being anæsthetised—a few examples may be here cited.

In the so-called struggling stage of strong men the temporarily obstructed breathing from muscular spasm is the factor which makes the simple anæsthesia complex. During the operation of staphylorraphy there is often such a degree of intercurrent asphyxia that anæsthesia may be quite as much dependent upon this state as upon the chloroform which is being administered. When, during partially established anæsthesia, the sphincter ani of a muscular subject is dilated, and breathing suddenly ceases from reflex spasmodic tongue retraction or reflex laryngeal closure, a complex anæsthesia again results, the intercurrent asphyxial state possibly acquiring an importance out of all proportion to the simple anæsthetic state. Similarly, prolonged stertor of reflex origin may gradually but completely transform the one kind of anæsthesia into the other (p. 68). When, during the manipulation of the intestines of a patient deeply under chloroform, sudden vaso-motor paralysis occurs we are again brought face to face with complex chloroform anæsthesia differing widely from the simple state. Anæsthesia may at one moment be simple, at another complex. Or the complex state may resolve itself into the simple, as when tracheotomy is performed upon a patient whose breathing is embarrassed; the embarrassment, the cyanosis, and the feeble pulse suddenly vanishing to be replaced by tranquil respiration, a natural colour, and a good peripheral circulation.

The above differentiation between simple and complex anæsthesia has been introduced, not with the object of considering the two states separately—for this would with our present limited knowledge be impossible—but with the hope of drawing the attention of all those who are interested in the physiology of anæsthesia to the important rôle played by the intercurrent complications to which reference has been made. It is, of course, necessary that we should know what effects general anæsthetics themselves produce, apart from all intercurrent complications during their administration ; and a vast amount of important work in this direction has been done by our leading physiologists. We have also at our disposal valuable recent researches concerning one form of surgical shock. There yet remains for investigation the experimental physiology of intercurrent asphyxia, the presence of which, in one form or another, is the immediate cause of the vast majority of difficulties and accidents during anæsthesia.

By **syncope** is meant a somewhat sudden, and as a rule temporary, state of circulatory failure marked by pallor of the skin and mucous membranes; feeble or imperceptible pulse; cold and clammy extremities; dilated pupils; separation of eyelids; and irregularity, or in the worst cases arrest of breathing. Although syncope is generally regarded as essentially a cardiac condition, there can be no doubt that in many cases it is largely if not wholly due to an inadequate supply of blood to the cardiac chambers, and not to any intrinsic cause in the heart itself. Thus it is the prominent feature in those cases of surgical shock which arise from sudden dilatation of the splanchnic area or from sudden and severe hæmorrhage. Similarly it may be the immediate result of an alteration in posture when the compensating mechanism for the effects of gravity is in abeyance (p. 122). Again the syncope which arises from stimulation of the cardio-inhibitory centre, whether by afferent impulses through the vagus or by (?) the anæsthetic directly affecting that centre, may be looked upon as of nervous rather than of cardiac origin. The syncope of asphyxia, the condition which obtains when cyanosis gives place to pallor, probably has many factors. The left heart receives less and less blood; the right heart is embarrassed by distention; and the heart muscle is poisoned by asphyxial blood. It is difficult to say whether, in the normal subject, syncope is ever purely and essentially cardiac in its nature. There is good evidence that when certain anæsthetics are administered in large doses the heart muscle may be suddenly paralysed; but it is highly probable that when anæsthetics are thus administered other important factors capable of bringing about circulatory failure come into play.

The term **shock** is most appropriately applied to serious respiratory [1] or circulatory states arising as the result of direct or indirect injury to some part or parts of the nervous system. From this definition, which the author ventures to put forward, shock may be—

(*a*) Primarily respiratory—called in this work for purposes of description **respiratory shock**;

(*b*) Primarily circulatory—**circulatory shock**; or

(*c*) **Composite shock,** *i.e.* respiratory shock rapidly followed by circulatory depression, or circulatory shock rapidly followed by respiratory depression.

These varieties of shock will be discussed when considering the reflex respiratory and circulatory phenomena of anæsthesia (pp. 67 and 69).

The use of the term **collapse** should be restricted to the more protracted and profound cases of circulatory depression. As a general rule there are several factors present in collapse. Profuse or protracted hæmorrhage, prolonged exposure or manipulation of parts rich in nerve-supply by which the vaso-motor system and cardiac action become depressed, long-continued or unnecessarily profound anæsthesia by which the cardio-vascular system suffers dilatation, and respiratory embarrassment by which the respiratory nervous mechanism becomes exhausted, are instances of the more common causes which combine to produce this condition.

The terms **open, valvular,** and **close anæsthetisation** will be defined and considered in the following section (p. 44).

[1] Although primary circulatory shock is far more common than primary respiratory I have thought it better, in dealing with this subject, to adopt this particular classification, as it is more in harmony with the general plan throughout the book, of giving the first place to respiratory and the second to circulatory phenomena.

The terms **dose, dosage, overdose,** and **overdosage** will also be defined and discussed in that section.

B. THE PASSAGE OF THE ANÆSTHETIC INTO AND OUT OF THE ORGANISM

Anæsthetics may act directly upon the organism by a simple process of imbibition and absorption. This is seen in the temporary arrest of development which takes place in germinating seeds when exposed to an atmosphere of ether or chloroform, and in the local loss of sensitiveness which occurs in the sensitive plant when similarly treated. Applied to the medusa, chloroform first arrests spontaneous movements and then brings about a state of diminished reflex activity.[1]

In organisms possessing a circulatory system, the absorption by the circulating fluid of the gaseous or vaporised anæsthetic will lead with greater or less rapidity to generalised effects; and this is true, no matter in what part of the organism the absorption takes place. Arloing has, for example, shown that general anæsthesia will become established in the sensitive plant when its roots are subjected to the action of an aqueous solution of chloroform.[2] In cold-blooded animals, such as frogs, Claude Bernard showed that so long as the circulation was intact the immersion of one half of the body in chloroformed water led to general anæsthesia; and he pointed out that, by reason of the comparatively slow elimination which takes place through the lungs, frogs are well fitted for this plan of inducing anæsthesia. General effects may also be produced in warm-blooded animals by the absorption of anæsthetics locally applied; but owing to the rapid elimination of volatile substances by the lungs, such effects are, as a rule, irregular and uncertain. Again, the gastro-intestinal tract may be made the site of absorption, as in the administration of chloral by the stomach, and of ether vapour by the rectum; but in this case also the results will be unreliable owing to the modifying influences exerted by digestion and other conditions. The most convenient channel for the introduction of gaseous and

[1] Brunton, *Pharmacology and Therapeutics*, 3rd edit. p. 111.
[2] Dastre, *op. cit.*

vaporised bodies into the general circulation is undoubtedly that presented by the respiratory passages, the large area furnished by the pulmonary alveoli and capillary network being particularly favourable to rapid absorption. Moreover, the blood circulating through the pulmonary arterioles and capillaries is specially suited for the reception and transmission of agents such as those we are considering; for immediately the blood has left the lungs it passes to the nervous centres wherein the essential changes necessary to the establishment of general surgical anæsthesia take place.

Putting out of the question, for the present, the administration of anæsthetic gases and vapours through a tracheal tube (*vide supra*), and assuming that we are dealing with a subject whose air-passages remain freely patent during both inspiration and expiration, it may be said that the effects produced by anæsthetics will depend in no small measure upon the precise system of anæsthetisation adopted. There are, in practice, three distinct systems of inhalation-anæsthesia, which may be termed (1) the **open**; (2) the **valvular**; and (3) the **close**. In the **open** system copious and undetermined quantities of atmospheric air gain access to the lungs with the gas or vapour, and all expirations freely escape into the surrounding atmosphere. This is the usual system by which chloroform is given from a Skinner's or Schimmelbusch mask (pp. 339 and 402). The term **semi-open** is appropriately applied to methods by which the inspirations and expirations both pass *through* some absorbent fabric moistened with the anæsthetic, or through some simple receptacle containing it (see remarks on p. 337). In the **valvular** system of administration both inspiratory and expiratory valves are present in the inhaling apparatus, and, as a general rule, the constitution of the gas or vapour thus administered is known. In methods of this class each inspiration consists of a quantity (usually undetermined) of the particular gas or vapour; and each expiration escapes into the atmosphere. Nitrous oxide, nitrous oxide and oxygen, and percentage mixtures of chloroform are thus usually administered. Lastly, we have the **close** system of anæsthetisation. The apparatus used in close methods contains no valves, or if it contain valves these are prevented from acting; it possesses a face-piece capable of accurate coaptation to the face; and to the inhaler is attached a bag usually of unknown capacity, into and out of which the patient breathes. When such an inhaler is accurately applied charged with a certain quantity of an anæsthetic, such as ether or ethyl chloride, the patient breathes backwards and forwards into the bag; the anæsthetic is vaporised and diffuses into the imprisoned air, and unless the inhaler be removed this imprisoned air gradually loses in oxygen and gains in carbonic acid. The effects produced by administering an anæsthetic by the close system will depend not only upon (1) the quantity of the anæsthetic gas or vapour available for respiration, but upon other important factors, such as (2) the quantity of the air which becomes mixed with the gas or vapour; (3) the composition of this air; and (4) the duration of the rebreathing. With regard to the quantity of anæsthetic originally taken, this may be small or large. There is, for example, a great difference between the rebreathing of four litres and of twenty litres of pure nitrous oxide gas. The extent to which the gas or vapour becomes diluted with air will depend upon the quantity of that gas or vapour in relation to the combined quantities of air within the inhaler and air within the respiratory passages, the quantity of air within the inhaler being largely dependent upon the size and flexibility of the bag, and whether the inhaler has been applied during an expiration or during an inspiration. As to the composition of the air, this will depend upon the relative proportions of air from the respiratory passages and air from the bag. There will, of course, be a progressive change in the composition of the imprisoned air corresponding to the duration of the to-and-fro breathing. In close anæsthetisation the oxygen of the air within the air-passages and bag will gradually diminish in amount, the carbonic acid excreted will increase, and the effects purely dependent upon the incarcerated anæsthetic gas or vapour will thus be intensified or modified according to the degree of oxygen deprivation and carbonic acid retention. As is pointed out elsewhere (p. 465), the inhalation, by the valvular system, of nitrogen with small proportions of oxygen, quickly leads to anæsthesia; and it is highly probable that in rebreathing methods the oxygen limitation factor is of greater importance than the concomitant carbonic acid retention factor. At all events close anæsthetisation generally has the effect of markedly intensifying the action of an anæsthetic. The experiments of Haldane and Lorrain Smith [1] with regard to the effects of breathing different proportions of air and carbonic acid, of air with less than the normal percentage of oxygen, and of hydrogen, are interesting in this connection.

Having arrived within the pulmonary alveoli, anæsthetic gases and vapours are **absorbed** by the blood circulating through the pulmonary capillaries. Snow and Paul Bert believed that this absorption was a simple physical process, but recent researches tend to show that there is, at all events with certain anæsthetics, something more than mere solution in blood. Buckmaster and Gardner have given careful attention to this matter,[2] and have shown that chloroform is distributed almost entirely in the red corpuscles in cats and dogs; the plasma remains free unless the anæsthetic is pushed to an extreme degree. They regard the red corpuscles as the essential agents in the transport of chloroform and in its absorption from the pulmonary alveoli. Speaking generally, it may be said that blood will continue to absorb anæsthetic gases and vapours till an equilibrium is established between alveolar and blood tensions. The rapidity of absorption will depend upon numerous circumstances, amongst which may be mentioned the degree of patency of the air-passages, the rate of respiration, the depth of each respiratory act, the rate of the capillary flow through the alveolar walls, and the temperature of the blood. Should such a condition as laryngeal spasm exist, or should respiration be of such a character that the bases of the lungs expand but feebly, a considerable time may be occupied in obtaining anæsthesia. The insusceptibility to anæsthetics of patients suffering from shock is thus to be explained. The influences of abnormal barometric pressures are discussed elsewhere (pp. 234 and 314). Snow showed that the percentage of chloroform vapour inhaled from a handkerchief or inhaler is considerably greater when the tempera-

[1] *Journ. Path. and Bact.* vol. i. 1892-93, p. 168.

[2] *Proceedings of the Royal Society*, B vol. lxxviii. 1906, and B vol. lxxix. 1907.

ture is high than when it is low. Gwathmey states[1] that anæsthetic vapour delivered warm is definitely less toxic than when it is cold; but Seelig ridicules the warming of anæsthetic vapours as unnecessary and unpractical.[2]

The terms **dose, dosage, overdose,** and **overdosage**, which are often used in connection with the subject of general anæsthesia, are not always appropriately applied. Strictly speaking, a dose of a drug is a definite quantity introduced into the organism with the object of producing some definite effect. In dealing with general anæsthesia, the term dose should be restricted to that quantity of the particular agent which has been taken up by the blood and tissues of the organism. It is important to remember that this has no necessary relation to the total quantity of anæsthetic administered. When an anæsthetic gas or vapour is progressively given by the valvular system until a point is reached at which the phenomena of full anæsthesia appear, it is, of course, possible to ascertain the quantity of the anæsthetic which has been used. But this quantity does not indicate the dose absorbed; for not only is the greater part of it dissipated in the patient's expirations, but at the termination of the administration there is still a portion of it within the respiratory passages. More important, perhaps, than the question of dose is that of dosage, by which is meant the adjustment of the percentage of the gas or vapour in the atmosphere entering the respiratory passages. With dilute atmospheres the full narcotic effect of an anæsthetic may never be attained, the total quantity of the drug which the blood is able to absorb, *i.e.* the dose, being insufficient. With pure or nearly pure gases, *e.g.* with nitrous oxide free from or mixed with only a small percentage of air, or with concentrated atmospheres of volatile anæsthetics, *e.g.* chloroform vapour of 4 per cent and upwards, absorption takes place till equilibrium is established between the blood and the gaseous contents of the lungs; the total quantity of the anæsthetic which the organism can absorb from such an atmosphere, *i.e.* the possible dose, is large; and unless the administration be suspended at

[1] *New York State Journal of Medicine*, February 1908.
[2] *Interstate Medical Journal*, September 1911, p. 927.

the proper moment, an overdose may be given. When an anæsthetic is administered by the close system, the quantity used more nearly approximates to the dose or amount absorbed, but even with this system an unused portion of the anæsthetic vapour must remain. When, for example, a few c.c. of ethyl chloride are vaporised in a limited quantity of fresh or expired air, the amount of anæsthetic taken up by the blood and tissues may so nearly equal the quantity originally vaporised, that many writers speak of the latter as the dose.

We must not forget that, whilst the pulmonary blood-stream is the great medium for the reception and transmission of anæsthetics, it is also the medium for their **elimination**, and for the escape of carbonic acid. When, as the result of the withdrawal of an anæsthetic and the access of fresh air, alveolar tension falls below the blood tension, the gas or vapour which has been absorbed begins to be eliminated, and after a period, varying widely according to circumstances, elimination becomes complete. There is no good evidence that any of the anæsthetics now in use are themselves decomposed during their period of association with the circulating blood. Waller, who has estimated the amount of chloroform recoverable from animals that have been anæsthetised, and Collingwood,[1] who has compared, in the same animal, the composition of the inspired and expired currents during chloroformisation, both agree as to the improbability, at all events in the case of chloroform, of any decomposition taking place. As regards carbonic acid, it would seem that, whilst its production is diminished during anæsthesia (see pp. 56, 92, and 112), there is no obstacle to its elimination from the lungs, provided that the respiratory passages be free, and that expirations escape into the surrounding atmosphere. In the absence of all obstructive conditions and with open anæsthetisation the elimination of carbonic acid will largely depend upon the degree of lung ventilation present. Haldane and J. G. Priestley have shown that the amount of lung ventilation at any time is regulated so as to maintain the same amount (or, more accurately, the same pressure) of CO_2 in the blood, the respiratory centre being at once stimulated by even the smallest increase above the

[1] *Journ. Phys.* vol. xxxii.

normal amount. The fact that the CO_2 content of the blood rises largely during chloroform anæsthesia would seem to point to chloroform lowering the sensibility of the respiratory centre to the stimulus of CO_2 in the blood which reaches it. When breathing becomes, as it often becomes, more or less obstructed, it may be regarded as certain that this gas remains to some extent incarcerated below the obstruction, and that, in consequence of this, its escape from the pulmonary blood will be retarded. Similarly, in close methods there is probably a progressive increase in the carbonic acid blood-tension, owing to the retention of the excreted gas within the air-passages.

C. THE PHENOMENA OF GENERAL ANÆSTHESIA

I. The Phenomena of Anæsthesia in Lower Forms of Life

It has been long known that general anæsthetics are capable of arresting the **germination** of seeds, and of suspending or destroying the sensitiveness of the sensitive plant. When solutions containing ether or chloroform are applied to cilia which are in motion, the ciliary movement is interrupted, or ceases. Waller and Farmer[1] have shown that the vapour of chloroform or ether, according to the strength used, suspends or destroys the movement of vegetable protoplasm in the same degree as animal protoplasm. Within the past few years the interesting discovery has been made that by exposing certain plants, such as the lilac and azalea, to the influence of ether or chloroform vapour, inflorescence may be considerably hastened.[2] Advantage is taken of this fact by those who grow flowers on a large scale for the market. In an interesting paper,[3] Professor F. J. Keeble has recently reviewed the effects of anæsthetics upon the lower forms of life. He finds that bacteria, except in spore condition, are killed by anæsthetic vapours. When cells in process of division are exposed to anæsthetics, the process

[1] *Proc. Roy. Soc.* vol. lxiii. 1898, p. 213.
[2] *Lancet*, Jan. 9, 1904, p. 108. [3] *Ibid.* Feb. 10, 1906, p. 377.

ceases so far as the cell itself is concerned. The nuclei, however, are unaffected. Ether and chloroform produce definite effects upon lower plant life, particularly upon the streaming movements, ciliary movements, and the throwing out of pseudopodia. Transient acceleration of movement and growth is observed with properly adjusted doses, but this is quickly followed by retardation and then by rest. Ether produces effects which are less powerful than those of chloroform and less likely to be permanent. Some interesting results were obtained with the tubers of gladioli. After exposure to the vapour of ether for twenty-four hours, the CO_2 produced by them rose from 12·2 milligrammes to 57 milligrammes for the first day, falling only to 40 for the third day. Professor Keeble states that ether is preferable to chloroform for hastening the inflorescence of plants. He also finds that when exposed to anæsthetics, plants lose their reflexes in an exactly similar manner to that observed in animals. By subjecting plants to suitable strengths of chloroform vapour, they are prevented from perceiving such a stimulus as the influence of gravity.

II. The Phenomena of Anæsthesia in Higher Forms of Life—General Surgical Anæsthesia

Having entered the pulmonary blood-stream, general anæsthetics are enabled to exert their influence upon all parts of the organism, and to affect the various systems of that organism in a more or less definite and characteristic manner. As already indicated, there is a considerable difference between the effects produced by one anæsthetic and those produced by another, the organism and the means adopted for introducing the anæsthetic remaining the same. This is exemplified in the behaviour of the same patient under ether and chloroform, each administered in precisely the same way, and with the same percentage of air. Then, as everyday experience teaches us, the same anæsthetic may produce very different effects upon the same subject according to the system or method adopted for administering it. This is well seen in the case of nitrous oxide, which is capable, according to the plan of administration adopted, of producing an asphyxial or a non-asphyxial form of anæsthesia. Again, the phenomena which arise during the administration of an anæsthetic will necessarily depend upon the rapidity with which the anæsthetic enters the circulation, and the quantity which is present within the circulation at the particular time. This was clearly demonstrated by Snow as regards chloroform, and it is true of other anæsthetics. In the next place, the effects produced by anæsthetics will depend, to some extent, upon the organism subjected to anæsthetic influence. There are, for example, certain differences between the effects produced by chloroform in man and the effects produced by this anæsthetic in lower animals. Finally, it is important to bear in mind that organisms, apparently similar to one another in all essential details, may display very different phenomena, even though precisely the same plan be adopted for inducing general anæsthesia. This is unquestionably the case with human beings; a fact which every anæsthetist has to bear in mind.

(*a*) The Respiratory Phenomena of General Surgical Anæsthesia

It will now be convenient to consider in an introductory and general manner the respiratory phenomena of surgical anæsthesia; and it will be better to study these as they present themselves in practice rather than to discuss them from the standpoint of the experimental physiologist. To the experimentalist, free and efficient breathing is dependent mainly, if not wholly, upon an intact and active nervous and muscular mechanism. Anæsthetics produce this or that change in the rhythm, rate, force, and amplitude of respiration by their action upon the nervous mechanism of breathing. They are regarded as substances which first stimulate, then depress, and finally paralyse this mechanism. But to the clinical observer respiration during anæsthesia has a wider and more important significance; for in actual practice as much attention has to be paid to the degree of patency of the nasal, oral, pharyngeal, and laryngeal channels (through which anæsthetic gases and vapours, with their proper proportions of air or oxygen, have to pass, and through which such gases and vapours with carbonic acid have to be eliminated), as to the motive force of the respiratory pump, whose function it is to maintain the inspiratory and expiratory currents. In considering the effects produced by anæsthetics in the human subject, it is impossible to over-estimate the importance of the freedom, or the want of freedom, with which the respiratory current enters and leaves the lungs. Many phenomena customarily ascribed to the direct effects of an anæsthetic upon this or that part of the nervous or circulatory systems are often in reality referable to a greater or less degree of occlusion of the air tract, the presence and effects of which are not realised.

In practice the character of the breathing during the administration of an anæsthetic for a surgical operation will depend upon a large number of factors.

(i.) **The local action of the anæsthetic upon the respiratory passages** may induce cough, retching, swallowing, or "holding the breath."

(ii.) But provided no such disturbing influences arise, the normal breathing gradually tends to become somewhat deeper and quicker, chiefly from **stimulation of the respiratory centre by the circulating anæsthetic.** Some anæsthetics produce a more stimulating effect than others.

(iii.) In the case of pure nitrous oxide and of other gases and highly volatile vapours which admit of being administered with little or no atmospheric air, the concomitant **deprivation of oxygen** may lead to exaggerated breathing, stertor, and tonic or clonic spasm of the respiratory muscles (*vide infra*, (d) muscular phenomena).

(iv.) In certain methods of administering anæsthetics, inhaling-bags are used (p. 45), and some **re-breathing** therefore takes place: in such circumstances the incarcerated carbonic acid leads to a greater or less degree of hyperpnœa.

(v.) Again, **psychical impulses** may interfere with free respiration. This is sometimes seen early in an administration, when nervous, apprehensive subjects hold the breath till cyanosis arises, or when hysterical subjects cry or laugh till a state of incipient asphyxia is brought about. It is quite possible that the association of extreme alarm and prolonged refusal to breathe may have been a factor in some of the fatalities which have occurred at the outset of chloroformisation (p. 421). When normal consciousness has just been lost, rapid or suspended breathing may result from a dream or hallucination.

(vi.) As the patient passes into the second stage of anæsthesia, respiration often tends to become modified as already indicated by **altered position, spasm, or swelling of parts within or about the upper air-passages** (see p. 554), or by **spasm of muscles directly concerned in the working of the respiratory pump** (see p. 578).

Various **respiratory sounds** may be emitted during the anæsthetised state. Whilst our knowledge as to their significance and immediate causation has certainly increased, there is need for further research concerning them. Provided the air-channels be thoroughly patent and the breathing be not laboured, the entry and exit of air to and from the lungs may be nearly or completely noiseless. But if the air-way be at all restricted, respiration will increase in force and frequency and become audible. In addition to the sound usually made by the air current during deep breathing, there are numerous superadded or adventitious sounds which deserve attention. These may be divided into inspiratory and expiratory. The former are as a rule snoring, stertorous, or stridulous, the latter strained, phonated, or moist in character. Just as the sound ordinarily made during deep breathing may acquire a nasal or oral character according to the channels involved in breathing, so may certain of the adventitious sounds be similarly modified. Snoring is by far the commonest of adventitious sounds and is often, though by no means invariably, proportional to the degree of anæsthesia. It always indicates a tendency towards occlusion of the air tract. It may be so soft as to be barely audible, or so harsh and rough as to be heard at a considerable distance. It is convenient to restrict the use of the word "stertor" to the latter variety of snoring. The commonest form of stertor during the anæsthetised state is that which is produced by the tongue vibrating against the pharyngeal wall. This vibration is generally regarded as dependent upon a flaccid or paralytic state of the tongue; but the author is convinced that, in most cases, it is dependent rather upon spasm of muscles drawing the base of the tongue backwards during inspiration than upon a paralytic state of the organ. He has elsewhere[1] shown that with pure nitrous oxide the stertor is distinctly spasmodic, and that with mixtures of nitrous oxide and oxygen this stertor lessens as the oxygen percentage rises, till with certain mixtures the snoring is identical in all its characters with that of ether or chloroform anæsthesia. In certain subjects anæsthetics may cause so much muscular spasm about the fauces, palate, pharynx, floor of the mouth, and larynx, that an obstructive stertor is produced and life may thereby be threatened (see p. 560). In some cases, too, an engorged state of the tongue and adjacent parts obviously contributes to the production of stertor. Stertor may also be reflexly produced by surgical stimuli—"reflex stertor" (p. 67). Whilst stertor and snoring are the audible expressions of a greater or less degree of obstruction *above* the larynx, stridor always indicates a tendency towards occlusion of the larynx itself. Two varieties of laryngeal stridor present themselves in practice. The first of these is a short, deep, and coarse sound probably caused by collapse or falling together of the superior aperture of the larynx. The other variety is a prolonged and high-pitched sound, sometimes altering in pitch during inspiration, and dependent upon laryngeal spasm rather than upon collapse. In surgical practice laryngeal stridor may arise from the direct effect of the anæsthetic vapour, from the presence of mucus or other adventitious substances, or as the reflex result of some sensory stimulus, *e.g.* peritoneal traction (see p. 212). As regards expiratory adventitious sounds, these are, as a rule, phonated and dependent upon approximation of the true vocal cords. As a general rule any phonated sound indicates a moderate degree of anæsthesia. "Strained" expiratory sounds are generally if not always of pathological significance. When there are considerable phonation and strained expiration, *together with the presence of a slight corneal reflex*, the cause is usually a collection of mucus in the larynx. After an act of coughing such sounds will often entirely subside. Moist expiratory sounds indicate the presence of fluid immediately above, within, or below the larynx.

[1] *Trans. Roy. Med. Chir. Soc.* vol. lxxxii.

(vii.) When once the patient has been brought well under the influence of the anæsthetic, the respiration may usually be made to vary with the **quantity of the anæsthetic given**, becoming deeper, quicker, and (often) more stertorous with more, and shallower, slower, and (often) less stertorous with less. Respiration is chiefly performed by the diaphragm during anæsthesia, the sternum and intercostal spaces receding somewhat during each inspiratory act. In young athletic subjects, however, inspiration may be chiefly thoracic, being effected principally by the intercostal muscles. Whenever any slight impediment to the free entry of air takes place, whether in athletic or other subjects, breathing tends to become diaphragmatic, the chest walls, particularly when the obstruction is considerable, receding with each jerk of the diaphragm. Expiration is a less passive process than in the conscious subject, the recti and other abdominal muscles often taking part in its performance. The respiratory phenomena of overdosage are considered under the respective anæsthetics.

(viii.) In addition to the respiratory changes which are strictly dependent upon the action of the anæsthetic itself upon the respiratory centre, there are other changes which are dependent upon the **blood-supply to that centre.** Other factors remaining the same, the better the arterial supply the better the breathing, and *vice versa* (see pp. 111 and 587). The shallow breathing of chloroform overdosage is, for example, largely due to low blood-pressure.

(ix.) Any hindrances to free thoracic and abdominal movement, such as **tight-lacing,** the adoption of **certain postures,** etc., may readily introduce an asphyxial element into the administration (pp. 238 *et seq.* and 577).

(x.) In certain cases "**physiological apnœa**"[1] may be met with. It is most common under nitrous oxide and oxygen, but it may appear under other anæsthetics, and is nearly always preceded by a phase of rapid and deep breathing. According to Haldane and J. G. Priestley,[2] apnœa is dependent upon

[1] In this work the term "apnœa" is restricted to that form of suspended breathing which is associated with a good pulse and colour. It seems to the author that apnœa is an inappropriate term for any of the varieties of respiratory arrest discussed in Chapter XVIII.

[2] *Journ. Phys.* vol. xxxii. p. 225.

a fall of CO_2 pressure in the respiratory centre to below the "threshold exciting value," the oxygen pressure being at the same time sufficiently high not to excite the centre.

(xi.) **Cheyne-Stokes breathing** has been observed in dogs subjected to chloroform after morphine. It is sometimes seen in practice, particularly in elderly and feeble subjects, under chloroform. It is certainly rarely, if ever, observed during administrations attended by rebreathing. This is in harmony with the observation of Ettore Levi of Florence, viz. that by the administration of a mixture of carbonic acid gas and oxygen, containing 15 per cent of the former, Cheyne-Stokes breathing may be corrected and the normal rhythm of breathing restored (see p. 588).

(xii.) In practice it will be found that the rate, rhythm, and amplitude of respiration undergo important modifications dependent upon the **operation** itself. Traumatic, thermal, and electrical stimuli are all capable of modifying breathing, either in the direction of augmentation or in that of arrest. The modifications, which are as interesting as they are important, will be specially discussed when dealing with the reflex phenomena of anæsthesia (p. 65) and respiratory shock (p. 67).

It is generally admitted that **respiratory exchanges** are greatly modified during anæsthesia. Thus, Rumpf found with ether, chloroform, alcohol, and chloral a decrease of 40 per cent, and a corresponding diminution of temperature. Richet[1] found that chloralised dogs only produced on the average 0·6 gm. of CO_2 per kilo. per hour, whilst normal dogs produced 1·2 gm.—in other words, the chemical activity of the organism was reduced 50 per cent.

The rapidity with which a given anæsthetic produces its **effects** will greatly depend upon the rate and depth of the respiratory movements, and the activity of the pulmonary circulation, a quick and deep respiration and a forcible and full pulmonary blood-stream being favourable to absorption and rapid transmission of the anæsthetic.

It is clear from the foregoing facts that the respiratory phenomena of general surgical anæsthesia are dependent upon three main factors: (1) The **activity of the respiratory centres,**

[1] *Dict. de Physiologie.*

i.e. the amount of nervous energy available for the working of the respiratory pump; (2) the **degree of patency of the upper air-passages** through which the respiratory current passes; and (3) the **state of the respiratory pump itself**, particularly as regards the presence or absence of any external impediment to lung expansion. Given the absence of all conditions capable of depressing the activity of the nervous mechanism of breathing, a free air-way, and the absence of any hindrance to lung expansion, respiration will be satisfactorily performed. On the other hand, no amount of energy in the nervous mechanism of breathing will be of any avail when an occluded air-way is present, or when there is some external condition at work preventing lung expansion. Both minor and major degrees of occlusion of the air-way may exist with but little audible evidence, and the intercurrent asphyxial state thus induced may escape attention. So closely may minor anoxæmic or asphyxial symptoms resemble those of anæsthesia, so nearly may the phenomena of the latter simulate those of the former condition, and so easily may the one state be made to intensify the other, that the closest attention may sometimes fail to distinguish between them.

(*b*) The Circulatory Phenomena of General Surgical Anæsthesia

The circulatory phenomena of general surgical anæsthesia have for many years been the subject of much controversy, and a large number of important researches have been conducted concerning them. Although each anæsthetic brings about circulatory states more or less special to and characteristic of that anæsthetic, so that generalisations must be made and received with caution, it is important that certain cardinal points concerning the circulation during anæsthesia should be understood before considering these special or characteristic states in the following chapter.

The state of the circulation of a normal subject at any given moment during anæsthetisation for a surgical operation will depend upon a variety of factors. Unfortunately our knowledge is insufficient to enable us to enumerate all of these, or to place those with which we are acquainted in their true order of importance.

Before consciousness has been completely destroyed by an anæsthetic, the circulation is liable to disturbances of **psychical** origin. Of these, cardiac acceleration is usually the most noticeable phenomenon. Highly nervous and apprehensive human beings may, however, display pallor or even slight lividity during the initial stages of anæsthetisation, and these phenomena may persist till full anæsthesia has been secured. Cases have been recorded in which patients have suddenly died from fright immediately before the inhalation of an anæsthetic, the probable explanation of such accidents being that psychical disturbance has so profoundly affected the cardiac and vaso-motor centres that syncope has resulted. It is, of course, conceivable that such an event might occur in a highly nervous and excitable subject during the first few inhalations of an anæsthetic, the latter being in no sense responsible. The influence of the psychical state as a factor in chloroform accidents will be specially considered in later pages (p. 421).

When consciousness has been destroyed the state of the **respiration** already discussed (p. 51) is undoubtedly the most important factor in determining the state of the circulation; the rate, force, and amplitude with which the respiratory pump works, the freedom with which lung expansion, contraction, and ventilation take place, and the state of the blood so far as its respiratory gases are concerned, having very material influences upon both the greater and the lesser circulation. Efficient respiration is necessary for efficient circulation. A *barely noticeable* degree of obstruction to air-entry leads to a good type of breathing and hence to good circulation. When the degree of obstruction increases, the venous system will begin to show signs of over-fulness; the veins at the site of operation bleed more freely than usual, and the tongue increases in size so that it projects between the teeth. This altered distribution of blood, however, may be quite compatible with a good pulse, so long as the obstruction remains slight. It is very common in practice to find *nasal* respiration associated with these circulatory changes, simply because such respiration is usually inadequate; directly free oral breathing is secured, the veins cease to bleed and the tongue lessens in size. The degree of venous fulness and the rapidity with which it is brought about will depend upon the total quantity of blood and the state of the tissues. In some subjects a rapidly advancing and dangerous venous swelling of the tongue and adjacent parts may quickly follow arrested breathing. (See Illustrative Case No. 42, p. 562). It is not uncommon, in the case of rather feeble and anæmic subjects, to find that, so long as respiration remains somewhat exaggerated in type, as, for example, from very *slight* laryngeal spasm, the pulse will be good and regular and the colour florid; whereas directly the cause of the slight obstruction in the larynx ceases to operate and the breathing falls in force and frequency, the pulse will become comparatively feeble and distinctly irregular, and the colour paler. The diastolic dilatation of the cardiac cavities, the passage of blood along the great veins into the right auricle, its circulation through the lungs, and particularly its return from the pulmonary capillaries to the pulmonary veins and left auricle, are all dependent upon efficient lung expansion. As already indicated (p. 55), breathing is largely diaphragmatic during anæsthesia, and the powerful contraction of the diaphragm is no doubt of great value in maintaining the pulmonary circulation, particularly in the bases of the lungs. Persistently shallow or obstructed breathing, intense expiratory spasm, or arrest of the respiratory pump from any cause, will, after an interval varying with other circumstances present, be followed by lividity or cyanosis, an obstructed pulmonary circulation, general venous engorgement, and, consequently, by a diminution in the quantity of blood entering the left heart. It is thus easy to understand how variations in the wrist pulse may depend upon respiration. The author is inclined to the belief that when the embarrassment to breathing is of such a nature that respiratory movements continue, although little or no air enters the chest, the abortive attempts at lung expansion still further favour the retention of venous blood within the lungs and right heart. He has notes of a case of partial laryngeal obstruction during anæsthesia, in which, with each imperfect inspiration, the wrist pulse vanished, reappearing during each expiration, clearly showing that in certain cases in which there is partial occlusion of the inlet of the respiratory pump there may be such negative pressure within the thorax during attempted inspiration that the output of blood from the lungs and heart to the great arteries is intermittently checked. Should anæsthesia be of a light type when respiratory embarrassment occurs the circulation will hold out for a considerable time against the asphyxial strain. But should it be profound, symptoms of circulatory failure will more rapidly ensue, particularly if chloroform be the anæsthetic in use.[1]

In the next place must be mentioned the **effects of anæsthetics upon the muscular elements of the cardio-vascular system.** In addition to the heart muscle, the muscle walls of the arterioles—particularly the arterioles of certain organs—are directly affected by anæsthetics, the effects being dependent upon the kind of anæsthetic employed and the extent to which its administration is carried. According to some observers the fall of blood pressure met with under certain anæsthetics is referable rather to direct vascular dilatation than to dilatation of central nervous origin.

As regards the influences of anæsthetics upon the **nervous elements of the circulation** our knowledge is insufficient to warrant us in making any general statements. The experimental work that has been done in this direction with each anæsthetic will be discussed in the following chapter.

With regard to the effects of **surgical procedures** upon the circulation there is good evidence to show that these effects play a more important part than is generally supposed in modifying the usual circulatory phenomena. The reflex circulatory phenomena of surgical anæsthesia and circulatory shock will be specially considered below (*vide infra* (*c*)). Closely connected with these effects must be mentioned those of cutaneous exposure, room temperature, profuse sweating, etc.

Finally, the **posture** of the subject must not be omitted as

[1] The reader must bear in mind that these statements do not apply when certain morbid states are present.

a factor, particularly in deep chloroform anæsthesia and in cases of surgical shock (pp. 122 and 238).

Little is accurately known as to the changes which anæsthetic gases and vapours produce in the **blood** itself. The facts which are at our disposal will be discussed when dealing with each anæsthetic. According to Buckmaster and Gardner [1] the fall in the oxygen content of the blood during narcosis is well marked even in the early stages and at the time of disappearance of the reflexes; while in profound anæsthesia the reduction is 40 per cent. These results refer to chloroformed cats, and care was taken to eliminate the possibility of slowing of the respiration. They believe that the fall in oxygen content of the blood is due to direct interference with the function of the red corpuscles. When, as is the case with certain of these agents, the oxygen supply is greatly diminished or the elimination of carbonic acid is retarded, the usual effects of asphyxial blood upon the medullary centres, and upon the cardio-vascular system, will be produced. Sansom, Wittich, Böttcher, and other observers have, however, described alterations in the red corpuscles,[2] and, according to the Glasgow Committee of the British Medical Association, disintegration of these corpuscles takes place within the pulmonary capillaries during inhalation.[3] Grube urges that as urobilinuria may occur two or three days after anæsthesia, it is probable that the destruction of red corpuscles is a result rather than an accompaniment of the administration. Sherrington and Copeman have shown that in healthy animals the specific gravity of the blood commences to rise after an operation has been in progress for some little time,[4] and that the increase in specific gravity lasts for several days after the operation.

(*c*) The Nervous Phenomena of General Surgical Anæsthesia

Although anæsthetics produce their specific or characteristic effects by their action upon the nervous system, the

[1] *Journal of Physiology*, Nos. 3 and 4, 9th November 1910, p. 246.
[2] Dastre. [3] *British Medical Journal*, vol. ii. 1880.
[4] Mummery, "On Surgical Shock," *Lancet*, 18th May 1905.

nervous phenomena of anæsthesia belong, so to speak, to the background rather than to the foreground of an ordinary administration. At the same time, when these agents are slowly and progressively given in a diluted form, and when various stimuli are from time to time brought to bear upon the semi-anæsthetised or anæsthetised subject, the most interesting and instructive phenomena may be elicited. Speaking generally it may be said that the most highly evolved parts of the central nervous system are first affected. This is true of all organisms, whether high or low in the scale of evolution. In the case of man and other mammals the cerebral cortex usually seems to be affected before any other part of the central nervous system. In all probability the basic ganglia and cerebellum are next involved. The sensory tracts and centres of the cord which connect the brain with the periphery seem next to share in the process. The cerebro-spinal motor tracts and centres are then influenced. Finally the respiratory, vaso-motor, and cardiac centres cease to act, and death ensues. It is, however, difficult to speak with anything approaching precision on these points; and it must be remembered that variations are displayed by apparently similar subjects.

Claude Bernard showed by a series of experiments on frogs that ether and chloroform primarily and chiefly affect the **sensory centres** of the cerebro-spinal axis, and that the sensibility of sensory nerve endings is destroyed, not from the action of anæsthetics upon those endings, but from their action upon the centres themselves. He pointed out, however, that as in death of sensory nerves from want of nutrition, the peripheral ends first show signs of suspended function; that the trunks are next involved; and that finally the roots share in the process. It is certain that in a large number of cases the earliest sensation experienced by a patient inhaling an anæsthetic is one of "numbness and tingling" in the extremities; and this may exist without any disturbance of consciousness. Claude Bernard expressed the belief that the brain, playing the rôle of a principal nerve-centre, influences the secondary nerve-centres of the spinal cord, although it is itself incapable of being influenced by the latter. So far as the cord is concerned he held that, as in the case of sensory nerves, the function of excitability is lost from below upwards, the lumbar, dorsal, cervical, and bulbar regions being affected in the order named. In the initial stages of anæsthesia the application of traumatic or other stimuli may evoke responses which have all the appearances of, and, in one sense, are conscious responses; but owing to a want of synthesis in the sensory impressions received, and to disturbances within the perceptive centres themselves, pain is either not appreciated as pain, or, if appreciated, is not remembered. Whilst some impairment of common sensibility is frequently met with at the outset of inhalation, typical analgesia, that is to say, the absence of the power of appreciating pain, whilst consciousness, tactile sensibility, and all other faculties are preserved, is rare; and with our present knowledge we are unfortunately unable to depend upon establishing this condition. The best results in this direction have been attained by the combined action of morphine and scopolamine during labour. By the judicious use of these drugs a state can be produced in which the patient responds to stimuli (*e.g.* to the pain of uterine contraction) but has no recollection of them afterwards. True analgesia is, moreover, not uncommonly observed, and particularly in feeble subjects, during recovery from deep anæsthesia. According to Dastre, the analgesia of the induction stage depends upon the sensory nuclei of the cord or cerebral ganglia being affected by the anæsthetic before the cortical centres, so that sensory impressions are blocked on their way to the perceptive areas of the cerebrum. This author suggests that this abnormal sequence of effects may be due either to diminished excitability of the hemispheres, or to increased excitability of the spinal and ganglionic sensory centres. Other physiologists, however, believe that the block takes place in the cerebral cortex.

The order in which the special senses are invaded is not precisely known. Sight is generally lost before hearing. The latter sense, indeed, may persist up to the point at which stertor commences. The author has met with one case in which the patient, a highly intelligent man, assured him that, on recovery from nitrous oxide and oxygen, the sense of colour returned before appreciation of size and shape. Thus he recognised a red bowl as being red before he realised that it was a bowl and made of glass. Dastre points out, and the author can corroborate his assertion, that patients, although unconscious of their surroundings, may sometimes be made to repeat or pronounce reflexly a sequence of words. Dastre also draws special attention to the fact that before anæsthetics bring about their paralysing influence upon the various and successive parts of the nervous system, they induce a pre-paralytic state of excitement, and it thus happens that we find certain excitation phenomena belonging to the excitement stage, through which a certain centre is passing, side by side with the paralytic phenomena of another centre. He further points out that when an equal excitation affects both the augmentor and the inhibitory parts of a nervous mechanism, it is the inhibitory or moderating influence which predominates.

Although the sensory system is primarily and fundamentally affected by anæsthetics, the motor functions are also profoundly modified. The changes, indeed, which the **motor system** undergoes in the different stages of anæsthesia are very interesting. Claude Bernard found that in the deeply anæsthetised frog motor nerves preserve their excitability. In the sciatic nerve the central terminations of the sensory filaments are anæsthetised, but not the motor filaments. In the chloroformed dog the application of vinegar to the tongue produces no salivary secretion; whereas stimulation of the chorda tympani—the secreto-motor nerve of the submaxillary gland—does so. As in the case of the sensory system, excitation phenomena first appear, to be subsequently followed by phenomena of a paralytic nature. In the earlier stages of the administration the centres capable of executing complex and co-ordinated movements are first affected. As the administration proceeds, those centres which evoke simple muscular acts fall victims to anæsthetic influence. And lastly, the automatic motor centres of respiration and of circulation fail to act and death ensues.

In an interesting and valuable research on the action of anæsthetics on nervous tissues, Waller[1] has shown that the physiological power of chloroform and of ether is in the relation of **7 or 8 to 1.** This observer employed the isolated nerve as being the most convenient representative of living matter, and by means of its negative variation, evoked by stimulation at intervals of one minute, examined its behaviour to anæsthetics.

The **reflex phenomena** of general surgical anæsthesia are of great interest and importance. Their occurrence, as the result of surgical procedures, frequently transforms simple into complex anæsthesia (p. 39). Broadly speaking, reflex phenomena may arise at all stages of the administration, from the commencement of the induction period, *i.e.* when consciousness is more or less intact, to the period immediately preceding respiratory paralysis when only certain efferent effects can be elicited.

When the degree of anæsthesia is but slight, reflex responses to stimuli may have all the external characters of conscious and purposive responses, although no true consciousness or purpose is present, owing to the cerebral cortex being at the moment unable to interpret correctly the sensory stimuli which reach it. During the second stage of anæsthesia (p. 77) there is still a brisk response to most stimuli—traumatic, thermal, electric, and chemical. But as the effects of the anæsthetic increase, the reflexes vanish in a more or less definite order; so that it is possible, in practice, to maintain appropriate degrees of anæsthesia by carefully studying reflex phenomena. Patients differ considerably, however, in regard to their reflexes. Some remain passive to violent stimuli during a light anæsthesia: others display persistent reflexes in response to comparatively slight excitation during well-established narcosis. Moreover, the same patient may, during the continued administration of a properly adjusted and diluted anæsthetic vapour, *i.e.* without any noteworthy change in the supply of the anæsthetic to the nervous centres, exhibit variations in his reflexes according to the state of his nervous system at the moment. Thus, it may happen,

[1] "The Action of Anæsthetics upon Nerve," *Brit. Med. Journ.*, November 20, 1897. "The Dosage of Chloroform," *ibid.*, April 23, 1898.

particularly during the earlier stages of chloroformisation, when no surgical stimuli are at work, that the nervous system, including a centre, is in a slack, passive, and irresponsive state, so that when a certain afferent excitation is brought to bear, as by touching the cornea, nothing but a small efferent effect follows, the lids feebly closing or not at all. But if, during this condition some stimulus be applied to some other part of the body, the nervous system is thrown into a state of tension and activity so that precisely the same treatment of the cornea is now followed by a much more powerful efferent effect, the lids tightly closing. The application of an ice-cold douche to the face may have this effect. In other words, a strong stimulus may induce a state of excitability in a centre or centres so that a reflex phenomenon, which was previously impossible, by reason of such centre or centres being inexcitable, now appears. This state of things is often met with in the spurious chloroform sleep of children (pp. 79, 411, and 539). It may also be observed when two operations have to be performed upon the same patient. Thus during the first operation the afferent stimulus from the cornea may only produce a trifling effect. But directly the surgeon commences the second operation upon another part of the body, the degree of anæsthesia (so far as the supply and elimination of the anæsthetic are concerned) remaining the same, not only may the lids tightly close when the cornea is touched with the finger, but reflex movement of the body in response to the surgical stimulus may result. The author has also met with cases in which surgical stimuli at particular periods in the anæsthetisation have apparently inhibited and not stimulated sensory centres. For example, he has often altogether withdrawn the anæsthetic during the continuance of a surgical operation, and has observed that a slight but distinct corneal reflex, which was present at the moment of withdrawal, has *not* increased in degree, as is usual under such circumstances, but has altogether vanished for several minutes. The operations during which he has noted this interesting phenomenon have principally been intra-abdominal, and the disappearance of corneal reflex has occurred more or less simultaneously with symptoms of surgical shock. Possibly some lowering of pressure in the cerebral circulation may have produced the phenomenon.

The **reflex respiratory phenomena** of anæsthesia are important. They are more common with certain anæsthetics than with others. They are much more common during light and moderate than during deep anæsthesia. Reference has already been made (p. 52) to the influence of psychical stimuli upon respiration. In the vast majority of cases traumatic and other stimuli augment rather than diminish the activity of the nervous mechanism of respiration. Thus, other factors remaining the same, the breathing of an anæsthetised patient who is not undergoing an operation is usually quieter, slower, and shallower than when traumatic stimuli are at work. This fact is particularly evident when, for some reason or another, a patient has been anæsthetised for a considerable time before the first incision is made: the quiet breathing at once becomes and remains deeper in response to the cutaneous stimulation. Coughing, deglutition movements, retching, inspiratory or expiratory spasm, laryngeal spasm, and stertor dependent upon the base of the tongue being drawn spasmodically over the laryngeal orifice, may one and all be brought about by surgical stimuli applied to parts of the body far removed from the site of the reflex phenomenon.

When reflex respiratory phenomena assume threatening proportions the condition already defined and described as **respiratory shock** will result (p. 42). In most cases the intercurrent asphyxial state thus brought about by surgical procedures is one dependent upon muscular spasm. Thus, laryngeal spasm, stertor from tongue retraction, muscular spasm about the jaws, fauces, and neck, or spasm of the thoracic or abdominal muscles, may all arise reflexly and culminate in respiratory arrest. As a general rule the reflex respiratory phenomena which are capable of causing respiratory shock occur during moderate anæsthesia. When proper narcosis has been established surgical stimuli rarely affect breathing prejudicially. But as Illustrative Case No. 50 would seem to indicate, traumatic stimuli may, in rare instances, inhibit the action of the respiratory centres without causing any simultaneous circulatory effect. Primary respiratory shock, occurring as it generally does in moderate anæsthesia, is usually unattended by circulatory depression, although the latter state will necessarily follow unless breathing be quickly re-established. When the circulation begins to fail as the result of the asphyxial state which may thus be brought about by peripheral stimuli, the condition which has been called composite shock (p. 42) will result.

It is interesting to note that respiratory conditions brought about reflexly will often vanish reflexly. Thus, let us suppose that a moderately deeply anæsthetised patient is undergoing an operation, and that at a particular juncture swallowing movements or laryngeal spasm are being excited by the surgical manipulation. As a result of this there is necessarily some temporary interference with the air-supply to the lungs, and hence some degree of cyanosis. By briskly rubbing the lips with a cloth the reflex act is at once inhibited, the air-way is again rendered patent, respiration recommences and cyanosis disappears. Lip friction is thus often exceedingly valuable in restoring free breathing.

Reflex circulatory phenomena are very common during general surgical anæsthesia; but they are more difficult to differentiate from one another than reflex respiratory phenomena. Reference has already been made (p. 58) to the influence of psychical stimuli upon the circulation. Reflex circulatory phenomena differ in their incidence and intensity according to numerous circumstances, such as the kind of anæsthetic in use, the degree to which its administration has been carried, the nature, situation, and intensity of the stimulus, the state of the vaso-motor, the cardio-inhibitory, and the cardio-accelerator centres, the character of the discharges from those centres, and the posture. The existence of two varieties of vaso-motor nerves—those the stimulation of which causes constrictor effects, and those the stimulation of which causes dilator effects—is well borne out by a study of the reflex phenomena of anæsthesia. Crile, whose work on circulatory shock is considered below, found that the excitation of sensory nerve fibres as by traumatic stimuli causes either a rise or fall in general blood-pressure according to the particular nerve mechanism which is affected, the stimulation of pressor nerves causing vaso-constriction and a rise in blood-pressure, and of depressor nerves vaso-dilatation and a fall of blood-pressure. Mechanical stimulation of sensory nerves, when both the animal and the nerve are fresh, at first produces pressor effects; but with the continuance of the stimulus these generally lessen and are then replaced by depressor effects. After repeated stimulation of the same nerve or of several nerves the animal passes into a state in which no stimulation even of a fresh nerve trunk will produce a rise in blood-pressure. Pressor action seems to be brought out by first or early stimulation and to be more readily exhausted than depressor action. We find, clinically, that reflex circulatory phenomena are much more common with chloroform than with ether. They may occur at all stages of the administration, but they are chiefly of importance during profound narcosis.

We now come to the consideration of **circulatory shock**. It is difficult to speak with certainty as to the precise circulatory effects which may take place in human beings when operations are commenced during semi-consciousness. Prior to the introduction of anæsthetics deaths were not uncommon at the moment of the commencement of an operation; and it is therefore not unreasonable to suppose that if an operation be begun before consciousness has been completely destroyed the risk of such an accident will still remain. It is possible that the respiratory and circulatory disturbances which, as we have seen (pp. 52 and 58), may arise from the dread of an impending operation, predispose to sudden syncope from surgical stimuli applied before consciousness has been annulled, death taking place from cardiac inhibition, vaso-motor paralysis, or both these conditions combined.

When the administration of an anæsthetic has been carried to that point at which pain can no longer be felt, the commencement of a surgical operation is probably unattended by any risk of primary and fatal reflex syncope. From this point onwards to the point at which the corneal reflexes vanish and the muscular system relaxes, surgical procedures may produce primarily circulatory effects, but these are not, as a rule, of importance. But when once profound anæsthesia has become established, and particularly when chloroform has been used, certain surgical stimuli are capable of producing very marked effects upon the general circulation. This is undoubtedly due to the fact that, in deep chloroform anæsthesia, the blood-pressure is already low from toxic dilatation of the cardio-vascular musculature, so that the effects of reflex vaso-motor dilatation or of reflex cardiac inhibition, which would not have been obvious had the blood-pressure been high, now become exceedingly obvious and circulatory shock results.

The physiology and pathology of surgical circulatory shock concern the anæsthetist chiefly in so far as they dictate the proper lines of treatment. At the present time there are two schools holding diametrically opposed views on the subject. One school, whose founder is G. W. Crile, of Cleveland, Ohio, teaches that the vaso-motor centres are paralysed in shock, and that there is a "manifest transference of the blood from the arteries and capillaries to the veins."[1] The leading exponent in Great Britain of these theories is J. L. Mummery, whose experimental work has confirmed that of Crile. This school relies for the prevention of shock upon saline infusion, ether anæsthesia following morphine, and the Trendelenburg position; and for treatment upon morphine, bandaging the limbs (auto-transfusion), intravenous infusion of weak solutions of suprarenal and pituitary extracts.[2] Strychnine is absolutely prohibited.

The opposing school adopts the "acapnia" theory of Yandell Henderson.[3] In this country this theory has been supported especially by J. D. Malcolm.[4] It asserts that in shock the condition of the vaso-motor centre is one of intense hyperactivity, not of paralysis; and that one of the chief causes of this state is loss of CO_2 from the tissues and the circulating blood. In prevention, morphine, saline infusion, slight rebreathing (to increase the proportion of CO_2 in the blood), warmth, and vaso-dilators are recommended. After the

[1] *Surgical Shock*, p. 140.

[2] Mummery, *Brit. Med. Journ.*, 17th Sept. 1910, p. 760; and *Lancet*, 18th Mar. 1905, p. 696.

[3] *American Journal of Physiology*, February 1908, Feb. and April 1909, and other papers in the same journal during 1910 and 1911.

[4] *Brit. Med. Journ.*, 17th Sept. 1910, p. 760.

causes of shock have ceased to act, vaso-dilators are no longer to be given, but strychnine and other stimulants are indicated; saline infusion subcutaneously (not into a vein) is also praised, but suprarenal and pituitary extracts are strongly condemned.

Such are the rival hypotheses of shock. It is obvious that clinical experience alone can decide between these two utterly different modes of treatment for the symptoms of shock arising in the operating-room, as distinct from the physiological laboratory. Fortunately the points on which the two schools agree are just those with which clinical experience is most in accord. Warmth and saline infusion, *both of which should be used as prophylactics* when there is reason to anticipate severe shock during an operation, are unquestionably useful; ether anæsthesia is also much less conducive to shock than is chloroform; and morphine (with atropine) is now a recognised aid to open ether anæsthesia. There is one other feature of Henderson's treatment as to which further clinical experience is desirable: that is, the use of CO_2 either in the inspired air or dissolved in saline solution. Clearly, the risk of anoxæmia should be at the same time minimised by oxygen (see also p. 588).

Furthermore, while fully admitting that the Crile hypothesis is open to damaging criticism in various details, on the question of vaso-constrictors versus vaso-dilators theory cannot be allowed to govern practice. If, as a number of clinicians believe, pituitrin really does relieve the symptoms of shock when injected into the veins, then neither the acapnia nor any other hypothesis can be valid which regards this agent as pernicious and dangerous. If, as others believe, pituitrin does in practice more harm than good when administered for shock, that is a point adverse to the contentions of Crile. At the same time, the experiments of Y. Henderson, and the arguments he founds on them, are extremely attractive; and it seems quite possible that in time some third theory will be formulated which will harmonise the two discordant hypotheses and at the same time provide a sure and safe basis for prophylactic and remedial treatment.[1]

[1] For a more complete exposition and comparison of these hypotheses of shock, the reader is referred to *The New Physiology in Surgical and General Practice*, by Dr. A. R. Short.

When circulatory shock is very pronounced, respiration may become feeble, or cease, owing to diminished cerebral blood-supply. In this way composite surgical shock (p. 42), characterised by suspension of both circulation and respiration, may arise.

The clinical aspects of all these varieties of surgical shock are discussed in Chap. VIII. (p. 253), Chap. XIX. (p. 562), and Chap. XX. (p. 603).

The corneal, laryngeal, pharyngeal, rectal, vesical, peritoneal, and genital **reflexes**, *i.e.* reflex muscular contraction when any of these parts are stimulated, are amongst the latest to disappear. In dogs the patellar reflex is at first exaggerated; it then lessens and finally disappears before the corneal reflex vanishes. The spinal cord undoubtedly preserves its power of transmitting sensory impulses till the very last; for certain stimuli may evoke reflex-effects (particularly upon respiration) even when a very profound narcosis is present. It is difficult to say with certainty at what particular point in the course of anæsthesia the main vaso-motor centre becomes paralysed, but it is probable that, in the absence of surgical or other stimuli capable of disorganising its action, it retains its controlling function till quite late. According to Richet, stimulation of the vagus will slow or even arrest the heart movements in all stages of anæsthesia. It is difficult, however, to produce a fatal result by vagal stimulation. Brodie and Russell [1] found that the pulmonary fibres of the vagus produce the most marked inhibition, the cardiac branches being much less effective, whilst those below the pulmonary are still less active. According to these observers the connection of the respiratory tract with the cardio-inhibitory centre is very close. As to the respiratory centre itself, it appears to remain sensitive to certain stimuli till just before its automatism is finally abolished. If the vagi be divided during deep anæsthesia, the usual respiratory phenomena still appear.

[1] *Journ. Phys.* vol. xxvi. p. 92.

(*d*) The Muscular Phenomena of General Surgical Anæsthesia

The muscular system is capable of being affected both directly and indirectly by general anæsthetics. Little is definitely known as to the *direct* effects of these substances upon muscle. Claude Bernard found that the application of etherised or chloroformed water to muscles induced rigidity and loss of sensibility, and that cloudy changes appeared microscopically. Ringer's experiments with regard to the action of anæsthetics upon the muscular tissue of the frog's heart will be subsequently considered; whilst those of Sherrington and Sowton on the dosage of the mammalian heart by chloroform will also be referred to. It would seem that when muscles are subjected to anæsthetic action they gradually lose their power of responding to stimuli. Thus, when the peripheral end of the sciatic nerve is stimulated during the administration of chloroform, a progressive diminution in the work done by the muscle takes place, the diminution becoming more marked as the duration of anæsthesia increases (Dastre). Most of the muscular phenomena of anæsthesia are dependent upon *indirect* (nervous) action. The following muscular phenomena may be witnessed in human subjects during the inhalation of anæsthetics:—

(1) **Conscious voluntary movements,** such as adjusting the head to a comfortable position, crossing the legs, etc. These may or may not be associated with some degree of analgesia.

(2) **Uncontrollable "nervous" movements,** such as tremor, hysterical outbursts, etc.

(3) **Sub-conscious purposive movements.** These are often very interesting. A patient may, for example, attempt to remove a mouth-prop placed between his teeth under the impression that it is a pipe or cigar. A movement originally initiated during normal consciousness may become greatly exaggerated as will-power lessens. Hardly noticeable movements of the feet may, for example, gradually increase to uncontrollable stamping.

(4) **Unconscious excitement or intoxication movements.**

These may vary from the simple laughter of intoxication to the most violent maniacal excitement.

(5) **Simple tonic spasm.** This may be local or general, and may occur in all stages of anæsthesia. It is usually referable either to a surgical stimulus, to some irritant within the air-tract, or to diminished air-supply.

(6) **Clonic spasm.** This may occur with all the usual anæsthetics; it is, however, most common with pure nitrous oxide. With this agent clonic movement is, as the writer has shown, of anoxæmic origin; and there is reason to believe that even with other anæsthetics such movement is often of a similar nature. Clonic movements may affect the arms, hands, legs, feet, trunk, or neck. To the more violent spasm, such as is seen with pure nitrous oxide, the term "jactitation" is applied. The author has sometimes observed, in patients under chloroform, twitchings of the fingers suggestive of the movements in piano-playing, and believes them to be usually dependent upon some slight inadequacy in the air-supply. Thus he has seen them come and go in obedience to the kind of breathing which he has made the unconscious patient adopt. They are, in fact, significant not of light or imperfect anæsthesia, but of incipient asphyxia; and great care should be taken not to push the anæsthetic at such times. Other convulsive twitchings may take place under chloroform (p. 416). Paul Bert[1] found that when an animal is anæsthetised and then submerged, asphyxial convulsions are still produced, although they are less marked than when asphyxia is brought about in the non-anæsthetised state. Convulsive phenomena are sometimes witnessed when a poisonous quantity of chloroform has been swallowed (Taylor).

(7) **Slow, co-ordinated movements,** particularly of the fingers, hands, and arms, sometimes occur in deep anæsthesia. Their nature is unknown (see p. 416).

(8) **Fine tremor** of the legs, arms, or whole body is sometimes met with in moderately deep anæsthesia, especially under ether.

It is difficult to say what particular parts of the central nervous system are involved in the development of the

[1] *Acad. des Sciences*, 18th March 1867.

muscular phenomena just described. As regards the disorderly and convulsive movements of the early stages of anæsthesia, Duret attributes them to excitation of the psycho-motor centres; whilst Dastre considers them to be caused by excitation of the bulbo-spinal sensory tracts. As already indicated, many of the muscular phenomena of anæsthesia are in reality asphyxial, or more properly anoxæmic, in their origin. According to some physiologists, the medulla oblongata at its junction with the pons contains what is known as a "spasm centre." When this centre is irritated, as by sudden venosity of the blood, or by sudden anæmia of the medulla, general convulsions occur. The clonic phenomena of nitrous oxide anæsthesia would thus be explained.

(*e*) The Effects of General Anæsthetics upon the Glandular System

Different anæsthetics produce different effects upon the various glandular organs of the body, and these effects will also be found to vary according to the particular stage of anæsthetisation. There is usually, for example, a more copious secretion from the mucous, the salivary, and the sweat glands under ether than under chloroform. The author has noticed that when intercurrent surgical shock takes place the mucous secretion of the mouth is suspended, reappearing as the shock subsides. The sweat glands, on the other hand, are active during surgical shock, the "cold sweat" being replaced by a warm and dry skin as the circulation becomes re-established.

The effects produced by anæsthetics upon the **kidneys** and their secretion will depend upon such circumstances as the kind of anæsthetic employed, the method adopted for its administration, the degree to which the administration has been carried, the presence or absence of shock, and other factors which, in the present state of our knowledge, hardly admit of enumeration. Some observers[1] find that with both ether and chloroform there is an increase in urinary secretion up to the point at which surgical anæsthesia (loss of corneal

[1] See Prof. W. H. Thompson's article, *Brit. Med. Journ.*, 25th March 1905, p. 649; also a paper by Drs. H. Pringle, Maunsell, and S. Pringle, *Brit. Med. Journ.*, 9th September 1905, p. 542.

reflex) occurs; that during full narcosis urinary secretion is more or less completely arrested; and that during the recovery period the renal functions are resumed and urine is again secreted. The latest clinical observations agree in the main with these views, except that a decrease of secretion is noted at once after the commencement of the administration,[1] in the case of chloroform; whereas with ether there is an increase at first, followed shortly by a decline. For further remarks upon this subject the reader is referred to the following chapter, in which will be discussed the special effects of ether and chloroform upon the kidneys, and to the clinical section of the work, in which the various after-effects of these and other anæsthetics are considered.

D. DEGREES OR STAGES OF ANÆSTHESIA

By carefully studying the effects produced by anæsthetics upon man, observers have from time to time proposed to speak of different **degrees or stages** in their action. Thus Snow spoke of five degrees.[2] In the first of these consciousness is not abolished; there are various disturbances of special senses, and some diminution of common sensibility. In the second the mental functions are impaired but not necessarily suspended; there are laughing, talking, and excitement. In the third, voluntary motion is suspended, but involuntary movements continue; rigidity and spasm occur, muttering is common, and although there is no consciousness or perception of pain the subject may cry out during a surgical procedure. In the fourth, the breathing becomes stertorous, the pupils dilated, and the muscular system relaxed. In the fifth and last degree the breathing is difficult, feeble, or irregular, and is sometimes performed only by the diaphragm; respiration then ceases, and the heart, which for a time pulsates distinctly, soon fails as in death from asphyxia.[3]

Dastre[4] describes four periods: (1) suspension of brain

[1] J. W. Bovee, *American Journal of Obstetrics and Gynæcology*, June 1909, p. 1004.

[2] *Op. cit.* p. 35.

[3] As we shall presently see (p. 114), Snow also believed that *with concentrated chloroform atmospheres* the heart might cease before respiration

[4] *Op. cit.*

functions—sleep; (2) abolition of functions of spinal cord considered as a conducting organ of sensibility—complete anæsthesia; (3) abolition of motor functions of cord; and (4) bulbar paralysis — cessation of respiration and circulation. The objection to Dastre's classification is that there is good evidence to show that even in deep anæsthesia both sensory and motor impulses may be transmitted by the cord.

Taking all circumstances into consideration we may conveniently speak of the following degrees or stages in simple general surgical anæsthesia when no complication, asphyxial or traumatic, is present (p. 39):—

Degree or Stage.	Effects.
1. Stage of analgesia.	Excessive ideation; disturbances of judgment, control, and volition. Analgesia. Vertigo and loss of power of maintaining equilibrium. Pleasurable or distressing sensations. Disturbances (exaggeration or diminution) of common sensibility and of special senses. Misinterpretation of external impressions. Emotional disturbances, *e.g.* laughter and crying. Reflexes well marked and often exaggerated; sensory stimuli produce co-ordinated and apparently purposive movements. Loss of power of remembering (fixing) sensory impressions. Dreams. Rise of blood-pressure and increase of cardiac action. Respiration increased, but regular and free, unless interfered with by emotional causes or by direct irritation of anæsthetic, inducing cough, "holding of breath," deglutition movements, retching, or vomiting. Pupils dilated.
2. Stage of light anæsthesia.	Complete loss of consciousness. Delirium; articulate speech passing into unintelligible muttering. Respiration still deeper and quicker than normal; often irregular and impeded by General tonic muscular spasm, deglutition, closure of glottis, spasm of jaws, etc. Clonic muscular spasm. Reflexes still persist; but motor results of stimuli devoid of purposive character. Inarticulate phonated (expiratory) sounds. Coughing, retching, vomiting. Heart's action still excited (much dependent on character of breathing). Pupils smaller.

Degree or Stage.	Effects.
3. **Stage of deep anæsthesia or narcosis.**	Relaxation of most muscles. Breathing regular, often softly snoring or stertorous. Decrease of respiratory exchanges; fall of temperature. Increasing fall of blood-pressure (chloroform). Heart's action weakened, variable degree of cardiac dilatation. Loss of corneal, pharyngeal, laryngeal, patellar, and most but not all reflexes. Pupils larger.
4. **Stage of bulbar paralysis.**	Loss of bladder distention, rectal, and other very late (*e.g.* certain peritoneal) reflexes. Breathing becomes shallow. Increasing lividity or pallor. Breathing ceases (paralysis of respiratory centres), loss of respiratory reflexes. Paralysis of vaso-motor centres (?). Feeble, irregular cardiac action; complete cardio-vascular paralysis. Widely dilated pupils. Separation of eyelids. Death.

The above table is only intended to indicate in a general sense the order in which the various effects produced by anæsthetics make their appearance. As already mentioned, there are so many factors capable of modifying the course of anæsthesia that it is exceedingly difficult, if not impossible, to generalise.

E. ON THE INTIMATE PHYSIOLOGY AND CHEMISTRY OF GENERAL SURGICAL ANÆSTHESIA

Although many of the problems which have for years surrounded the subject of anæsthesia may now be regarded as solved, there remains one problem which has hitherto defied all attempts at solution, viz. the nature of the changes within the central nervous system which are capable of bringing about a state of general anæsthesia. As we have seen, this state may be induced by a variety of therapeutic agents; but it may also be established, in a more or less complete and typical form, in numerous other ways.

There is, in natural sleep, some degree of anæsthesia; the degree varying in different subjects, and in the same subject according to the special circumstances which may be present. The auditory, olfactory, visual, and tactile stimuli which will arouse one person may not even disturb the slumbers of another. But apart from the question of anæsthesia, there are several other interesting points of similarity between natural and artificial sleep. Thus we find in regard to both states that a rapid flow of confused ideas immediately precedes unconsciousness; that vivid dreams, dependent upon some suggestion or incident prior to unconsciousness, are remembered on awakening;[1] that the muscular system is relaxed; that complicated reflex phenomena may be elicited; that the eyelids are closed; that the pupils are, as a rule, contracted;[2] that the production of heat is reduced; that the exhalation of carbonic acid is diminished; and that respiration is often snoring or stertorous in character. It has also been urged that both in natural and in artificial sleep cerebral anæmia is present; but whilst it is undoubtedly true that in the former state a general fall of arterial tension occurs, and that as a consequence of this the blood-supply to the brain becomes reduced, the analogy only holds good so far as *chloroform* anæsthesia is concerned. With nitrous oxide and with ether no such fall in pressure takes place, and the blood-supply to the brain is therefore not lessened. The similarities between natural and artificially induced sleep are most striking when we compare heavy natural sleep with the state of "false anæsthesia" or "chloroform-sleep" (pp. 66 and 411).

It is not, indeed, beyond the limits of possibility that future research may indicate that a similar change within the elements of the cerebral cortex is responsible, at all events in part, for the phenomena of both states. At the present time little if anything is definitely known as to the nature of the physiological changes which are involved in the production of sleep; but the existence of the analogies here referred to may perhaps be taken to support the view that this state is dependent upon the presence within the circulation of some chemical substance capable of exerting, in association with other factors, temporary soporific influences. Such a view, however, is by no means generally accepted; for, according

[1] This is only true as regards very short administrations of anæsthetics.

[2] As regards the pupils, the analogy only holds good when we compare the sleeping subject with the anæsthetised patient who is allowed to remain free from all traumatic and other stimuli, and who is, moreover, free from all intercurrent asphyxial conditions.

to one hypothesis,[1] the unconsciousness of natural slumber is to be regarded as resulting not so much from changes induced by this or that agent or agency within the "neurons" and other structures which collectively constitute the independent elements of the nervous system, but from simple alterations of a histological character affecting the dendritic processes which connect individual neurons one with another. According to some authors a retraction of these processes takes place, with the result that the individual neurons become isolated (Lépine and Duval), whilst according to others a widening in these communicating paths occurs, so that nervous impulses more readily travel from one cell system to another (Lugaro). If we adopt the former view, then the isolation of independent cell systems is to be regarded as the immediate cause of sleep; whilst according to the latter the widening of impulse-paths is to be looked upon as responsible—such widening leading to confusion of thought and finally to unconsciousness. It is an interesting fact that it is frequently possible, by very gradually administering chloroform during sleep, to make the natural pass into the artificial state (p. 418). Natural sleep or a feeling of drowsiness is, moreover, a common sequel of anæsthetisation. The peculiar movements of paralysis agitans cease during general anæsthesia just as they cease during natural sleep.[2]

It has been shown by Bonwill that it is possible, with certain subjects, to induce a state of analgesia or (?) anæsthesia by the simple expedient of rapid and deep breathing. Dental operations have thus been painlessly performed; but the method has, in other hands, proved uncertain, whilst its *modus operandi* has yet to be established. Some have explained the phenomena by supposing that the exaggerated respiration so modifies the cerebral circulation that the normal activity of the intellectual and perceptive centres becomes temporarily suspended. It is possible, however, that "suggestion" or "inhibition" may play a part in some cases, whilst simple nervous exhaustion may constitute a factor in others.

The analgesic and anæsthetic effects produced by hypnotism hardly admit of discussion in the present work. Experience has shown that only certain susceptible persons can be thus influenced, that a long education is needed to render subjects hypnotisable, and that the general health of those who submit themselves to this treatment is liable to become seriously injured.[3]

Claude Bernard fully realised the occasional presence of an asphyxial element in ordinary cases of chloroformisation, and threw out the suggestion that asphyxia is probably capable of producing an anæsthesia of its own—a suggestion which is of interest when considered in the light of more recent research. According to Reboul and Morat,[4] frogs placed

[1] For many interesting points in connection with sleep I am indebted to Dr. Bradbury's lectures. See *Lancet*, 24th June 1899, p. 1685.

[2] I have observed this not only with chloroform, but with nitrous oxide and oxygen.

[3] For a good example of results that may be achieved under favourable circumstances see *Lancet*, p. 527, 22nd August 1903.

[4] Dastre, *op. cit.*

in vacuo, or in an inert gas, become immobile and insensible; reflex movements disappear; respiration then ceases; but circulation persists for a considerable time. Pure nitrogen rapidly destroys consciousness and produces complete insensibility to pain; and mixtures of this gas with small proportions of oxygen (up to 7 per cent) are similarly capable of inducing anæsthesia, the rapidity of action diminishing as the oxygen percentage rises (see p. 466). It is noteworthy that these results occur when every provision is made for the escape of carbonic acid gas from the lungs, so that we are justified in regarding them as due simply to anoxæmia or want of a sufficiency of oxygen to carry on normal metabolism within the nervous centres. Nitrous oxide produces very similar effects, but they come about with a somewhat greater rapidity and are more persistent—a difference doubtless dependent upon the greater solubility of this gas. With both nitrogen and nitrous oxide the muscular system is thrown into an epileptiform or tetanic state; and it is this factor which renders these gases irrespirable when administered in a state of purity. The anoxæmic anæsthesia which we see in its typical and pure form in the case of nitrogen and hydrogen is also met with as a by-product, so to speak, when ether, chloroform, or other agents are being employed; and the intensity of the effects produced by these drugs is, in practice, often largely dependent upon the degree of anoxæmia present (see p. 351). In addition, however, to the simple limitation or deprivation of oxygen thus favouring or actually producing general anæsthesia, there is ample proof that, in certain methods of anæsthetisation in which re-breathing is permitted, the presence of carbonic acid gas (itself an anæsthetic) may contribute to the narcosis.

Richet[1] contended that a temporary and dissociable combination is produced between the anæsthetic and the protoplasmic matter with which it comes in contact; and this view has received support from recent researches. Thus Moore and Roaf conclude, as the result of numerous experiments,[2] that anæsthetics form unstable compounds or aggregates with the proteids of the tissue cells; that anæsthesia is due to a paralysis of the chemical activities of the protoplasm as the result of the formation of such aggregations; and that the compounds so formed are unstable and remain formed only so long as the pressure of the anæsthetic in the blood is maintained. They find, moreover, that the solubility of all the anæsthetics with which they experimented is higher in serum than in water; that at a certain concentration, definite for each anæsthetic, there occur opalescence and commencing precipitation of proteid; that at equal concentration of

[1] *Dict. de Physiologie.*
[2] *Proc. Roy. Soc.* vol. lxxvii. Series B, No. B 515, p. 86.

chloroform in water or saline on the one hand, and in serum, hæmoglobin, or the tissues (brain, heart, muscle, and liver) on the other, the vapour-pressure is always higher in the former than in the latter; and that accompanying the combination of the anæsthetic with the proteid there takes place a splitting off of electrolytes. Hamilton Wright[1] maintains that ether and chloroform produce bio-chemical changes within the central nervous system, the nerve-cells of both brain and spinal cord undergoing "rarefaction," or, in extreme cases, "pseudo-degeneration," whilst the tips and stems of the chief dendritic extensions of many pyramidal cells display early and constant moniliform enlargements. He states that these enlargements increase in size during anæsthetisation and spread along the dendrons of the cell body. The nervous structures of rabbits are more easily affected than those of dogs. He ascribes the moniliform swellings observed in the dendrons to the effects of the anæsthetic upon the Nissl's bodies within the cells, believing, in common with many other observers, that these bodies possess nutritional and energy-producing functions.

Meyer and Overton believe that the action of anæsthetics is upon the lipoids of the brain cells, and that a chemical combination is formed which destroys temporarily the functioning power of the cell. Reicher, working out this idea, showed that during anæsthesia the amount of lipoid, especially of lecithin, in the blood is greatly increased; hence he supposes that the anæsthetic dissolves lecithin out of the brain. Nerking[2] administered anæsthetics to rabbits, rats, and dogs to which lecithin had been given either hypodermically, intraperitoneally, or intravenously: he tried not only ether and chloroform, but also various local anæsthetics, morphine-scopolamine, etc. He found in all cases that much larger doses are required to produce anæsthesia than in control animals of the same size. It is suggested either that the injected lecithin abstracts the drug from its combination with the brain lecithin; or else that the new lecithin takes the place of that which has been dissolved out of the brain by the

[1] "The Action of Ether and Chloroform on the Neurons of Rabbits and Dogs," *Journ. Phys.* vol. xxvi. pp. 30, 362.

[2] *Münch. medizin. Wochenschr.*, 20th July 1907.

anæsthetic. According to another German authority, this hypothesis does not of itself suffice.[1] A chemical reaction is postulated in addition, by which the narcotic agent takes possession of some of the active oxygen of the nerve tissue. By this means a temporary asphyxiation, with consequent loss of function, is brought about. The products of this oxidation process of the narcotic explain the acidosis of anæsthesia; and the fats and lipoids thus split up are the source of the acetone which is formed at the same time. The most recent discussion of these problems is that of Verworn.[2] In an elaborate paper, which well repays reading *in extenso*, he states, "it is an established fact that narcotics induce an acute asphyxia of the cell. Herein is the essence of narcosis." After considering and rejecting various hypotheses as to the mechanism of this asphyxia, he thinks it most probable that "the narcotic renders the oxygen-carriers incapable of activating the oxygen, so that the oxidisable materials could no longer be oxidised and decomposition would proceed only in non-oxidative form." He further contrasts narcosis with sleep, dwelling upon the wide differences between them.

In attempting to summarise this portion of our subject, all we can say is that general anæsthesia is probably brought about by some change of a physico-chemical character within the protoplasm of nerve-cells; that the most delicate and vulnerable of the nervous elements—those which give to the organism its characteristic peculiarities, attributes, and functions—are first affected; and that, finally, the most resistant centres, upon which life is dependent, are attacked. Whether this change is due to the local effect of the anæsthetic itself upon the cell-contents, or whether some alteration in the blood produced by the anæsthetic is the immediate cause of such changes, it is at present impossible to say. As is pointed out in many parts of this work, there are remarkable analogies between the effects of simple anoxæmia and those produced by general anæsthetics, and it is not at all improbable that future experimental research may lead us to the conclusion that general anæsthetics produce their characteristic effects by

1 Bürker, *Münch. medizin. Wochenschr.* No. 27, 1910.
2 *Johns Hopkins Hospital Bulletin*, April 1912.

limiting the normal processes of oxidation upon which the intellectual, sensory, and motor centres depend for the execution of their respective functions. The fact that during the inhalation of pure nitrogen, or of nitrogen mixed with small percentages of oxygen, a peculiar "thrilling" is experienced identical with that met with during the inhalation of nitrous oxide, ether, chloroform, and similar agents is strongly in favour of the view that diminished oxidation plays an important, if not an essential, part, in the production of general anæsthesia. It would be interesting to ascertain whether, during anæsthesia induced by nitrogen, changes similar to those described by Hamilton Wright (*vide supra*) are to be detected within the central nervous system.

F. THE AFTER-EFFECTS OF GENERAL ANÆSTHESIA

After the withdrawal of an anæsthetic the animal which has been subjected to its influence generally recovers its vital functions without the supervention of any injurious after-effects. This is conspicuously the case with such anæsthetics as nitrous oxide and those of the ethyl-chloride and ethyl-bromide type which are rapidly eliminated. The prolonged administration of ether, however, not unfrequently leads to fatal **lung complications**; whilst protracted anæsthetisation by chloroform, or the repeated administration of this agent, is liable to be followed by **degenerative visceral changes.** After-effects of the last-mentioned variety have been described by numerous observers. In 1866 Nothnagel[1] showed that fatty degeneration of the liver and heart followed the introduction of chloroform into the stomach or subcutaneous tissues of rabbits. In the subcutaneous injections fatty degeneration of the kidneys was also produced, and the urine was found to contain blood corpuscles and casts. He concluded that chloroform produced fatty degeneration by destroying the blood corpuscles, and compared its action with that of the bile acids, arsenic, and phosphorus. Ether produces only a very slight fatty change. Ungar and Junker[2] appear to have been the first to demonstrate in animals the

[1] *Berlin. klin. Woch.*, 1866, No. 4.

[2] For this and other references I am indebted to the writings of Stiles and M'Donald (*Scottish Medical and Surg. Journal*, Aug. 1904).

fatty changes produced by chloroform when administered by inhalation. In dogs extensive changes of this nature are met with in the liver, heart, and voluntary muscles some hours after a single prolonged inhalation. Repeated administrations are followed by fatty degeneration in the kidneys, spleen, and mucous membranes of the respiratory and alimentary tracts, in addition to changes in the liver and heart. Strassmann has confirmed the observations of Ungar, and has shown that chloroform causes an increased excretion of nitrogen in starved animals, thus pointing to the increased destruction of proteids. Loss of blood before chloroformisation intensifies the degenerative effects produced by the drug. In 1889 Ostertag also confirmed Ungar's observations. The results of chloroforming several animals for an hour or so at a time during a period of many days are thus summed up by Ostertag:[1] (1) "Fatty degeneration of organs, especially fatty infiltration of the liver, and fatty metamorphosis of the cardiac and skeletal muscles, kidneys, and stomach; (2) these fatty changes result from the action of chloroform upon the blood (destruction of red corpuscles) and upon the tissue cells; (3) some individuals have a greater susceptibility to this action of chloroform, and succumb at an earlier period to its effects; and (4) the fatal effect is due to cardiac paralysis which may occasionally be accompanied by but slight anatomical lesions of the myocardium, and also the general carbonisation of the blood." More recently these experiments on animals have been corroborated by Heintz, by Bandler, and by Ferdinand Schenk,[2] who examined the livers of animals before and some days or weeks subsequent to chloroform narcosis, and found that the fat which appeared in the organs a few hours after inhalation sometimes did not disappear for days or even weeks. Ether gave rise to similar but less marked changes. Quite recently G. H. Clark[3] has published results which confirm entirely the work of all these observers. He gave very small doses of chloroform every day to rabbits, and found that such doses are actually more dangerous than a single large dose. His post-mortem findings agree with those of Ostertag, except that he

[1] I am indebted to Dr. L. Guthrie for this information.
[2] Guthrie, *Lancet*, 6th July 1903. [3] *Lancet*, 21st Jan. 1911, p. 158.

found the kidneys to be markedly less degenerated than the liver. However, in his experimental researches on the poisonous effects of chloroform upon the kidneys Offergeld found [1] that animals chloroformed for a long time (up to two hours) recovered well from the immediate effects of the anæsthetic, but on the second and subsequent days they became lethargic, and in from 48 to 60 hours they died. Post-mortem examinations of rabbits and guinea-pigs thus killed by a single administration showed **parenchymatous degenerations in the heart, liver, and kidneys.** Fatty degeneration of the kidney did not occur in the organ which had had its arterial supply cut off by ligature of the renal artery after 40 minutes' anæsthesia; but pronounced degeneration of the kidney occurred after ligature of the renal vein and an anæsthesia of 30 minutes. Offergeld came to the conclusion that in these cases of **postponed chloroform death** the fatal result was due to the effect of the drug on the kidney cells. He found that a mixture of chloroform and oxygen was less likely to induce these changes than one of chloroform and air. These investigations are of interest in connection with the subject of post-anæsthetic toxæmia, a full account of which will be found on p. 634.

[1] Quoted by Bevan and Favill, *Journ. of Amer. Med. Assoc.*, 2nd Sept. 1905, p. 691.

CHAPTER IV

THE SPECIAL PHYSIOLOGY OF THE CHIEF GENERAL ANÆSTHETICS

A. NITROUS OXIDE

Humphry Davy believed that nitrous oxide was decomposed into its constituent elements during its passage through the circulation. The intoxicating effects which the gas produces were hence ascribed to hyper-oxygenation of the blood, whilst the anæsthetic effects were explained on the assumption that the over-production of oxygen leads to the formation of such quantities of carbonic acid that "internal asphyxia" arises. It soon became clear, however, that nitrous oxide is too stable a body to be decomposed at the temperature of the blood; and Frankland,[1] who analysed the expiratory products of several administrations, failed to find any distinct evidence of decomposition. In 1864 Hermann[2] came to the conclusion that nitrous oxide is simply absorbed by blood plasma, that it produces no change in blood, and that it is not itself altered during its period of association with blood. Hermann found that 100 volumes of blood at the temperature of the body absorb somewhat less than 60 volumes of nitrous oxide. Several years later, Bert fixed the solubility at 45 volumes of gas per 100 volumes of blood. The hyper-oxygenation theory was therefore abandoned, and a precisely opposite hypothesis took the field. It was now maintained, and particularly by Jolyet, Blanche, and Duret, that the anæsthetic effects of nitrous oxide were dependent, not upon excess, but upon want of oxygen. Many of the phenomena which attend

[1] *St. Bartholomew's Hospital Reports,* vol. v.
[2] *Brit. Med. Journ.*, 18th April 1868, p. 378.

the administration of pure nitrous oxide were admitted to be asphyxial in their type; and it was thought highly probable that the same intimate mechanism which gave birth to the phenomena of asphyxia also gave birth to the phenomena of anæsthesia. There were certain considerations which seemed to support this view. Thus, the unconsciousness was certainly deepest when the asphyxial seizure was at its height, whilst the admixture of air with the anæsthetic gas was believed to interfere with or prevent good anæsthesia. It was soon ascertained, however, that by attention to detail a non-asphyxial form of anæsthesia can be secured by administering air or oxygen with nitrous oxide. Andrews of Chicago was the first to demonstrate this fact (p. 282). Later on Paul Bert devoted much attention to the subject (p. 282), and placed upon a scientific basis the truth at which Andrews had arrived. The French physiologist, however, found that the best results, so far as anæsthesia was concerned, were attainable by increasing the atmospheric pressure at which the nitrous oxide and oxygen were administered (see p. 314). Subsequent experience has shown that whilst such an increase of pressure undoubtedly has certain advantages, it is by no means essential. Even with mixtures containing 20 per cent of oxygen, anæsthesia may be attained at ordinary atmospheric pressures (p. 312). For further remarks on this point the reader is referred to Chapter X., which deals with the clinical aspects of nitrous oxide.

It became clear then that, whatever the physiological action of nitrous oxide may be, it certainly possesses anæsthetic properties of its own. As regards the asphyxial phenomena which characterise the action of this gas when administered free from air or oxygen, these are looked upon as accidental, and dependent upon the crude system of administration. It is difficult to believe that the anæsthesia is caused by asphyxia, seeing that anæsthesia still results when nitrous oxide is administered with as much free oxygen as is present in atmospheric air. We must be careful, however, of our grounds as we approach this aspect of the subject. The fact that anæsthesia can be secured by nitrous oxide without producing any *obvious* asphyxial symptoms cannot be held to prove that the anæsthesia of this gas is not dependent upon some alteration in or reduction of the normal oxidation processes taking place within sensory and other nerve-cells. The remarkable influences exerted by increasing and diminishing the percentage of oxygen in nitrous oxide and oxygen mixtures would seem to suggest that there is a very close affinity between the intimate action of nitrous oxide itself upon the central nervous system and the effects of diminishing the normal oxygen supply (see p. 311). It is quite conceivable that the effects of nitrous oxide, ether, and chloroform, when administered with a sufficiency of oxygen to avoid obvious asphyxial (anoxæmic) symptoms, may be the same, and that this action may be of the nature of deoxidation.[1] The initial sensations under nitrous oxide are of an agreeable and stimulant character — almost identical with those of ether and chloroform; and when non-asphyxial and deep nitrous-oxide anæsthesia is established, this anæsthesia is similar in its main features to that produced by other anæsthetics. Were nitrous oxide anæsthesia the result of simple oxygen deprivation we should not expect the initial sensations produced by the inhalation to be of an exhilarating character. Nitrous oxide has, in fact, quite as great a claim as chloroform to be considered a general anæsthetic. It is true that, as the former is gaseous at ordinary temperatures and pressures, it may be administered in its pure state; whilst the latter, being liquid, needs vaporisation. It is also true that the toxicity of nitrous oxide is of a lower order than that of chloroform. Both anæsthetics, however, require dilution with air or oxygen in order that the anæsthesia of each may become satisfactorily established, and this anæsthesia may be readily intensified by reducing the air or oxygen supply.

It has been contended by some observers that the phenomena produced by pure nitrous oxide are one and all special and specific, and that none of them are asphyxial or, more properly speaking, anoxæmic in their nature. This view, however, must now be discarded; for we know that by adding oxygen to nitrous oxide the stertor, the epileptiform movement,

[1] R. Gill, *The $CHCl_3$ Problem.*

and the cyanosis may be prevented without disturbing the anæsthesia. Animals killed by pure nitrous oxide display post-mortem the usual signs of asphyxia, the right cavities of the heart being full, and the left comparatively empty. Sir G. Johnson[1] believed that the great difference in the fulness of the right and left chambers is to be ascribed to contraction of the pulmonary arterioles brought about by the non-oxygenated blood. He maintained that, however asphyxia is induced—whether by nitrous oxide, by nitrogen, or by paralysing respiration by curare—the same effects follow; but, as Dr. P. Black[2] had previously suggested, it is more probable that the distension of the right heart is consequent upon arrest of respiratory movement. Dr. Black appears to have been the first to put forward this explanation of the characteristic post-mortem appearances of asphyxia. As has been pointed out (p. 58), there is ample evidence in administering anæsthetics of the great dependence of the pulse upon the fulness and efficiency of respiration; it may be going too far to say that the pulmonary stasis of asphyxia is in no way dependent upon the blood condition, but it may be affirmed with certainty that the factor of suspended breathing is one of great importance in preventing the passage of blood from the right to the left cardiac cavities. There are, as we might expect, certain differences between the phenomena produced by nitrous oxide, by nitrogen, and by mechanical closure of the trachea; but they one and all lead to fatal asphyxia. As Sir G. Johnson urged (p. 466), there are close resemblances between the effects produced by nitrous oxide and those produced by nitrogen. With each of these gases swelling of the tongue, cyanosis, epileptiform spasm, and deep stertor occur. Although both nitrous oxide and nitrogen are respirable to a certain point, they are irrespirable beyond that point. As originally stated by Jolyet and Blanche, nitrous oxide cannot support animal or vegetable life owing to lack of available oxygen. Germinating seeds cease to germinate in an atmosphere of the pure gas. In the case of man the average inhalation period is about 56 seconds: at

[1] *Brit. Med. Journ.*, 21st and 28th April 1894. The researches of Bradford, Dean, and others appear to render this theory untenable.

[2] See *Brit. Med. Journ.*, 11th March 1876, p. 316.

the end of that time fresh oxygen must be admitted to the lungs or permanent asphyxia will result (p. 293). That nitrous oxide and oxygen can be breathed for a long period without materially interfering with respiration or circulation is shown by a remarkable experiment of M. Claude Martin of Lyons, who administered to a dog a mixture of nitrous oxide with 15 per cent of oxygen for three consecutive days (72 hours).[1]

M. Martin employed a chamber of the capacity of 250 litres, and capable of withstanding an internal pressure of 1·5 atmospheres. Dog put in at 5 P.M. 85 parts of nitrous oxide and 15 of oxygen introduced. Pressure progressively raised to 110, 115, and 120 cm. At 6 P.M. dog well anæsthetised. 25 litres of the mixture supplied every hour. Potash solution used to absorb CO_2. After 12 hrs. respiration calm and remained so until end of experiment. After 72 hrs. dog removed. In 15 min. feet commenced to move and eyes opened. 35 min. later made efforts to stand, and trembled as if cold. After 35 min. he moved paws when pricked, and was able to walk and obey commands. He refused milk. Intelligence apparently unimpaired. At 7 A.M. next morning (14 hrs. after experiment) he was in good spirits, and ate well. The total amount of gas consumed was 2500 litres.

The nature of the **blood changes** in nitrous oxide anæsthesia is still *sub judice.* There is no definite evidence that this anæsthetic forms any combination with hæmatin or any substance within the blood, although some such association is regarded by many as highly probable. As already indicated, nitrous oxide is very soluble in blood.[2] According to Davy, it has the power of turning out oxygen or air from water, and it is probable that, in addition to its preventing the access of fresh oxygen to venous blood, it actually dislodges more or less completely the oxygen still remaining therein when it reaches the pulmonary capillaries. As regards the gases present in blood during nitrous oxide anæsthesia little is definitely known. Oliver and Garrett[3] in their experiments found that carbonic acid was present in the blood in small quantities as compared with the amounts met with under

[1] See a pamphlet entitled "Sur l'anesthésie prolongée et continue par le mélange de protoxyde d'azote et d'oxygene sous pression (méthode Paul Bert)," by Claude Martin.

[2] See Kemp, *Brit. Med. Journ.*, 20th Nov. 1897, p. 1482.

[3] *Lancet,* 9th Sept. 1893, p. 625.

other anæsthetics; but in a very large quantity relatively to the amount of oxygen. In the case of a rabbit the percentages were CO_2 15·66, O 3·49, N_2O 22·49, and N 11·23 per 100 vols. of blood. Kemp has also found a great reduction in the CO_2 of arterial blood. We can hardly be surprised, however, at the diminution in this gas, seeing that, during the inhalation of pure nitrous oxide by the ordinary means, the air-supply is cut off. The comparatively large percentage of nitrogen in the above analysis is interesting but difficult of explanation, and it is to be hoped that further researches will be conducted to throw light upon this and other results. Observations are also needed with regard to the blood gases under nitrous oxide and oxygen. Some observers have suggested that by the use of oxygen with nitrous oxide an increased production of CO_2 might lead to a locking-up of this gas within the blood, but it is difficult to see how this could take place provided all expirations escape, as they certainly do in practice, at the expiratory valve. The only condition under which such an accumulation might arise would be that of feeble lung ventilation.

The **blood-pressure** under pure nitrous oxide is markedly raised, as shown by Kemp's tracings.[1] This observer points out that the results which he obtained are clearly parallel to those met with in asphyxia, the excursions of the kymographic tracings being more pronounced than with any other anæsthetic. He found, moreover, that there was no depression of the heart until the respiration had become much affected by pushing the anæsthetic. Buxton [2] has attempted to prove by sphygmographic tracings that there is no rise of tension in the human pulse during nitrous oxide anæsthesia; and argues against any analogy between nitrous oxide anæsthesia and asphyxia. There is little doubt, however, as to the increase in arterial tension. When the usual respiratory embarrassment of deep nitrous oxide anæsthesia takes place, there is necessarily a fall of pressure in the systemic arteries owing to impeded pulmonary circulation; but this late fall of tension is hardly to be regarded as directly due to the nitrous oxide, and it is quickly recovered from when fresh air is admitted to the

[1] *Loc. cit.* [2] *Trans. Odont. Soc.* vol. xviii.

lungs. Guy, Goodall, and Reid[1] agree with Kemp that there is a marked rise of blood-pressure under nitrous oxide; and they find it to be greater with valves than when rebreathing is allowed. This difference they attribute to the effect of the asphyxial element; when a gallon of oxygen is first inhaled to eliminate this, nitrous oxide anæsthesia causes the blood-pressure to rise hardly at all. So that, on this point, they favour Buxton rather than Kemp. Pickering[2] found that after several minutes' action pure nitrous oxide arrested in diastole the embryo heart of the chick; that a mixture of nitrous oxide with 30 per cent of CO_2 rapidly stopped the heart after 30 seconds; but that a mixture of 70 per cent of nitrous oxide and 30 per cent of oxygen stimulated the heart, which still acted after several hours' exposure to the mixture. Kemp finds that the heart beats more strongly under nitrous oxide and air than under nitrogen and air, so that the gas may be said to possess a stimulant effect upon the heart.

As regards the effects of nitrous oxide upon the **kidney**, Kemp[3] states that contraction of the renal vessels takes place, and that urinary secretion rapidly diminishes. He finds that albuminuria is produced, though not to any great extent, in complete narcosis.

When pure nitrous oxide is administered to a **lethal degree**, respiration ceases, and death takes place from asphyxia, the heart continuing to beat, in some cases for several minutes, after the breathing has ceased. The immediate cause of the respiratory arrest is usually, if not always, muscular spasm, and not muscular paralysis (see p. 299).

B. ETHER

Ether occupies a position which, so far as its anæsthetic properties are concerned, is in many respects intermediate between nitrous oxide on the one hand and chloroform on the other. It is more potent than the former; less potent than

[1] *Lancet*, 12th Feb. 1910, p. 436.
[2] *Trans. Odont. Soc.*, Dec. 1893, p. 46.
[3] *New York Med. Journ.*, Nov. 1899.

the latter. Waller's views as to the relative toxicity of ether and chloroform have already been referred to (p. 65). The two main characteristics of ether are: firstly, that it is one of the most energetic stimulants known, not only to the circulatory, but to the respiratory, nervous, and glandular systems of the organism; and secondly, that its vapour is, as compared to that of many other anæsthetics, more irritating to the respiratory passages, so that mucus is often freely secreted. By reason of the low boiling-point of the drug it is quickly eliminated from the circulation when the administration is discontinued. As in the case of nitrous oxide, very powerful effects may be secured by limiting the oxygen supply; and the phenomena of etherisation will, as in the case of the phenomena of nitrous oxide, greatly depend upon the extent to which air is withheld during the inhalation.

The Committee of the Royal Medical and Chirurgical Society (1864) found that ether depressed **cardiac action** to a very slight degree, and that in ether toxæmia, respiration usually ceased before the heart, although the pulse might cease before the respiration. They state that in one case they observed the heart cease before respiration. The "Glasgow Committee" came to the conclusion that when frogs, rabbits, and dogs were anæsthetised by ether, and artificial respiration was maintained, the heart continued to beat so long as the experiment lasted. Ringer [1] found that whilst 1 or 2 minims of chloroform arrested the ventricle of the frog's heart, 50 minims of ether merely accelerated and slightly weakened the beats, without interfering with the total quantity of work done. Pickering states [2] that upon the embryonic chick's heart ether produces a powerfully stimulant effect, and that depression only comes about when enormous doses are used.

The Glasgow Committee were unable to satisfy themselves that ether produced any appreciable effect upon **blood-pressure.** Kemp [3] in his experiments upon dogs states that the effect of ether upon general arterial pressure is to raise it from the beginning, even with moderate anæsthesia, and that when the anæsthetic is pushed the pressure rises again slightly. A corre-

[1] *Practitioner*, vol. xxvi. p. 436.
[2] *Trans. Odont. Soc.*, December 1893, p. 46.
[3] *New York Med. Journ.*, November 1899.

sponding fall takes place when the administration is discontinued. In MacWilliam's[1] experiments the blood-pressure usually fell slightly; but there was either no cardiac dilatation or a very slight and transient dilatation, and this was chiefly noticed when ether vapour was given with great suddenness. By administering ether and chloroform alternately to the same animal, MacWilliam found a very marked difference so far as cardiac dilatation was concerned. He affirms that ether depresses the vaso-motor centre, causing arterial dilatation and a general but slight fall of pressure.

As regards the **blood changes** during and after anæsthesia, these must depend to some extent upon the degree to which respiration is interfered with during the administration. Harley[2] believed that ether was not nearly so powerful as chloroform in diminishing the absorption of oxygen and the elimination of carbonic acid. Von Lerber[3] found that the drug produced practically no effect upon the hæmoglobin of blood, and that in 83 cases in which the urine was spectroscopically examined there was no increase in urobilin, such as might be expected were the red blood corpuscles disintegrated. On the other hand, Bierfreund finds a hæmoglobin destruction of from 5 to 10 per cent. Oliver and Garrett have come to the conclusion that under the influence of ether the blood and the tissues become deoxidised, but they do not make it clear to what extent destruction of corpuscles is to be held responsible for this effect.

Da Costa and Kaltéyer draw attention to the fact that the preparation of patients by purgation and fasting tends to "inspissate" the blood, and that when profuse perspiration accompanies the inhalation of ether this result must be enhanced. They find also that hæmoglobin is reduced absolutely in amount, and conclude that etherisation produces increased hæmolysis. Anders and Boston,[4] as the result of a research upon this subject, also find that ether produces increased hæmolysis, which, however, according to their experiments, is followed by rapid regeneration of cells, with an

[1] *Brit. Med. Journ.*, 11th October 1890.
[2] *Transactions Roy. Med. and Chir. Society*, 1864, p. 159.
[3] *Year-Book of Treatment*, 1898, p. 166.
[4] *Lancet*, 11th June 1904.

increased number of red corpuscles. A research by Dr. F. J. Dawson[1] is in harmony with these conclusions.

The effects of anæsthetics upon the **nitrogenous metabolism** of the body have been estimated so far as ether is concerned. It was found that the chief effect in this respect following upon the administration of ether to a healthy subject was a marked fall in urea excretion upon the day following the inhalation, and a considerable rise on the two subsequent days.[2]

In the course of a research concerning the effects of anæsthetics upon the **kidneys**, Kemp[3] came to the conclusion that ether caused a special contraction of the renal arterioles, and that this contraction led to diminished secretion of urine. He believes that etherisation gives rise to a damaged state of the secreting cells and that albuminuria appears early in the urine secreted. Oncometric tracings demonstrate a shrinkage of the organ. Buxton and Levy, however, who have repeated the experiments made by Kemp, maintain[4] that this "specific" effect is not constant, and that it occurs chiefly, if not wholly, in cases in which the ether has been unduly and unnecessarily pushed. In some more recent observations upon etherised dogs Prof. W. H. Thompson finds that the urinary secretion is usually increased during the induction stage; that it is greatly lessened or even arrested during full anæsthesia; and that it is re-established again during the recovery stage. Clinical corroboration of these results has been afforded by a valuable and careful research by Drs. H. Pringle, Maunsell, and S. Pringle.[5] After estimating the amount of urine secreted per half-hour by patients prior to etherisation, these observers found that this amount was increased during the period immediately preceding etherisation; that it was sometimes increased and sometimes diminished during the induction stage; that it was invariably diminished during full anæsthesia, the diminution becoming more marked in

[1] *Edin. Med. Journ.*, November 1905, p. 426.

[2] Pechell, *Brit. Med. Journ.*, 20th June 1903, p. 1425—"The Influence of Ether Administration on Nitrogenous Metabolism."

[3] *New York Med. Journ.*, November 1899.

[4] *Brit. Med. Journ.*, 22nd September 1890, p. 833.

[5] *Brit. Med. Journ.*, 9th September 1905, p. 542.

proportion to the duration of narcosis; and that it again increased during the recovery period.

Bovee's results are in the main similar.[1] He finds with ether an increase of the quantity of urine in the first fifteen minutes of the administration, counting from the beginning of the induction period. As he employed the open ether method, the operation had not as a rule been started during this time. In subsequent quarter hours he notes rapid decline in the excretion, the rate being lowest at the end of forty-five minutes, after which it rises again. There is a diminution of urea output even greater than in proportion to the urine excreted; *i.e.* the percentage of urea in the urine is diminished. Carefully and skilfully given ether has little effect on the production of albumen and casts, inducing it in some and stopping it in others. In the Trendelenburg posture there is an even greater interference with urine excretion; partly, Bovee suggests, from retention in the renal pelvis, but partly also from a certain degree of arrest of renal function directly due to the position.

Dr. Hooper[2] of Boston was the first to draw attention to the fact that whilst stimulation of the recurrent laryngeal nerve during light ether anæsthesia produces adduction of the **vocal cords**, stimulation during deep etherisation produces abduction. His results have been corroborated by Semon and Horsley.[3]

According to Dastre, the **temperature** falls somewhat more rapidly with ether than with chloroform. S. G. Davis[4] denies this, and maintains that the loss is the same for both drugs. He also finds that the preliminary injection of morphia does not increase, to any marked degree, the loss of heat caused by ether. (*Vide* also p. 236.)

As regards the **patellar reflex**, Dastre states that it persists, in lower animals, even during complete ether anæsthesia.

The Anæsthetics Committee of the British Association for the Advancement of Science (Third Interim Report, 1911)

[1] J. W. Bovee, *American Journal of Obstetrics and Gynæcology*, June 1909, p. 1004.

[2] *Transactions Amer. Laryngolog. Association*, vol. vii.

[3] *Brit. Med. Journ.*, 28th August 1886, p. 405, and 4th September 1886, p. 445.

[4] *Johns Hopkins Hospital Bulletin*, April 1909, p. 118, where a full bibliography of this subject is given.

find that an ether vapour of approximately 10 per cent produces a highly satisfactory type of anæsthesia. The work of this Committee will be again referred to when dealing with the so-called "open ether" method (p. 338).

C. CHLOROFORM

When **locally applied**, chloroform exerts an irritant or even a vesicant effect. In dilute aqueous solutions it quickly destroys the irritability and contractility of muscles, rendering them "chloroform-rigid," and producing, microscopically, cloudy and other structural changes (Bernard[1]). When **subcutaneously injected**, it produces a local anæsthetic effect, but owing to its caustic action upon the tissues it passes but slowly into the general circulation, and by reason of free elimination taking place during its passage through the lungs, deep anæsthesia is not attainable (Dastre). The application of the drug over large cutaneous surfaces has produced general anæsthesia in animals (Brown-Séquard), but this result has been attributed to inhibition of the nervous mechanism involved in the perception of pain. General anæsthesia may be produced by injecting chloroform into veins.

Injections of chloroform into the carotid **arteries** cause, according to Gaskell and Shore, cessation of breathing from paralysis of the respiratory centre, and sudden fall of blood-pressure from paralysis of the vaso-motor centre. That the latter centre is paralysed would seem to be evident from the fact that the cessation of breathing is not followed by an asphyxial rise of pressure; nor does the stimulation of a sensory nerve have any effect in raising pressure.

The effects produced by injecting chloroform into the large **veins** have been much discussed. The Hyderabad Chloroform Commission obtained only the usual phenomena of anæsthesia. The comparatively negative results, however, which were obtained by the Commission were doubtless due, as pointed out by Gaskell, Shore, and Leonard Hill, to the faulty method which they employed, a method which prevented the chloroform mixing with the venous blood and passing into the heart

[1] *Leçons sur les anesthésiques et sur l'asphyxie.*

cavities. Gaskell, Shore, Hare, Thornton, and Leonard Hill all agree as to the depressing effect which chloroform produces upon the heart when the drug is thus introduced into the circulation. The last-named physiologist finds that if 1·5 min. of chloroform be injected into the jugular vein and washed in with saline fluid, a brief stimulant effect is produced which is followed by a diminution in the output of the systole, and slight dilatation; whilst 5 mins. have the effect of instantly producing profound dilatation and feebleness of action. The tracing of Fig. 1 clearly shows these effects.

The results of the **ingestion** of considerable quantities of chloroform are not without interest in this connection, and are well illustrated by a case[1] reported by Dr. John Hayward.

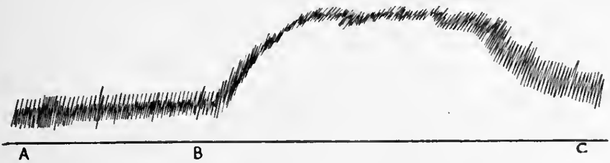

FIG. 1.[2]—Heart enclosed in tennis ball connected with piston recorder. Record of diastolic and systolic volume. A, 1·5 min. of chloroform injected into jugular vein. B, 5 mins. injected. Great diastolic distention shown by rise of base line and small systolic strokes. Paralytic distention of heart. C, Heart recovered from distention. In other experiments 5 mins. proved fatal.

Two ounces were swallowed, and death occurred from syncope during the act of retching. The author has also been furnished with notes of a case in which a melancholic patient attempted to commit suicide by swallowing chloroform. For a space of 15 minutes there was no attempt at breathing, nor could any pulse be detected. Life was saved by vigorous and protracted artificial respiration. The case is interesting by reason of the fact that complete unconsciousness persisted for 18 hours.

We have now to consider the physiological effects produced by chloroform when introduced in a vaporised state into the circulation through the **respiratory passages** of the organism.

Snow was the first observer to recognise the importance of **vapour**

[1] *Brit. Med. Journ.*, 11th Oct. 1902.
[2] Dr. Leonard Hill's tracing. See *Brit. Med. Journ.*, 20th Nov. 1897, p. 1497.

dilution, and to administer chloroform by **quantitative** or **dosimetric methods**. (See remarks on the dosage of anæsthetics, p. 47.) He carefully conducted a series of experiments upon animals with the object of ascertaining the **percentages** of chloroform vapour needed to produce the various "degrees of narcotism" (p. 76), which he described; and he also roughly calculated the actual quantities of chloroform which were present in the blood at various stages in the administration. He arrived at the conclusion that one grain of chloroform to every 100 cubic inches of air sufficed to induce his "second degree of narcotism," the fraction $\frac{1}{56}$ expressing the degree of saturation of the air from which the vapour was immediately absorbed into the blood, and consequently also the degree of saturation of the blood itself.[1] He further found that two grains of chloroform to every 100 cubic inches of inspired air caused a state of very complete insensibility, corresponding with his "fourth degree of narcotism"; and the fraction $\frac{1}{28}$ expressed the extent of saturation of the blood in this degree. As regards quantities of chloroform exceeding two grains to 100 cubic inches of air, these had a tendency to embarrass and arrest the function of respiration, provided that the inhalation was continued; and he calculated that three grains of chloroform to every 100 cubic inches of air is very nearly the quantity which has the power of arresting the breathing when the temperature of the body is 100°, the fraction $\frac{1}{18}$ or $\frac{1}{19}$ representing the blood saturation in this toxic state. Snow also calculated that for his second degree of narcotism it is necessary that the blood of an average adult patient should contain about 12 minims; for the third degree, 18 minims; for the fourth degree, 24 minims; and for the arrest of respiration, about 36 minims.

Paul Bert's results were similar to those obtained by Snow. With 4 grammes of chloroform to 100 litres of air insensibility was not produced, but the animal died at the end of 9 or 10 hours with a low temperature. With 6 grammes to 100 litres a diminution of sensibility was noted, and the animal died at the end of 6 or 7 hours. With 8 grammes to 100 litres insensibility was slowly produced, and death took place in 4 hours. With 10 grammes to 100 litres[2] anæsthesia was obtained in a few minutes, and death took place in 2 or 3 hours. With 12 grammes to 100 litres the animal died in rather less than 2 hours. With 15 grammes to 100 litres death occurred in 40 mintues; with 20 grammes to 100 litres, in 30 minutes; with 30 grammes to 100 litres, in 3 minutes. As Dastre points out, it is interesting that weak chloroform atmospheres affect nutrition without destroying sensibility.

In 1897 Waller demonstrated that successful chloroform anæsthesia requires the regular respiration of air in which the chloroform vapour is maintained between the limits of 1 and 2 per 100.

Of the various ingenious **instruments** by means of which the physiologist is enabled to administer definite percentage

[1] More recent researches show that the association between chloroform and blood is not merely one of simple solution.

[2] This mixture is roughly equivalent to a 2 per cent mixture of chloroform vapour and air.

mixtures of chloroform vapour and air, those of Dubois, of Waller, of Collingwood, and of Alcock deserve brief notice.

In **Dubois' apparatus,**[1] air is expressed from a small cylindrical gasometer containing four litres, by means of a piston working inside the cylinder. As the piston rises, four litres of air are expelled above the piston and pass through a tube into a face-piece. At the same time air rushes into the cylinder below the piston. As the piston descends, the action is reversed. The air below the piston now rushes out into the face-piece, and there is an inrush of air into the cylinder above the piston.

When the apparatus is in use, the inrush of air always takes place closely over the surface of a few drops of liquid chloroform thinly spread out at the bottom of a vessel. By this means the few drops are completely vaporised. It is necessary that the few drops of chloroform should be supplied in constant quantity, and that they should be instilled into the vessel just before each upward and downward movement of the piston previous to the inrush of air. Therefore use is made of the momentary dead-points occurring at the reversal of the upward or downward movement of the piston. The piston is moved by a wheel moving always in one direction, the reversal of the movement of the piston being automatic. Projecting laterally from the circumference of the wheel are two little nuts which alternately catch (at the moment of the reversal of the movement of the piston) on the arm of a crank which moves a horizontal lever. At each thrust of the lever in a horizontal direction, movement is imparted to a vertical screw, which conveys a slight downward movement to a plunger attached to it. The plunger dips into a small cylindrical vessel (clamped beneath it, but easily detachable) containing when full some four ounces of liquid chloroform. At each descent of the plunger a uniformly regulated number of drops of $CHCl_3$ run out of the vessel, through a lip projecting from the upper part of it, into the before-mentioned small vessel, through which the inrush of air passes, and where it is wholly vaporised. By means of a "cam" the horizontal movements of the lever can be made more or less excursive, thereby taking up fewer or more cogs connected with the vertical screw carrying the plunger. By this means it is easy to obtain, within minute limits, a faithful percentage of 1·2 per cent, 1·6 per cent, or 2 per cent of chloroform vapour.

A method for the rapid estimation by densimetry of chloroform vapour was introduced by Waller and Geets.[2] "Experimentally it is important to possess a ready means of frequently gauging the percentage of chloroform administered and exhaled. Clinically it is important to possess a ready means of familiarising students with the smell of mixtures of known percentage. This method consists in the direct weighing on a chemical balance of a flask of known capacity (*circa* 500 c.cm.) (*a*) filled with air, (*b*) filled with the mixture of chloroform and air." A litre of

[1] I am indebted to Dr. Paul Chapman of Hereford for this description.
[2] *Brit. Med. Journ.*, 20th June 1903.

chloroform is 4·032 grammes heavier than a litre of air. In practice the excess of weight of (*b*) gives the percentage of the mixture. Waller [1] has applied the same method to ether. "A litre of ether vapour is 2·018

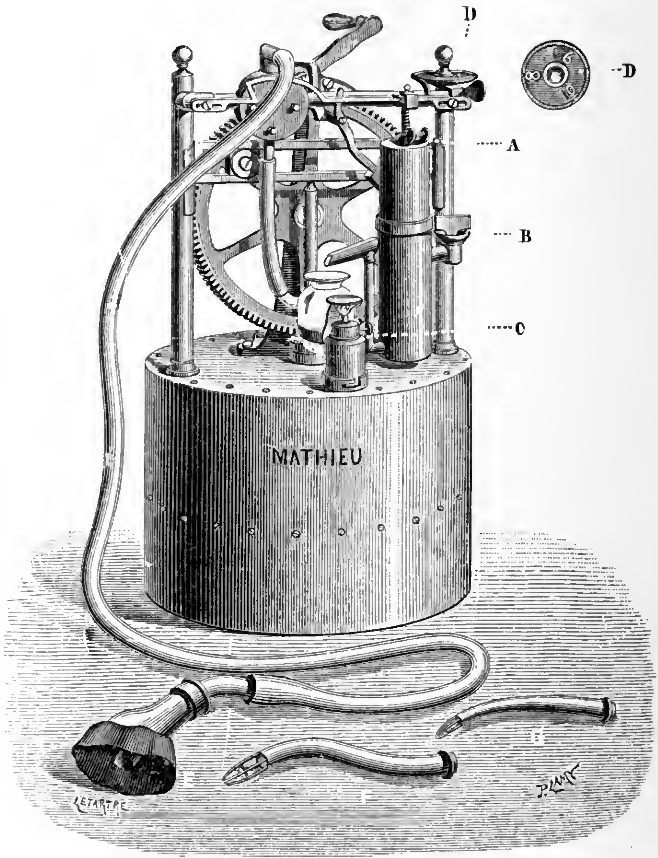

FIG. 2.—Dubois' Chloroform Apparatus. A, plunger; B, chloroform vase; C, spirit lamp; D, cam; E, face-piece; F, G, end pieces which may be substituted for face-pieces.

grammes heavier than a litre of air. This is almost precisely one-half the analogous value for chloroform, and allows us to use the same densimetric flasks for rapid percentage readings."

[1] *Proc. Physiol. Soc.*, 11th July 1903.

Waller's chloroform balance[1] consists of an ordinary enclosed balance, the scale pans of which are replaced respectively by a closed glass bulb of a capacity between 500 and 1000 c.c., and by a brass counterpoise. The bulb rises and falls according as the density of atmosphere in the balance case is raised and lowered by chloroform vapour driven into the case from the chloroform flask. The sensitiveness and range of movement of the beam are such that the deflections of the index embrace a

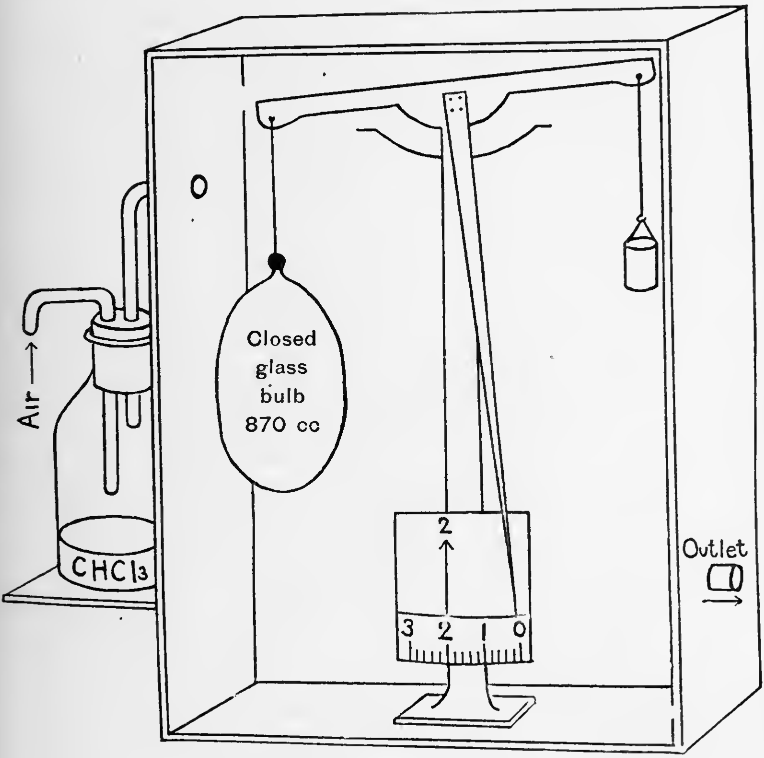

FIG. 3.—Waller's Chloroform Balance.

range of at least 3 per cent of chloroform vapour present. The graduation of the scale necessarily depends on the exact size and weight of the bulb, and can be adjusted by means of riders on the beam.

To obtain absolute accuracy the observed readings of the scale must be

[1] *Journ. Phys.* vol. xxxvii. The illustration of this instrument is here reproduced by kind permission of Mr. John Murray; it first appeared in *Science Progress*, April 1908.

corrected for temperature and pressure; but for clinical work this refinement is not necessary, as the corrections are as a rule small.

The liquid chloroform over which the current of air is driven by a rotary pump into the balance-case is contained in two identical vessels, each provided with a two-way tap so that the current of air may pass direct into the balance-case, or over the surface of the liquid chloroform. The two vessels are in series, so that by turning taps on or off the current of air can be directed through one or other or both vessels.

With a balance-case of a capacity of 30 litres, and an air current of 10 litres per minute directed through only one chloroform vessel, the percentage of chloroform vapour in the case rises steadily to a maximum value from which it slowly declines to a minimum; it then remains constant for an indefinite time, so long as the conditions are not varied. The rise is such that at the end of the first minute the atmosphere in the case contains about 1 per cent of chloroform, and in the third minute about 2 per cent. The maximum value is between 2 and 3 per cent; the subsequent minimum is about 1·5 per cent.

By turning on the tap of the second flask the percentage offered can be raised rapidly if the vapour obtained from the one flask alone is not sufficiently concentrated. Diminution of the vapour percentage is less quickly obtainable; if symptoms of overdose should arise, the simple process of removing the mask from the patient's face is advisable, though the percentage of chloroform can be quickly lowered by turning off the taps so as to admit air alone into the balance-case.[1] The balance can be used to give graphic records of the percentages of chloroform supplied, but at some slight sacrifice of delicacy and accuracy.

The same apparatus can be adapted for ether, but by reason of the more abundant vapourisation, and the more rapid cooling, the ether bottles must be surrounded by a warm-water jacket.

Collingwood's apparatus for the delivery of chloroform vapour of known dilution[2] attains its end by drawing air up an inclined tube, down which a fine stream of chloroform is constantly running. By opening one or more inlets in this tube the proportion of air to chloroform vapour may be regulated, the air passing over a longer or shorter stream of chloroform, as the case may be. Air gains access to the tube by the alternate suction action of two bellows worked either by the hand or by a motor. Collingwood has obtained with this apparatus very constant results in the percentage composition of the chloroform atmospheres delivered.

Yet another apparatus has been invented by **N. H. Alcock.**[3] It consists of a circular copper vessel, 5 inches in diameter and $4\frac{1}{2}$ inches in depth,

[1] A full description of this apparatus as installed under the direction of Professor Waller in the out-patient operating theatre at St. George's Hospital will be found in the *Proceedings of the British Association for the Advancement of Science*, 1911.

[2] This apparatus was described before the Roy. Med. and Chir. Soc. (*Transactions*, 1905, vol. lxxxviii. p. 695).

[3] *Brit. Med. Journ.*, 15th Aug. 1908, p. 372.

in which is placed 150 c.c. of chloroform. A shelf closed except for two oblong holes is fixed $1\frac{1}{4}$ inches from the bottom. Immediately above and touching the shelf is a circular plate, movable by means of a hollow rod in the centre, and pierced by two triangular apertures. These can be adjusted by the centre rod so as to expose more or less of the fixed oblong holes in the shelf, and so produce greater or smaller openings into the space below. Air, supplied from a small foot-bellows, enters the chamber by one tube opposite one aperture, and leaves by another tube, taking up more or less chloroform vapour according to the size of the apertures. A thermometer in the hollow rod indicates the temperature of the chloroform below, and a water-jacket surrounding the chamber serves to keep the temperature within certain limits. It is claimed that the percentage of chloroform in the air thus delivered is independent of the current, so long as the latter is between 8 and 20 litres per minute; the latter is considerably above the amount usually required. It is also said that the percentage is unaffected by shaking, and that the apparatus can be violently rocked without any disturbance of its efficiency. The scale which indicates the percentage of chloroform being offered is made to slide so that variations of temperature in the copper drum are allowed for, and thus the readings remain accurate. The inventor claims that this apparatus is accurate to 0·1 per cent of chloroform—*i.e.* that when the reading is 2·0 per cent, the vapour concentration will be somewhere between 1·95 and 2·05 per cent.

All the above ingenious instruments deliver chloroform atmospheres of known percentages by what has been termed the "plenum" system, the animal receiving the diluted vapour at a slightly positive pressure, *i.e.* without any suction action on its part. This is a matter of no small importance, the plenum system being free from certain definite objections which surround the suction system (p. 107). Moreover, careful estimations have proved that all these instruments are reliable as regards their percentages. For a description of the Vernon Harcourt inhaler see p. 389. This, the best known of all the machines for delivering a vapour of known strength, is on the "drawover" or "suction" principle, by which the patient's respiratory muscles supply the force necessary for extracting the chloroform vapour from the inhaler.

It is very important that the rôle played by the **percentage** of chloroform in chloroform atmospheres should be clearly understood. Were all chloroform accidents attributable, as many believe them to be, to vapour concentration it would be impossible to over-estimate the value of this factor. As many of the dangers, however, during chloroformisation may arise during the inhalation of the most perfectly adjusted mixture, we must not fall into the error of regarding chloroform concentration as the invariable cause of difficulties and accidents.

A very interesting physiological experiment is recorded in connection with the work of the Special Chloroform Committee of the British Medical Association (*Brit. Med. Journ.*, 14th July 1906, p. 82). A small cat, rather thin, but otherwise healthy, was anæsthetised with a weak (1·06) chloroform mixture. It is to be noted that the anæsthetic was administered *by means of a mask and not through a tracheal cannula.* The percentage mixture used in this experiment was weaker than that employed in any of the other experiments of this particular research, in all of which no other fatality occurred. "The depth of the respiration decreased almost at once, and at the end of the fourth minute respiration ceased. The heart was still beating, though feebly, and soon stopped. Attempts to recover the animal by massage of the heart and by artificial respiration were unavailing." From the point of view of those who consider that low vapour percentages necessarily mean safety, this death is, naturally enough, inexplicable; but considered in the light of the principles laid down in these pages, it is readily intelligible. The differences between face-piece administrations and tracheal cannula administrations are fully considered on p. 39. It is in the highest degree probable that in this particular physiological experiment, as in a large proportion of fatalities in practice, some obstructive element was present.

The author has had reported to him an interesting clinical illustration of the point under consideration. The patient was an elderly man of spare build, with a beard. He had a somewhat receding lower jaw and slight nasal inadequacy. There were no upper teeth and the lower therefore came in contact with the upper gum. The patient's general condition was good; his heart sounds were distinct and normal; he had no cough. The operation was for mastoid disease. Chloroform was administered by a well-known anæsthetist, and the Vernon-Harcourt inhaler was employed. It was necessary to envelop the face-piece with a towel, in order to exclude the surrounding air. A bystander observed that the patient was not obtaining a sufficient supply of air. Whilst the operation was in progress both pulse and respiration ceased, the eyes appeared glazed, and it was thought that the patient was dead. The tongue was drawn out and artificial respiration performed, and fortunately the patient recovered. The author anæsthetised this patient about ten days later, employing the C.E.-chloroform sequence, and administering the latter anæsthetic by means of a Skinner's mask. Owing to the physical state of the upper air-passages, there was some tendency towards obstructed breathing throughout; but this was easily prevented by keeping the finger within the mouth, separating the tongue from the palate and hooking the lower jaw forwards. Circulation was well maintained throughout the operation. It was quite clear that in this particular case a tightly fitting face-piece could not have been applied without embarrassing breathing, the slightest pressure at once limiting the ingress of air. It is in the highest degree probable that the combination of a Vernon-Harcourt face-piece and the suction-action of that inhaler had brought about, in this particular patient, an intercurrent asphyxial state which nearly proved fatal.

Although intercurrent asphyxia, surgical shock, and other conditions are often responsible for dangerous symptoms during chloroform anæsthesia, yet the question of **vapour concentration** is also very important. There are in fact vapour percentages which are *in themselves* safe, so long as no complication (such as air limitation, for example) is introduced. There are also percentages which are *in themselves* dangerous. And there are intermediate percentages which may be safe *in themselves* at the commencement of anæsthesia, but dangerous after an hour or two of administration. Such percentages may also be safe *in themselves* for some individuals, but dangerous for others. In deciding then upon what can be regarded as the *limits of safety so far as the avoidance of toxic symptoms is concerned,* it should be understood that the percentages named apply to ordinary healthy adults and refer to the early stages of an administration, say the first twenty minutes. By restricting the percentage of vapour that is offered, undoubtedly an important element of risk is eliminated from chloroform anæsthesia.

Waller placed the maximum limit of safety at 2 per cent; Embley considers even this as dangerous, and says the limit should be 1 to 1·5 per cent. Alcock,[1] using his own apparatus, concluded that if it is desired to induce anæsthesia in from eight to ten minutes, the ordinary adult must be given percentages rising to 2 in two minutes, and to 2·5 in three minutes. This suffices for most patients; but some require more, and he says there is no objection to 3 per cent *provided due care is exercised.* When induction is complete, 2 per cent is usually ample; and diminution to 1·5 and then to 1 per cent is advisable in 20 to 25 minutes. Children require more dilute vapour; 2 per cent should be their maximum. In one of Alcock's patients—a big, muscular, alcoholic man submitted to laparotomy for a penetrating

[1] *Brit. Med. Journ.*, 6th Feb. 1909, p. 325.

wound of the abdomen—even 3·5 per cent failed to produce surgical anæsthesia, and a mask and drop-bottle had to be requisitioned. Probably this man had had no proper preparation, and apart from that he was of exactly the type that might be expected to require an exceptionally large dose. As showing the other extreme, a case is mentioned where 0·75 per cent kept a patient perfectly anæsthetised for the last ninety minutes of an operation which lasted two hours and a quarter.

This question has been very carefully considered by a Committee of the British Medical Association, which reported in 1910.[1] Their conclusions are:—

1. A 1 per cent vapour is insufficient to induce surgical anæsthesia in an adult, at all events within the limits of time ordinarily available.

2. A 2 per cent vapour is sufficient to induce full surgical anæsthesia.

3. In pathological conditions the definite dose is below 2 per cent, and must be determined in each case.

4. The dosage of the maintenance of anæsthesia is of as much importance as that of the induction period, and neglect of this has caused many deaths and constantly delays convalescence.

5. No definite limit of safety can be fixed for this dose; but it is in most cases 1 per cent at first, and less later on.

Discussing this report, A. G. Levy[2] agrees with Alcock that the 2 per cent limit is definitely insufficient for a certain proportion of patients; and he goes on to say that the want of agreement on this point must be due either to difference of opinion as to what constitutes a clinically sufficient anæsthesia, or else to errors in the measurement of the vapour. Probably the former is the correct explanation, since it is notorious that surgeons disagree among themselves as to what constitutes full anæsthesia, especially in respect of abdominal relaxation.

The **absorption** of chloroform by the pulmonary circulation

[1] *Brit. Med. Journ.*, 9th July 1910.
[2] *Ibid.*, 17th Sept. 1910, p. 755.

during a given period has lately occupied the attention of physiologists.

In the course of a preliminary investigation upon the rate of absorption of chloroform during the induction of anæsthesia,[1] Brodie and Widdows found that the percentage of chloroform in the expired air was least in the first two minutes, the minimum being nearly always reached in the second minute. Subsequently the percentage rose, but it remained below that of the mixture inhaled even in the tenth minute. Generally speaking the amount of chloroform absorbed increased with the concentration of the chloroform in the anæsthetic mixture, but it was by no means in proportion to that concentration.

Vernon Harcourt,[2] in the course of some experiments concerning the proportion of chloroform retained by patients during and after the use of his inhaler, found that about one-third of the total amount of chloroform used was retained at the conclusion of anæsthetisation.

The researches of Buckmaster and Gardner[3] have carried matters a stage further, and their methods are much more precise than those of previous authors. The chloroform content of the blood rises in the initial stages of anæsthesia (induced with a vapour of constant strength by Dubois' apparatus) with great rapidity to a value which approaches a maximum. During this period the quantity of chloroform in the blood appears to affect particularly the respiratory centres; failure of the heart is not noticed at this stage. The chloroform content then falls slightly, but soon rises again, much more slowly than before. Either a state of equilibrium is then attained, or else the percentage of chloroform rises slowly until respiratory failure and asphyxia occur: this depends on the strength of the vapour offered. These experiments were conducted on cats, in whom (these authors say) the phenomena of narcosis are more similar than in any other animals to those in human beings.

As regards the **respiratory phenomena** of chloroform anæsthesia, little remains to be added to what has already been said in discussing respiration under anæsthetics in general (p. 51) and the differences between simple and complex chloroform anæsthesia (p. 39). The remarks already made in these preceding pages apply, indeed, with special force to chloroform. Many years ago Claude Bernard and the Committee of the Royal Medical and Chirurgical Society pointed out that if chloroform is given in a concentrated form, intercurrent asphyxial complications are at once introduced, and free breathing is more or less completely suspended from reflex closure of the larynx. This reflex suspension of breath-

[1] *Brit. Med. Journ.*, 14th July 1906, p. 79.
[2] *Ibid.*, 14th July 1906, p. 83.
[3] *Proc. Roy. Soc.* B. vol. lxxix. 1907, p. 555.

ing, however, does not appear to be dangerous in the case of lower animals, even though associated, as it often is, with temporary cardiac inhibition. The principal risk in a concentrated vapour is that of simple toxæmia.

When chloroform narcosis is well established, the breathing is generally quiet and inclined to be shallow; but much will depend upon the activity of the cerebral circulation. Paul Bert,[1] in his experiments upon dogs, found that costal breathing became gradually less marked, and that eventually most of the respiratory work was carried on by the diaphragm. If diaphragmatic breathing was paralysed by section of the

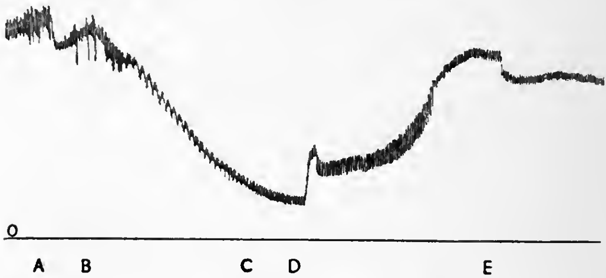

FIG. 4.—(Published in the *Journal of Physiology* in Paper 1—"On the Influence of Gravity on the Circulation.") Cannula in carotid placed in axis of rotation. Dog. Morphine. At the bottom of the fall produced by chloroform the respiratory waves disappear. On turning the animal feet-up the blood-pressure rises and the respiratory waves immediately reappear on the trace. This shows that paralysis of the respiratory centre is partly due to fall of arterial pressure. A, Feet-down: vertical posture. B, Chloroform pushed. C, Withdrawn. D, Feet-up posture. E, Horizontal.

phrenics, costal breathing began. As regards the expansive force of respiration, this is diminished in proportion to the degree of narcosis. Thus, Dastre found, in the case of a dog of 12 kilos. 850 grammes, whose respiration became arrested by a weight of 75 kilos. when no anæsthetic was administered, that respiratory arrest during anæsthesia occurred with a weight of 58, 55, or 25 kilos., according to the duration of the insensibility. The same author states that the experiments of Langlois and Richet led these observers to the conclusion that, during anæsthesia, expiration was considerably more depressed than inspiration. The inspiratory efforts

[1] Dastre, *op. cit.*

of an anæsthetised dog were not much modified by anæsthesia; but there was a considerable reduction in the expiratory force.

As regards the immediate causation of respiratory failure in chloroform toxæmia, there is good evidence that, in addition to the factor of the anæsthetic itself acting upon the nervous mechanism of breathing, and bringing about respiratory paralysis, there is often another, and perhaps a more important factor present, viz. low arterial tension. This is well seen in Fig. 4.

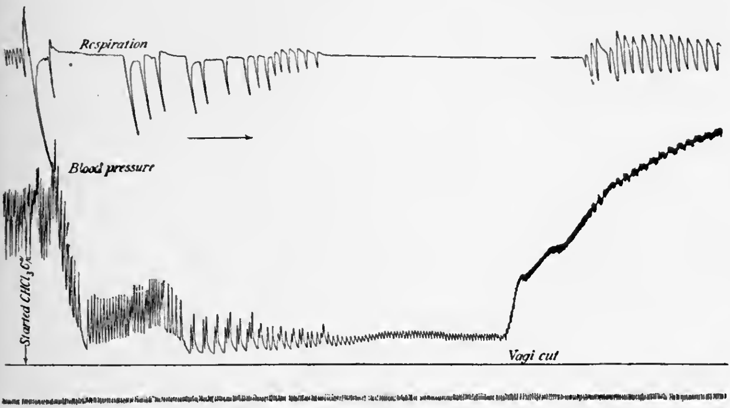

Fig. 5.—(Embley, *Brit. Med. Journ.*, 19th April 1902, p. 957.) Showing "Relation of respiration to circulation. Respiration the upper, and blood-pressure the lower tracing. Dog, weight 33lb. Morphine. Chloroform, 6 per cent vapour in air taken in respiration at 'started,' and continued till the respiration ceased. Respiration ceased when the blood-pressure was equal to 16 mm. mercury-pressure. Vagi were cut and the blood-pressure rose. Respiration recommenced when the blood-pressure had reached 92 mm. mercury-pressure."

As already pointed out, low arterial pressure may depend upon numerous causes; but whatever these causes may be, the effect upon respiration will be the same, provided the fall be sufficiently acute. The dependence of respiration upon circulation was pointed out many years ago by the Glasgow Committee; and more recently Gaskell, Shore, Hill, and Embley have brought forward corroborative evidence in the same direction. The point has such an important bearing in practice that a second tracing (Fig. 5) is worthy of study. Hill maintains that the tracings of the Hyderabad Chloroform

Commission also conclusively prove that circulatory failure is a common cause of respiratory arrest.

Salivation is generally somewhat increased during the early stages of chloroformisation, and diminished during deep anæsthesia. According to Dastre, the chorda tympani retains its excito-secretory action throughout, whilst the reflex action of the lingual nerve on the submaxillary gland is lost soon after the corneal reflex disappears.

As regards the **respiratory exchanges** under chloroform, Arloing[1] found that less oxygen was absorbed and less carbonic acid exhaled than under normal circumstances, but that the diminution was most marked in the case of the latter gas. Paul Bert's experiments led him to the same conclusion. As we have already seen (p. 56), Rumpf arrived at results similar to those of Paul Bert. The Glasgow Committee, however, came to the conclusion that an *increased* amount of CO_2 was exhaled during chloroform anæsthesia.

With regard to the **blood changes** during chloroformisation, Harley[2] believed that chloroform diminished the power of the constituents of the blood to unite with oxygen and to give off carbonic acid, and Oliver and Garrett[3] have endorsed his views. The quantitative researches of Buckmaster and Gardner lead to the same conclusion (*vide* Chapter III. p. 61). Harley described various degrees of disintegration of the red blood cells as referable to the action of chloroform, and corroborative evidence in the same direction has been advanced by Ostertag, M'Kendrick, Sansom, Wittich, and Böttcher.[4] The recent researches of Clark[5] entirely confirm these findings. Among this observer's most interesting discoveries is that of numerous very large phagocytes in the spleen, packed with red blood corpuscles and with masses of iron containing pigment. On the other hand it is contended by some observers[6] that chloroform is only feebly hæmolytic and has but little action in destroying the red blood corpuscles and practically no action

[1] Dastre, *op. cit.*
[2] *Transactions Roy. Med. Chir. Soc.*, 1864, p. 159.
[3] *Lancet*, 9th Sept. 1893.
[4] I am indebted for this and other statements on this subject to Dr. Guthrie's excellent article in the *Clin. Journ.*, 24th March 1897.
[5] *Lancet*, 21st Jan. 1911, p. 158.
[6] See a paper by Dr. F. J. Dawson in the *Edin. Med. Journ.*, 1905, p. 426.

in reducing hæmoglobin. Pohl found that the blood of a dog under chloroform contained from ·01 to ·06 per cent of chloroform,[1] the average amount being ·035 per cent; and that the red corpuscles contained about two and a half times more than the serum. Buckmaster and Gardner[2] find that the red corpuscles contain practically the whole of the absorbed chloroform in deep anæsthesia; and that only when the anæsthetic is pushed to extremes is any chloroform taken up in the plasma. They also show[3] that chloroform administration leads to a progressive diminution in the oxygen content of the blood, which diminution reaches to 40 per cent in deep anæsthesia. They criticise severely all previous estimations of the blood gases during chloroform narcosis. They agree with Pohl as to the percentages of chloroform in the blood; as does also Nicloux[4], who says the red corpuscles take up seven or eight times as much as the plasma. Tunnicliffe and Rosenheim[5] showed that the effect produced by relatively strong solutions of chloroform upon the isolated heart was somewhat delayed by the presence of lecithin. Sherrington and Sowton[6] find that chloroform in blood is less toxic to the heart than chloroform in saline solution. Moore and Roaf[7] hold that chloroform forms an unstable chemical compound or physical aggregation with blood proteids, and that it is thus carried by the blood. In an independent research Waller[8] has come to similar conclusions. When whipped bullocks' blood was treated with chloroform and an attempt was made to remove the latter, the deficit was found to be 85 per cent.

The **elimination** of chloroform from the blood-stream has been studied by Buckmaster and Gardner,[9] who find the rate of output is at first comparatively rapid when administration is suspended, and then subsequently becomes slower. The initial rates of elimination are, however, much less rapid than the initial rates of the intake; and elimination is, in fact,

[1] *Arch. f. exp. Path. u. Pharm.* vol. xxviii., 1890-91.
[2] *Proc. Roy. Soc.* B vol. lxxix., 1907, p. 566.
[3] *Journ. Phys.*, 9th Nov. 1910, p. 246.
[4] *Brit. Med. Journ.*, 22nd Dec. 1906, p. 1793.
[5] *Journ. Phys.* vol. xxix. p. 15 of *Proceedings.*
[6] Brit. Med. Assoc. Chloroform Committee.
[7] *Proc. Roy. Soc.* vol. lxxiii., 1904, p. 382.
[8] *Ibid.* vol. lxxiv.
[9] *Ibid.* B vol. lxxix , 1907, p. 579.

a much slower process than assumption. Thus also Nicloux[1] has shown that after seven hours the blood may still contain 1 to 2 milligrams per 100 gr. of chloroform; and he even records one case where a cat got up and walked away, half an hour after ceasing to inhale chloroform, at a moment when its blood still contained 10 milligrams per 100 gr.

The direct action of chloroform upon **blood-vessels** is of interest in relation to the causes of the fall of blood-pressure during chloroform anæsthesia. The view now generally accepted is that the whole cardio-vascular system tends to dilate as the result of the direct effects of the drug, although some observers maintain that, in certain vessels at all events, a constrictive action is produced. In conjunction with Martin, Embley has studied the action of anæsthetic quantities of chloroform upon the blood-vessels of the bowel and kidney.[2] These observers find a marked dilatation due to the direct effects of chloroform upon the neuro-muscular mechanism of the blood-vessels of these organs, and conclude that a considerable part of the fall in blood-pressure constantly associated with the administration of chloroform may be thus explained. Schäfer and Scharlieb[3] maintain, however, that chloroform has a direct constrictive action upon the muscular elements of most peripheral blood-vessels, although they admit that in the case of the renal vessels dilatation occurs. They regard the fall of blood-pressure which takes place under chloroform as due principally to cardiac weakening, and look upon the constrictive action of the blood-vessels as counteracting, to some extent, this fall of pressure.

We have next to consider the question: What is the **direct action of chloroform upon the heart?** Snow's observations led him to the conclusion that *primary* cardiac paralysis only took place with high percentages of vapour, and that, provided precautions were taken to avoid such concentration, the heart only failed secondarily to the breathing. In the case of cats chloroform atmospheres of 3 to 6 per cent caused stoppage of breathing before arrest of the heart—an interval of two or three minutes separating the cessation of respiratory and cardiac action in

[1] *Comptes Rendus*, 1906, vol. lx. p. 14.
[2] *Trans. Phys. Soc.* vol. xxxii. No. 2, 28th Feb. 1905, p. 147.
[3] *Trans. Roy. Soc. of Edin.* vol. xli. Part 2, No. 12.

many cases. But with atmospheres of 8 per cent to 10 per cent "the action of the heart was always seriously affected and rendered extremely feeble, if it did not actually cease, at the time the breathing was arrested." The experiments of the Committee of the Royal Medical and Chirurgical Society also pointed in the same direction. The Committee found that the strongest doses of chloroform destroyed animal life by arresting the action of the heart, and that moderate doses considerably weakened cardiac action before death ensued, although respiration generally ceased before the heart's action completely failed. The strongest doses of chloroform caused the pulse and respiration to cease nearly simultaneously (in from 1′ 20″ to 1′ 45″), whilst the heart's action continued for a short time subsequently (from 3′ 10″ to 5′ 30″). When, however, equally strong atmospheres were administered through an opening below the glottis, death was much more rapid, "and the heart, as a rule, ceased to beat several seconds before the final arrest of the respiratory movements." With moderately strong and weak vapours little or no difference was observed, whether the chloroform entered above or below the glottis. The Committee found that a strong chloroform vapour did not cause a more permanent stoppage of the heart's action than a milder vapour. Some years later (1879-80) the Glasgow Committee arrived at very similar conclusions. Not only did they find that in the dog, rabbit, and frog, cardiac action soon ceased under chloroform—far sooner than under ether[1]—but they came to the conclusion that chloroform sometimes exerted an unexpected and capricious action on the heart, causing a rapid fall of pressure—a conclusion which was subsequently challenged and criticised by the Hyderabad Commission, who regarded the tracing upon which the Glasgow Committee had based their views as indicating an asphyxial element in the administration. Ringer showed[2] that, so far as the frog's heart was concerned, chloroform undoubtedly produced a powerfully depressant effect upon the muscular tissue itself. On the other hand, the Hyderabad Commission attempted to prove by a large number of obser-

[1] *Brit. Med. Journ.* vol. i., 1879, p. 1.
[2] *Practitioner*, vol. xxvi. p. 436.

vations that, during the administration of chloroform, the heart was never primarily affected—in other words, that its action was maintained till respiration ceased. As we have already pointed out, however (p. 14), these observations have not been accepted by the physiological world. Some years ago MacWilliam clearly showed that under chloroform a varying degree of dilatation of the heart's cavities took place, the dilatation commonly commencing when the corneal reflex disappeared. All chambers shared in the dilatation, and when the anæsthetic was lessened the dilatation usually ceased. In some cases the dilatation was rather sudden, and it was as a rule independent of rate. When the dilatation was extreme the heart failed, although rhythmic movements persisted for a while. MacWilliam further found that the cardiac dilatation was not due to fall of pressure, nor was it dependent upon increased pulmonary resistance from vascular contraction. It was, in fact, due to the effect of chloroform on the heart itself. He observed, in some cases, periodic cardiac dilatation *after* chloroform, and found that ether dispelled this. Dilatation did not usually come on after blood-pressure had fallen. In some cases MacWilliam observed a state of "delirium cordis" —the ventricle being thrown into a condition of incoordinated fibrillar contractions. Gaskell's and Shore's experiments[1] also led them to the conclusion that chloroform exerted a direct paralysing influence upon the heart and blood-vessels; and they pointed out that the so-called proof in the Hyderabad tracings, that chloroform did not depress the heart, was in every case an instance of a slight increase in the size of the pulse-excursions due to a slowing of the heart's action. Wood and Hare[2] also showed that chloroform had a direct effect upon the heart itself. Experimenting with the heart of the embryonic chick—*i.e.* with a heart not yet supplied with any nervous mechanism—Pickering[3] found that ·5 c.c. of a chloroform solution containing ·00003 c.c. of pure chloroform, when injected under the blastoderm of the embryo, rapidly reduced its cardiac rhythm and produced an exaggerated diastole. After the injection of ·00004 c.c. the heart stopped in a dilated

[1] *Brit. Med. Journ.*, 28th Jan. 1893.
[2] *Medical News* (Phila.), 22nd Feb. 1890.
[3] *Trans. Odont. Soc.* vol. xxvi. No. 2, N.S., Dec. 1893, p. 42.

condition. He found a mixture of CO_2 and chloroform to be far more toxic to the embryonic heart than a mixture of chloroform and air. The final proof of the error of the Hyderabad doctrine was, however, brought forward by Leonard Hill, who showed that the methods employed by the Commission for registering the efficiency of cardiac contraction were faulty. Hill corroborated MacWilliam's original observations as to chloroform producing paralytic dilatation of the heart. He found that it acted directly, like amyl nitrite, on the musculature of the whole vascular system. He very properly laid stress upon a point which is fully discussed in the clinical part of this work, viz. that the real question is—When does the heart *cease to expel its blood?* not—When does it cease to make *efforts at contraction?* If a dog be killed by a concentrated chloroform vapour, respiration will usually continue longer than the femoral pulse; and if the chest be opened, the heart will be found much dilated and exhibiting waves of contraction, although unable to empty its cavities. These waves, in fact, are ineffectual in maintaining a circulation—the heart having failed to act as a *circulatory organ.* Hill and Barnard also made some experiments, the results of which coincided with those previously obtained by Gaskell and Shore, and they pointed out,[1] in connection with cardiac dilatation under chloroform, that the power required to empty the cardiac cavities may be regarded as increasing approximately as the cube of their radius. The effects of chloroform upon the heart isolated from the general nervous system have also been studied by Embley,[2] who found the heart muscle to be very sensitive to chloroform, which has an immediate and progressively paralytic effect. He failed, however, to notice any abrupt change in efficiency in isolated hearts. Sherrington and Sowton,[3] in researches upon the action of chloroform on the isolated mammalian heart, find that the heart muscle rapidly takes up chloroform offered to it in the vessels of its coronary system, and that the quantities absorbed increase

[1] *Brit. Med. Journ.*, 20th Nov. 1897, p. 1496.
[2] *Trans. Soc. Anæsth.* vol. v. p. 82; also *Brit. Med. Journ.*, 5th April 1902, p. 821.
[3] *Brit. Med. Journ.*, 18th July 1903; also *ibid.*, 23rd July 1904, p. 167, and *ibid.*, 14th July 1906, p. 85.

with increasing tension of chloroform in the solution circulating through it. They find that the heart is affected by a much lower concentration of chloroform than are the blood-vessels of the limb or the skeletal muscles of the limb, and that there is an aggravation of the effect of chloroform in saline solution upon the heart, skeletal muscles, and blood-vessels when the chloroform is administered in unoxygenated saline solution containing carbonic dioxide, instead of in unoxygenated saline. Whether the drug poisons the muscle cells without entering into chemical combination with their substance; whether some easily dissociable compound is produced; whether the anæsthetic acts as an anti-katalysator on the ferment process at the root of the normal functional activity of the contractile tissue of the heart,—these and other questions must be left for future investigation. To sum up on this much-disputed point: it may be regarded as established that during chloroform anæsthesia this anæsthetic directly produces a depressing effect upon the heart itself; and that whilst it is true, not only in the physiological laboratory but in actual practice, that respiration generally ceases before cardiac action finally fails, it is the want of cardiac action which is the essential factor in the causation of death under chloroform.

The **indirect action of chloroform upon the heart** is responsible, according to certain observers, for many of the fatalities which have arisen under this anæsthetic. There are two possible ways in which this indirect action may operate, viz.—(1) by the vapour irritating the sensory nerve-endings within the nasal, laryngeal, tracheal, or pulmonary passages, and so stimulating the cardio-inhibitory centre; or (2) by the blood-borne anæsthetic directly affecting that centre. Dastre, Morat, and numerous French physiologists have attached great importance to the first-named inhibitory effects, and have even gone so far as to speak of a "syncope laryngo-réflexe." Brodie and Russell[1] have also obtained these inhibitory effects, and have laid stress upon the importance of reflexes originating in the pulmonary alveoli. According to Dastre, Franck found that excitation of the laryngeal nerves more easily arrested the heart during chloroform anæsthesia than when no anæsthesia

[1] *Journ. of Phys.* vol. xxvi.

was present. The Hyderabad Commission found that it is impossible to kill animals by direct vagal irritation, no matter whether the anæsthesia is light or profound. By inducing repeated and prolonged vagal arrest of the heart, however, Leonard Hill succeeded in bringing about a fatal issue, the low blood-pressure leading to paralysis of the respiratory centre and death by asphyxia. Some ten years ago the whole question of cardiac inhibition was exhaustively studied by Embley,[1] who maintains, as the result of a large number of experiments, that with atmospheres containing more than 2 per cent of

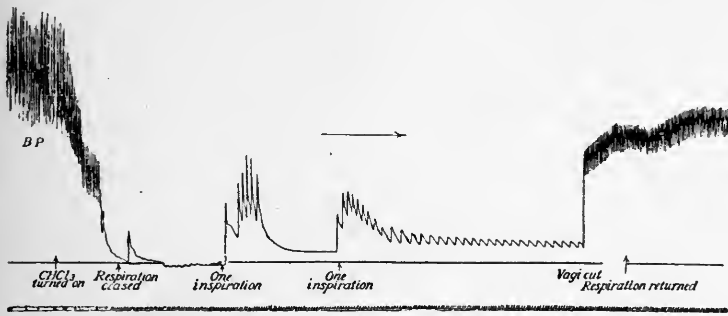

Fig. 6.—(Embley, *Brit. Med. Journ.*, 12th April 1902, p. 890.) Vagi cut after inhibition. Dog, weight 16 lb. Morphine. Natural respiration. Blood-pressure tracing only. Chloroform, 6 per cent in air administered. Chloroform stopped when inhibition occurred. Gasping liberated the heart twice. Respiration failed after the inhibition occurred. Vagi were then cut. Respiration returned 20 seconds after the vagi were cut, being 190 seconds in abeyance. Blood-pressure had risen again to 74 mm. of mercury-pressure.

chloroform vapour cardio-inhibitory effects are very common; the degree of inhibition is intensified with high percentages. The low blood-pressure thus induced rapidly rises when the vagi are cut, whilst cardiac action again becomes established (Fig. 6). Slowing or cessation of the heart never occurred in animals in whom the vagi had been divided; whilst the intravenous injection of atropine before chloroform had the same effect as section of the vagi. Embley undertook his investigation with the object of explaining the deaths which take place early in chloroformisation; but his results are not altogether conclusive as to the immediate causes of such

[1] "The Causation of Death during the Administration of Chloroform," *Brit. Med. Journ.*, 5th, 12th, and 19th April 1902.

fatalities. He finds, for example, that in order to produce fatal cardiac inhibition, the heart must have sustained considerable damage from the direct action of the drug—a state of things hardly comparable to that described in many chloroform accidents in which patients have died during light anæsthesia. Embley denies the proposition of the Hyderabad Commission as to the impossibility of killing animals by vagus excitation. As regards the immediate cause of the inhibition, he is unable to satisfy himself that the latter is due to the action of the chloroform upon sensory nerve-endings, and

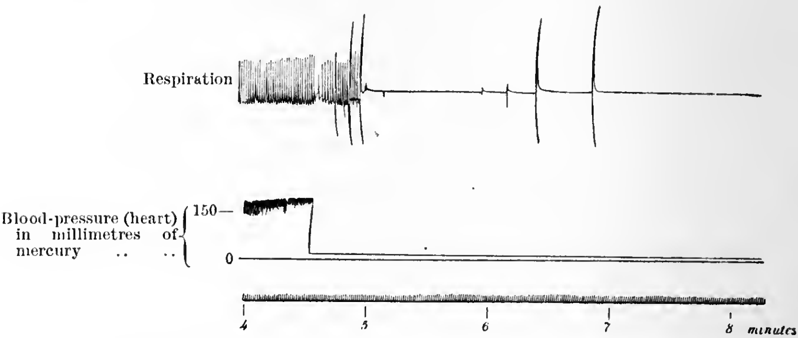

FIG. 7.—An early death by sudden cardiac arrest (primary syncope). Cat under chloroform at 5·75 per cent. No recovery possible. The four gasps apparent on the respiratory record are the terminal anæmic convulsions characteristic of a cardiac death (Waller).

believes that the increased excitability of the vagus mechanism is due to the action of chloroform on the vagus centre itself, and that the inhibitory action is more intense from being exercised upon a heart whose spontaneous excitability has become diminished. Waller [1] also agrees as to the suddenness with which cardiac arrest may take place from the influence of a concentrated chloroform atmosphere, and the author reproduces, by his kind permission, a tracing illustrating fatal chloroform syncope in a cat.[2] Schäfer and Scharlieb's experiments [3] with regard to vagus inhibition are very similar to

[1] *Lancet*, 28th November 1903, p. 1485.
[2] Dr. Waller does not give any explanation of this particular death. I introduce the tracing in connection with cardiac inhibition, because I gather from a letter he has written me upon the subject, that he rather favours this explanation.
[3] *Trans. Roy. Soc. Edin.* vol. xli. Part ii. No. 12.

those of Embley. Whether and to what extent these observations apply to the chloroformisation of human beings, it is at present difficult to say.

It is now generally held that the **action of chloroform upon the vaso-motor centre** is primarily one of stimulation, and that it is not till quite late in chloroform toxæmia that the centre becomes paralysed as the result of the direct action of the anæsthetic upon it. Embley and Martin's[1] researches have corroborated those of Gaskell and Shore upon this point.

We are now in a position to discuss the **blood-pressure** under chloroform. Whilst it is universally admitted that a marked and progressive fall in pressure takes place, it is still an open question which should be regarded as the essential factor or factors in the causation of this fall. The Glasgow Committee met with a pronounced fall in all their experiments, and attributed it, in some cases at least, to a direct effect of chloroform upon the heart. According to the Hyderabad Chloroform Commission, however, the characteristic fall of pressure—that which occurs with regular breathing—is due, not to weakening of the heart, but "solely to narcosis of the vaso-motor system."[2] The sudden fall in pressure observed by the Glasgow Committee was regarded by the Hyderabad Commission as due to intercurrent asphyxia. According to Wood and Hare,[3] chloroform produces a double initial effect upon blood-pressure—first a fall due to reflex inhibition of the heart or vaso-motor centre, and then a rise, due probably to reflex vaso-motor spasm. Gaskell and Shore found an initial rise and subsequent fall of pressure; the former was due, according to them, to a stimulation of the vaso-motor centre. As regards the causation of the subsequent fall, these observers found, as the result of a series of ingenious cross-circulation experiments,[4] that it was principally due to the effect of chloroform upon the heart, and not, as the Hyderabad Commission stated, to an effect upon the vaso-motor centre. They found that injections of the drug into the cerebral arteries caused a *rise* in pressure which was still present at the moment when respiration ceased.

[1] *Trans. Soc. Anæsth.* vol. v. p. 82.
[2] *Report*, p. 137.
[3] *Med. News*, 22nd February 1890.
[4] *Brit. Med. Journ.*, 21st January 1893.

They further found that, in other conditions—for example, when the brain arteries was ligatured, when amyl nitrite was injected into the cerebral vessels, and when the intracranial pressure was raised,—the respiratory centre failed before the vaso-motor centre. Leonard Hill[1] has shown, in an important research, that chloroform rapidly abolishes the vascular mechanisms which compensate for the hydrostatic effect of gravity. Thus, when the body of a chloroformed animal is brought from the horizontal to the feet-down position, there is a far greater fall of pressure than occurs in the absence of chloroform anæsthesia. Hill finds that the effect is principally due to a paralytic state of the splanchnic vaso-motor mechanism brought about by chloroform, leading to an accumulation of blood within the splanchnic area. The deeper the anæsthesia the greater is the damaging effect of the drug upon the vaso-motor controlling mechanism. Embley[2] agrees with Gaskell and Shore that chloroform stimulates rather than depresses the central vaso-motor system, at any rate for a time, and attributes the fall of pressure to the direct paralytic effect of this anæsthetic upon the heart and arterioles. He admits that the fall may be augmented by slowing of the heart's rate or by the cardiac inhibition which formed the special object of his research. There can be little doubt that the fall of tension under chloroform is often, if not invariably, the result of the action of several factors. Whilst recent researches point to direct cardio-vascular dilatation as the paramount factor (the vessels of the splanchnic area probably being chiefly affected), it is not improbable that in certain cases other factors come into operation. The blood-pressure at any given moment is in fact the expression of numerous conflicting conditions. Some of these conditions tend to raise pressure: for example, chloroform acting directly upon the vaso-motor centre; an asphyxial state of the blood acting in like manner; or the feet-up posture. Others tend to lower pressure: *e.g.* cardio-vascular dilatation; cardiac inhibition; feebleness or arrest of the respiratory pump; and the feet-down (vertical) posture. The

[1] *Brit. Med. Journ.*, 17th April 1897, p. 959.
[2] *Ibid.*, 19th April 1902, pp. 955 *et seq.* See also *Trans. Soc. Anæsth.* vol. v. p. 82.

net result is always on the side of diminution, the degree of fall being as a general rule roughly proportional to the degree of anæsthesia.

In the course of some observations[1] made in connection with the use of the Vernon Harcourt inhaler (p. 389), Dr. W. J. McCardie subjected himself to chloroformisation by this inhaler, Dr. Dudley Buxton administering the anæsthetic and Mr. Lockhart Mummery recording the blood-pressure by means of a sphygmomanometer. With 1 per cent of chloroform the blood-pressure sank at first slowly, then more rapidly, from 130 mm. of mercury to 110 mm. With 1·5 per cent it fell in ten minutes to 90 mm. and was steady at that point for seven minutes, at the end of which time the proportion of chloroform was lowered to 1 per cent, when the pressure rose again in about six minutes to 105, but did not rise on the average above this point during the next twenty-five minutes though the administration had ceased and consciousness had returned.

The action of chloroform upon the **renal functions** was studied some years ago by Thomson and Kemp,[2] who found that with this anæsthetic the urinary secretion was diminished only when the general circulation became depressed; that albumen only appeared after prolonged narcosis, and then in but small amount; and that oncometric tracings corresponded with the carotid tracings, and never fell to the base line. The results obtained by Buxton and Levy in a later research agree in the main with those of Thomson and Kemp. Professor W. H. Thompson[3] has shown that in dogs the volume of urine secreted is frequently increased during the early stages of anæsthesia, whilst during full anæsthesia it is always diminished and may even be suppressed. At the end of the administration there is invariably a great increase, which in certain periods may reach four times the normal volume for the same period of time. The total excretion of nitrogen is generally greatly reduced, more so than the quantity of urine. In the course of his experiments he found that the urine secreted during chloroform anæsthesia almost invariably contained less nitrogen per cent than the normal urine. This held good even though the volume of urine was diminished. The excretion of chlorides was much increased

[1] *Brit. Med. Journ.*, 14th July 1906, p. 84.
[2] *New York Med. Journ.*, 18th November and 25th November 1899.
[3] See *Brit. Med. Journ.*, 17th March 1906, p. 608.

both during and after chloroform narcosis. After-albuminuria was met with in a small proportion of the experiments. Many observers believe[1] that chloroform is more damaging to the renal epithelium than ether, as evidenced by the more persistent presence of albumen and casts in the urine after the former anæsthetic.

The results obtained in man by Bovee[2] do not quite bear out those met with in dogs. Thus he finds a steady fall in the output of urine from the commencement of anæsthetisation; the minimum secretion is reached after an hour and a quarter of anæsthesia. There is diminution of urea output, but in proportion to the diminished total quantity of urine; *i.e.* the percentage of urea remains normal. There is no evidence to show that (either ether or) chloroform has any influence on the production of albumen or casts. The Trendelenburg posture greatly retards the rapidity of urinary output; partly, Bovee suggests, from retention in the renal pelvis, but partly also from a certain degree of arrest of renal function directly due to this position.

Reference has already been made (p. 84) to the **degenerative visceral effects** which are liable to result from prolonged chloroformisation. As will be pointed out in the final chapter (p. 634), it is contended by many writers that there is some connection between these degenerative changes and the condition variously described as "**post anæsthetic toxæmia,**" "**acidosis,**" and "**delayed chloroform poisoning.**"

As a result of experiments upon the **quantitative estimation of chloroform in animal tissues** Waller[3] found that, in the case of small animals killed by chloroform inhalation, an amount of the drug was obtainable from the body after death equivalent to $\frac{1}{10{,}000}$ part of the body weight.

With the foregoing data at our disposal we are in a position to commence the consideration of the question, **How does chloroform kill?** It is certain that there is a special risk, at all events in the case of human beings, in the earlier stages of administration, and numerous theories have been advanced

[1] *Lancet*, 30th December 1905, p. 1920.

[2] J. W. Bovee, *American Journal of Obstetrics and Gynæcology*, June 1909, p. 1004.

[3] *Brit. Med. Journ.*, Dec. 1901, p. 1859 *et seq.*

to explain this early chloroform syncope. Thus Dastre not only speaks of the primary or laryngo-reflex syncope above mentioned, but he accepts Duret's hypothesis of an early "bulbar syncope," which is supposed to result from a very strong vapour stimulating and then paralysing the cardio-accelerator centre of the cervico-dorsal cord, whilst the cardio-inhibitory centre is in a state of excitement and brings the heart to a standstill. There is excited cardiac action; the blood-pressure, raised at first, quickly falls; the heart then slows and finally ceases, the slowing being due to paralysis of the accelerator centres of the cord, and the syncope to a direct and excitant action of the chloroform upon the inhibitory mechanism. As indicated above, Embley's researches concerning the causation of sudden death during the administration of chloroform also point to a direct action of this anæsthetic upon the cardio-inhibitory centre. He believes that the vagi are most active during the induction stages; that concentrated chloroform atmospheres act prejudicially, through the medium of the blood, directly upon the vagus centre; and that the greater the cardiac depression which has been produced by chloroform, the greater the liability to vagus arrest. Schäfer and Scharlieb also attach importance to vagal inhibition as a factor in early chloroform syncope.

Owing to the fact that the experimental physiologist cannot reproduce many of the clinical phenomena which play such an important rôle in the chloroform accidents of practice, we shall not be in a position to complete the consideration of the question before us till we have studied the nature and origin of these clinical phenomena (see pp. 418 *et seq.*). The physiological facts which have been embodied in this chapter merely give us an insight into the mechanism of death from simple chloroform toxæmia. The introduction into the circulation of poisonous quantities of chloroform quickly brings about cardio-vascular paralysis, the central and most important factor in this toxic state. As we shall subsequently see, many, and perhaps most, of the chloroform accidents of practice take place, not during simple but during complex chloroform anæsthesia (p. 39); not merely from an overdose of the drug, but from some intercurrent and often unrecognised asphyxial state, which, in conjunction with the presence of chloroform within the circulation, quickly leads to fatal cardiac paralysis.

So far as we have gone, then, it would seem that we have in chloroform a drug which is a powerful protoplasmic poison; which, when given in toxic quantities, leads to death of the organism, not because it paralyses respiration—for were it merely a respiratory depressant, artificial respiration would be invariably successful in averting death—but because, as recent researches have shown, it markedly depresses the circulation. It is this circulatory depression which renders it difficult to resuscitate patients. The fact that an overdose of chloroform

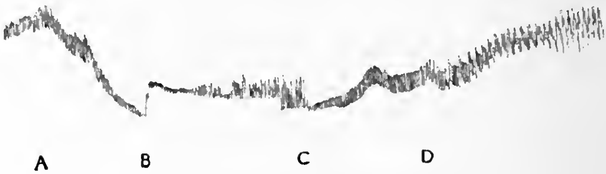

Fig. 8.—Cannula in carotid. Dog. Shows recovery from chloroform syncope brought about by rhythmic compression of thorax in horizontal posture. Abdomen was now and again gently compressed to fill heart. Shows that respiratory waves disappear as arterial pressure falls (A—B), and that natural breathing reappears when arterial pressure becomes raised during the period of asphyxia (C—D) which follows after the period of artificial respiration (B—C). Also shows how the artificial pressure can be mechanically maintained by artificial respiration. Blood is forced into the right heart and lungs by abdominal compression, and driven through lungs and left heart into aorta by thoracic compression. A, Chloroform pushed. B, Artificial respiration: alternate compression of abdomen and thorax. C, Artificial respiration left off, followed by asphyxial rise. D, Commencement of natural breathing.

generally paralyses respiration before the heart's action finally ceases must not be allowed to overshadow the more important fact that prior to and during the respiratory failure the heart has, in many cases, ceased to circulate blood through the organism. Whether in true chloroform toxæmia the fatal circulatory failure is principally (*a*) a failure of cardio-vascular origin due to chloroform directly affecting the musculature of the vascular system *as a whole*; whether it is principally (*b*) a failure of cardiac origin, the chloroform directly affecting the *cardiac muscle relatively more than the walls of the arteries and arteriols*; whether it is principally (*c*) a failure due to the action of chloroform upon the *nervous mechanism which controls* *cardiac action*; or whether it is principally (*d*) due to a paralysis of the *vaso-motor mechanism*—we cannot at present positively say.

The tracing of Fig. 8 (kindly presented to the author by Dr. Hill) is of interest in connection with the application of remedial measures in chloroform syncope.

D. OTHER AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

Comparatively few researches have been conducted with the other general anæsthetics to which incidental reference has already been made (pp. 32 to 35); and the reader will therefore find in the clinical part of this work (pp. 458 *et seq.*) most of the information which is at the present time available concerning the action of these substances. There are, however, certain theoretical and experimental data which call for brief notice in the present chapter.

The properties of **ethyl chloride**, an anæsthetic which is extensively used for short operations, were investigated by the Glasgow Committee, who found that it rapidly produced general anæsthesia. In one case respiration ceased, and in another general convulsions supervened. Kemp[1] also came to similar conclusions, recording stertor, difficult respiration, tremors, and convulsive movements of the legs. According to McCardie,[2] Koenig found that the rapidity of narcosis depended on the degree of dilution with air. A mixture of 10 per cent of ethyl chloride vapour with 90 per cent of air caused narcosis in small animals at the end of six or seven minutes. 50 per cent mixtures rapidly caused narcosis lasting for some minutes. Pure ethyl chloride vapour caused regular and rapid lowering of arterial pressure ending in respiratory and cardiac arrest. These effects were observed in dogs and monkeys. Guy, Goodall, and Reid report[3] that in man ethyl chloride causes very great disturbance of systolic pressure; but that whether in any given case this effect will be a rise or a fall cannot be predicted. The common result is a sharp fall, and with

[1] *New York Med. Journ.*, 2nd Dec. 1899, p. 804.
[2] *Lancet*, 4th April 1903, p. 953.
[3] *Ibid.*, 12th Feb. 1910, p. 436.

doses of 5 c.c. this fall is sometimes sufficient to endanger life. The fall is ascribed to inhibition of the heart. It can be eliminated entirely by the previous inhalation of five respirations of N_2O, which is supposed to depress the vagus inhibitory centre. When these five breaths of N_2O are given prior to ethyl chloride, an asphyxial rise of pressure takes place; this can be avoided by the inhalation of a gallon of oxygen before the gas. Thus the sequence, oxygen, N_2O, ethyl chloride entails no asphyxia and no alteration of blood-pressure; and the period of available anæsthesia remains the same as in the case of ethyl chloride alone. McCardie also states that Wood and Cerna found that ethyl chloride caused augmentation of the respiratory movements and lowering of blood-pressure during narcosis. The rate of the heart-beat was at first decreased and then increased. In some experiments which he conducted, W. Webster [1] found that small doses of ethyl chloride increased the force and depth of respiration, while large doses depressed this function. With very large doses the breathing ceased some considerable time before the heart stopped. With small doses the blood-pressure rose slightly, but with large doses it fell, these effects occurring not only with intact but with cut vagi. The pharmacology of ethyl chloride has been carefully studied by Embley.[2] This writer states that the effect of ethyl chloride vapour upon the heart is paralytic; but the quantity of ethyl chloride vapour in the air required is nineteen times as great as that of chloroform to produce comparable results. Ethyl chloride relaxes arterioles which are cut off from the central nervous system, as does also chloroform; but the amount of ethyl chloride required is vastly greater than that of chloroform. Further, the effect of ethyl chloride upon the central vasomotor mechanism is, for a time at least, stimulative, as is also the case with chloroform. The net result of the action of ethyl chloride on the vascular system of the living animal is dilatation. Vagus inhibition of the heart occurs very readily when ethyl chloride vapour of a strength of 10 per cent and upwards is administered in the air inspired.

[1] *Bio-Chemical Journal*, June 1906. Abstracted in *Lancet*, 14th July 1906, p. 106.

[2] *Proc. Roy. Soc.* B vol. lxxviii. 1906, p. 391.

According to Dastre, Rabuteau found that **ethyl bromide**, like other anæsthetics, arrested germination, but that its vapour was more poisonous to plants than that of ether. Dastre states, moreover, that whilst the bromide is undoubtedly a powerful anæsthetic, it does not, like chloroform, lead to "primary syncope," and he believes that this difference is due to the drug being less irritating and caustic in its local action. He explains the usual absence of excitement by the supposition that the cerebral hemispheres, bulb, and cord are peculiarly sensitive to the action of the drug. The effects produced upon blood-pressure by bromide of ethyl have been investigated by Ginsberg. According to Cole,[1] Ginsberg, who experimented upon rabbits and dogs, found that small doses of ethyl bromide, sufficient to produce anæsthesia, do not lower blood-pressure, but that large doses cause a fall of pressure with irregular pulse and rapid respiration. Death is due to respiratory failure which precedes cardiac failure. Ginsberg is stated to have ascribed the cardiac acceleration to stimulation of automatic cardiac centres or of peripheral accelerator nerves, and the fall of blood-pressure to paralysis of peripheral vaso-motor nerves. He is also stated to have found that the vagus, the vaso-dilator centres, and the peripheral vaso-dilator nerves are not affected by ethyl bromide. In the course of an experimental inquiry, Cole[2] found that under ethyl bromide the strength of the heart's contractions was diminished, not only with intact but with divided vagi, and that the vagus endings in the cardiac ganglia were paralysed. The rate of the heart's action was increased. Rigidity of the skeletal muscles was observed even during deep coma. He disagrees with Ginsberg as to the effects of ethyl bromide upon the vaso-motor system, for he failed to find any evidence of the drug paralysing peripheral vaso-constrictor fibres. W. Webster,[3] in the course of his experiments, found that ethyl bromide produced the same physiological effects as ethyl chloride (*vide supra*). He disagrees with Cole as to the action of this anæsthetic upon the vagus terminals, maintaining that

[1] *Brit. Med. Journ.*, 20th June 1903, p. 1423.
[2] *Ibid.*
[3] *Bio-Chemical Journal*, June 1906. Abstracted in *Lancet*, 14th July 1906, p. 106.

full vagus effects can be obtained with an animal completely anæsthetised by ethyl bromide.

Ethidene dichloride was experimentally studied by the Glasgow Committee,[1] who found that under its influence blood-pressure fell, though not to the same extent as in the case of chloroform. They found, moreover, that it had not nearly such a depressant action upon the heart as chloroform.

The Glasgow Committee also tested the effects of numerous other organic liquids.[2] Thus **Dutch liquid** was found to produce convulsions before true anæsthesia appeared; **butyl chloride** caused breathing to cease very soon after anæsthesia had become established; **acetone** set up only slight effects in a frog, even after a long administration; and **benzene** caused struggling and cardiac weakening, although the latter effect was not so marked as with chloroform. As regards the first named of these anæsthetics—Dutch liquid—this had previously been experimentally studied by Snow, Simpson, and Nunneley, and actually used in practice.

The action of **methyl oxide,** or **methylic ether,** as an anæsthetic is discussed in the clinical section of this work (p. 466).

The Committee also tested the anæsthetic properties of **isobutyl chloride** and **methyl chloride.** With the first-named drug rabbits and dogs were completely anæsthetised in from three to five minutes, and respiration was unaffected even after half an hour's administration. With human beings, however, isobutyl chloride produced excitement and proved itself to be but an imperfect anæsthetic.[3] With methyl chloride the Committee were unable to obtain any other effect than drowsiness, the rabbits on whom they experimented preserving their reflexes even after a prolonged administration.

Tetrachloride of carbon has been experimentally studied by Laffont, Rabuteau, and Morel. Frogs are slowly anæsthetised by it, and recover slowly from its influence. It is stated that in warm-blooded animals a powerful effect is produced, excitement and muscular spasm—both tonic and

[1] *Brit. Med. Journ.*, 4th Jan. 1879, p. 1. [2] *Ibid.*
[3] *Ibid.*, 21st June 1879, p. 923.

clonic—appearing, whilst during the period of anæsthesia the heart beats rapidly and the blood-pressure falls.

The physiological properties of **bichloride of methylene** have been investigated by Regnauld,[1] Villejean, and Richet. According to Dastre, the first two of these observers found that whilst anæsthesia came about very rapidly, the muscular excitement which the drug produced was so violent that the agent could not be regarded as an anæsthetic in the ordinary sense of the word. In addition to general muscular spasm of a tetanic character, epileptiform and choreiform movements appeared, and these persisted even after the anæsthetic effects had passed off. Richet has also administered bichloride of methylene to lower animals, and states[2] that the muscular phenomena resemble those of asphyxia, whilst the anæsthesia disappears very rapidly. The properties of the anæsthetic liquid introduced under the name of "bichloride of methylene" or "methylene" by Richardson will be discussed in the clinical section of this work (p. 460).

Acetate of ethyl, or acetic ether, has been used to anæsthetise frogs. It is stated that it is decomposed in the blood into acetate of soda and alcohol, and that anæsthesia is produced by the latter (Dastre); there is, however, but little ground for this assertion.

The anæsthetic properties of **carbonic acid** gas have long been known to physiologists; and the interesting experiments of Monjon, Ozanam,[3] Paul Bert, and Gréhant[4] have added much to our knowledge concerning this body. The last-named observer found that the best results were obtained with mixtures containing as much as 45 per cent of carbonic acid and a proportion of oxygen equal to or in excess of that present in atmospheric air.[5] With such mixtures rabbits were deeply anæsthetised in two minutes, and it was possible to maintain anæsthesia for a prolonged period. Respiration was much reduced in frequency, but its rhythm was unaffected. Blood analyses showed that the oxygen percentage remained

[1] *Soc. de. Biologic*, 22nd March 1884.
[2] *Dict. de Physiologie.*
[3] *Academie des Sciences*, 25th Feb. 1858.
[4] *Soc. de Biologie*, 29th Jan. and 12th March 1887.
[5] See Dastre, *op. cit.*

constant, but that the CO_2 was greatly increased, oscillating between 80 and 90 per cent. With less than 45 per cent of carbonic acid in the mixture breathed, it is stated that anæsthesia did not supervene. Richet[1] points out that carbonic acid is not eliminated so rapidly as many other anæsthetics, because, whilst within the organism, it plays the part of an acid and combines with the alkalies of the blood and tissues.

The effects produced by the **indifferent gases** will be subsequently studied (p. 465).

It has been shown that when introduced into the veins, **chloral** is capable of producing general anæsthesia (Oré), but there are considerable risks in such a procedure.[2] **Hedonal** is now being used by this method. Mr. C. M. Page has especially advocated this drug, and apparently there is less risk in giving a solution of it intravenously than is the case with chloral.

Finally, a few researches have been conducted with mixtures of anæsthetics, and with mixtures of anæsthetics with liquids not necessarily possessed of anæsthetic properties. Thus the **C.E. mixture** (p. 471) has given results very similar to those of chloroform. Kemp found[3] that when the vapour of this mixture was administered to dogs with 95 per cent of air, the carotid tracings closely resembled those obtained with chloroform, and that when the air-supply was lessened, very pronounced chloroform effects appeared. Leonard Hill found that when a small quantity of the C.E. mixture was introduced into the jugular vein of an animal whose heart had been enclosed in a tennis ball connected with a piston recorder, the tracing showed an immediate ether effect, and a subsequent chloroform effect. Upon the kidney Kemp observed the same effects as those produced by chloroform, provided that the open method was used. When a semi-closed method of administration was adopted, the effects resembled those of ether. The renal secretion was more copious than with pure ether, but less copious than with chloroform.

[1] *Dict. de Physiologie.* [2] See Dastre.
[3] *New York Med. Journ.*, 25th Nov. 1899.

Electric anæsthesia was described by Professor Leduc about five years ago, and has been practised by some of his pupils since. The current used is an intermittent one of low voltage and unidirectional. The current enters through electrodes placed on the head, and is turned on gradually, not in full strength straight away. The effects are described as being similar to those of chloroform anæsthesia, a stage of excitement preceding that of narcosis. When the current is turned off recovery is instantaneous without any after-effects. Further information on this subject will be found in an article by W. D. Butcher [1] and in Leduc's pamphlet.[2] For an account of the successful use of the method on the human subject a paper by M. M. Johnson may be consulted.[3]

For information concerning the physiology of **local** and **spinal** anæsthetics, the reader is referred to Chapter IX.

[1] *Lancet*, 16th Nov. 1907, p. 365.
[2] *Le Sommeil Electrique*, Paris, Masson et Cie.
[3] *Medical Record*, 23rd April 1910.

CHAPTER V

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN ORDINARY OR ROUTINE CASES

In opening the clinical or practical part of this work it may be well to define clearly certain terms which will be constantly employed. The term **anæsthetic** will be used to include, not only the simple or fundamental substances, such as nitrous oxide, ether, etc., whose properties have been considered in Chap. II., but also all stable mechanical **mixtures** of these bodies, such, for example, as the C.E. mixture—a name given in this work to a mixture of 2 parts (by volume) of chloroform to 3 parts of ether. The term **sequence** or **succession** will be used when two or more anæsthetics are administered consecutively. We shall, for example, speak of the nitrous oxide-ether sequence, the chloroform-C.E.-ether succession, etc. When an anæsthetic, mixture, or succession is administered according to a particular but broad principle, we shall speak of this or that **system** of administration. To Snow, for example, belongs the credit of introducing the percentage system of chloroformisation; to Andrews that of administering oxygen with nitrous oxide; to Clover that of administering ether with a limited air-supply. The term **method** will be restricted to the actual means by which the anæsthetic, mixture, or succession is administered. For example, Clover's system of employing nitrous oxide and ether in succession may be put into force by the use of different **methods**. Andrew's principle or system of obtaining non-asphyxial nitrous oxide anæsthesia may be carried into effect by employing Paul Bert's method. Lastly, it will also be convenient to speak occasionally of certain **modifications in methods.**

The anæsthetist of to-day has at his disposal not only a considerable number of anæsthetics, mixtures of anæsthetics, and successions of anæsthetics, but also a great variety of methods of administration. Putting aside for the present certain exceptional circumstances, to which reference will subsequently be made, it may be said that the practice of employing one anæsthetic for all cases must now be regarded as belonging to a bygone time. To ensure success in inducing and maintaining general anæsthesia we must vary our anæsthetic and our methods of using it, according to the exigencies of the case with which we have to deal.

Of the simple or fundamental anæsthetics referred to in Chap. II., there are only four which need engage our attention on the present occasion, viz:—

Nitrous Oxide,
Ether,
Chloroform, and
Ethyl Chloride.

Of the mixtures, that known as

The C.E. mixture

is most worthy of notice. And of the successions or sequences of anæsthetics, the following are the most important and useful:—

The Nitrous Oxide-Ether sequence;
The Ethyl Chloride-Ether sequence;
The C.E.-Ether sequence;
The Nitrous Oxide-Ether-Chloroform sequence;
The Nitrous Oxide-Ether-C.E. sequence;
The C.E.-Chloroform sequence; and
The Chlorofrom-C.E.-Ether sequence.

In attempting to formulate principles for the selection of anæsthetics, we have, in the first place, to decide what means should be adopted for inducing and maintaining anæsthesia in **ordinary or routine practice.** With this section of the subject the present chapter will deal. Next, we have to decide what modifications in this routine practice are advisable when anæsthetising patients belonging to this or that type, or suffering from this or that condition. This part of the subject will be discussed in Chap. VI. And in the third place, it is necessary to indicate the special lines of practice which should be pursued in administering anæsthetics for certain operations, procedures, or conditions. This part of the subject will be considered in Chap. VII.

In deciding upon the means to be employed for producing anæsthesia in ordinary or routine practice, one of the most important considerations should be the **safety of the patient.** It is clearly the duty of all who have not become specially familiar with some less safe anæsthetic to choose the safest of those which are available, always provided that its use is free from inconvenience to the surgeon and from discomfort to the patient. Two questions hence present themselves: (1) Which is the safest anæsthetic for brief operations not requiring total muscular relaxation? and (2) Which is the safest anæsthetic for operations demanding profound or continuous narcosis? It will be convenient to consider these questions separately.

(1) It is now universally admitted that nitrous oxide is the safest general anæsthetic known. When administered with a proper percentage of oxygen, in order to eliminate the asphyxial element, its inhalation is practically free from risk to life. Almost equally good results may be obtained with air as the oxygenating medium. Even when pure nitrous oxide is given by any one familiar with its use the risk to life is so slight as to be almost negligible. In addition to its being the safest anæsthetic, nitrous oxide is not unpleasant to inhale; it rapidly destroys consciousness; and its administration is rarely followed by unpleasant after-effects. On the other hand, the heaviness of its storage cylinders, the comparative lightness of its anæsthesia, the tendency to muscular rigidity, movement, and asphyxial accompaniments during the administration of the pure gas, and the somewhat lengthy experience required to obtain good results in all cases, combine to limit the employment of this valuable anæsthetic.

Given that the patient is of a suitable type, that the operation is one in which slight reflex movement would not be inconvenient, and that the apparatus required for the administration would not incommode the surgeon, there is no form of anæsthesia with which we are acquainted which is so perfect as that of nitrous oxide and oxygen. Many small operations, such, for example, as the removal of small tumours, the slitting up of sinuses, the dressing and examination of wounds, may usually be performed under this anæsthetic without causing the slightest after-effects, always provided that the patient be properly prepared, and that the other details connected with this form of anæsthesia be observed. Indeed, major operations lasting for hours have been successfully undertaken with this combination.

Within recent years ethyl chloride has come into extensive use for brief surgical operations; its great advantages over nitrous oxide are that it is far more portable, more manageable, and easier to administer. But from the somewhat numerous accidents that have occurred under its influence there is good reason to believe that the risk attending its administration is considerably greater than was at first supposed. At the same time ethyl chloride is a useful anæsthetic for certain cases, *provided that it be administered by some one thoroughly conversant with the principles of anæsthetisation.*

(2) Nitrous oxide and ethyl chloride being inapplicable for major surgical operations, it is important that every member of the profession should know which is the safest routine agent when muscular relaxation or protracted narcosis is needed. It may now unhesitatingly be affirmed that ether enjoys this position.

Statistics as to the relative safety of ether, chloroform, and other agents are unquestionably open to grave fallacies, and must be accepted with caution. So-called "deaths under anæsthetics" are often deaths partly or wholly attributable to other causes than the influence of the anæsthetic itself, and, conversely, fatalities which should be properly ascribed to anæsthesia are often either never reported or regarded as due to "surgical shock," "collapse," etc. Again, statistics generally ignore those cases of fatal bronchitis and pneumonia which undoubtedly occasionally follow the use of anæsthetics, and particularly ether, and which should in all fairness be included in any statistical inquiry. Moreover, the personal element—the experience of the administrator or administrators in any given series of cases—is often not taken into account. And, lastly, it must be remembered that desperate cases are often regarded as unsuitable for chloroform, so that ether is chosen for them, with the result that the ether death-rate is thereby unfairly increased. Still, with all these objections to statistics, there can be no doubt that they have their value. Whilst they may be regarded as roughly indicating the relative risks of ether, chloroform, etc., during anæsthesia, they cannot be accepted as representing the true relative death-rates.

The late Sir B. W. Richardson[1] obtained records of 35,162 chloroform administrations with 11 deaths, giving a death-rate of 1 in 3196, and of 8431 ether administrations with but 1 death.

It is stated[2] that in the Crimean War there were 20,000 chloroform administrations with but 2 deaths.

Dr. Julliard[3] of Geneva has collected, from various reliable sources, records of no less than 839,245 ether and chloroform administrations. The following table shows the relative frequency with which chloroform and ether were used, and the relative death-rate:—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	524,507	161	1 in 3258
Ether . . .	314,738	21	1 in 14,987

Dr. Ormsby of Dublin has put on record[4] the following administrations:—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	152,260	53	1 in 2873
Ether . . .	92,815	4	1 in 23,204
Chloroform with ether	11,176	2	1 in 5558
"Bichloride of methylene" .	10,000	2	1 in 5000

At the 1890 meeting of the German Surgical Society it was resolved to investigate collectively the relative safety of anæsthetics. 24,625 cases were reported[5] during six months. Of these there were 22,656 chloroform administrations, with 6 deaths, 2 of which, however, occurred from other causes than the anæsthetic. This would give a chloroform death-rate of about 1 in 5500.

[1] *Asclepiad*, Jan. 1892. [2] Dastre, *op. cit.*

[3] *L'Ether est-il préférable au Chloroforme?* Par M. le Professeur Julliard de Genève. (Extrait de la Revue Médicale de la Suisse romande, No. 2, février 1891.) [4] *Brit. Med. Journ.*, 14th April 1877, p. 446.

[5] See Gurlt's Summary, *Archiv für klin. Chirurgie*, vol. xlii. pp. 282 and 301.

Körte[1] has collected records of 133,122 chloroform administrations with 46 deaths, giving a death-rate of 1 in 2894 cases.

At St. Bartholomew's Hospital,[2] during the years 1875-1900, there were 80,255 administrations of chloroform, ether, and "gas and ether"; and the following table shows the fatalities and death-rates :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	42,978	33	1 in 1300
Ether and "Gas and Ether" .	37,277	4	1 in 9319

According to these figures, which are perhaps the most reliable at our disposal, although they deal entirely with ether given by closed methods, it would appear that ether is about seven times as safe as chloroform. The tendency to a too high ether death-rate from the inclusion amongst the ether cases of desperately bad subjects is counterbalanced to a greater or less extent by a tendency to a too low death-rate from the exclusion of cases of pulmonary complications referable to ether. It is interesting that the ratio seven to one corresponds to that obtained by Waller as the expression of the relative toxicity of chloroform and ether (p. 65).

If we combine Dr. Julliard's statistics with those of Dr. Ormsby, we obtain the following results :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	676,767	214	1 in 3162
Ether . . .	407,553	25	1 in 16,302

According to these figures ether is, roughly, more than five times as safe as chloroform.

With the above statistics before us we shall probably not be far wrong in assuming that, in the circumstances mentioned, **ether is about six times as safe as chloroform**; in other words, with a heterogeneous assortment of anæsthetists, patients and operations, and with ether and chloroform as the anæsthetics, the risk to life is about one-sixth as great with the former as with the latter agent. It is therefore clear that, in the absence of special circumstances, the anæsthetist is morally bound to

[1] *Deutsche med. Zeit.*, 12th Feb. 1894.
[2] See a letter by Mr. Roger Williams, *Lancet*, 7th June 1902, p. 1643.

employ ether in preference to chloroform for the majority of cases in ordinary surgical practice. This moral obligation is more than ever binding on the anæsthetist since the adoption of the open ether method and of preliminary morphine-atropine narcosis has minimised several of the disadvantages from which ether by closed methods is not free. But in laying down this principle, it is only right to emphasise again that circumstances alter cases, and that the proper choice of an anæsthetic to suit the particular purpose and the particular patient remains one of the most important of the duties of an anæsthetist.

So many and so diverse are the factors which influence the choice of an anæsthetic for any given case, that broad lines only can be indicated. With this proviso clearly understood, it may be asserted that **nitrous oxide** and **ether** are the two anæsthetics of choice in **ordinary surgical practice**; the former for very short operations, the latter for those of longer duration.

The relative advantages of open and closed methods of administering ether have aroused much attention during recent years. Briefly the advantages of the latter method are rapidity of induction and economy of ether. On the other hand the closed method involves the use of a complicated apparatus, terrifying to the patient and impossible to sterilise satisfactorily. It involves also a certain degree of cyanosis—depending on the skill of the administrator—and in consequence of mucorrhœa.

The open method is wasteful of ether and of time during the induction stage. It is, however, in every other way superior to the closed methods. The apparatus is simple and easily sterilised. No cyanosis need or ought to be produced; hence mucus secretion and after-vomiting are reduced in extent and frequency. For the same reason ether pneumonia is said to be less common, though this has not yet been conclusively proved, and may turn out not to be true. Moreover the open method is safer, though an overdose is possible even with this method. In short the open ether method is to be preferred for all but very short operations or when time is of great importance.

As the C.E. mixture is undoubtedly one of the best anæsthetics for a large number of cases in major surgery, one is often asked: Why should not this mixture, which is not unpleasant to inhale, which is certainly safer than undiluted chloroform, and which can be administered by a simple form of apparatus, be used for routine work; and if it be suitable for *bad* subjects, why should it not, *a fortiori*, be suitable for good ones? The fact is that for its safe administration considerable experience is needed; but when once this has been gained it may certainly be used as a routine anæsthetic. The explanation of the fact that the C.E. mixture answers better, as a rule, in unhealthy than in healthy subjects is that with the latter excitement, struggling, and rigidity are more likely to arise.

After many years of experience either with some special chloroform and ether mixture or with chloroform itself, such skill may be acquired that the administrator's results, so far as the avoidance of fatalities is concerned, may approach or possibly equal those of the ardent supporter of ether. It is doubtful, however, whether the exclusive administrator of chloroform can ever become so perfect in its administration as to be able to eliminate wholly the risk which attaches to the early stage of chloroformisation. But by what may be termed the "fine adjustments" in anæsthetisation it is possible for a practised anæsthetist to avail himself of the undoubted benefits of chloroform for some operations without incurring the chief risk of this anæsthetic, *i.e.* the risk of the induction period. He employs, for example, the nitrous oxide-ether sequence, the ethyl chloride-ether sequence, or the C.E.-ether sequence for the induction stage of anæsthesia, and then changes to chloroform for the remainder of the administration. By such successions of anæsthetics the advantages of certain agents are obtained, whilst the disadvantages of others are eliminated. It is not suggested that these complicated sequences are suitable for routine use by the comparatively inexperienced administrator. They are simply referred to here as instances of recent developments which have taken place in this branch of practice. They can, in fact, only be successfully used after experience has been gained with each of the agents included in the sequence.

CHAPTER VI

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR CASES

PART I.—THE STATE OF THE PATIENT AS A FACTOR

A CAREFUL consideration of the state of the patient is essential, not only in deciding upon the anæsthetic and the method of its administration, but in forming an opinion as to the probabilities of certain difficulties or dangers arising during the induction or maintenance of anæsthesia. The typically healthy patient is by no means necessarily the best subject for a general anæsthetic. It is a popular fallacy to imagine that, because the heart-sounds are normal and no visceral disease can be detected, the anæsthesia will run a perfectly normal and straightforward course. On the contrary, the best subjects are to be found amongst comparatively feeble persons. Were it merely a question of the supervention of toxic phenomena, the matter would be a simple one, for the strongest and healthiest patients would, as a general rule, be less liable to give cause for alarm than their more weakly fellows. Such, however, is not the case. It is, of course, true that asthenic subjects and those with morbid states of the heart or lungs will not be able to hold out against any given strain as long as stronger persons. But if we wish to avoid accidents we must study not so much the threatening symptoms themselves as the causes upon which they depend. From the point of view of the anæsthetist, patients may be arranged in classes or types, according to the presence or absence of the conditions enumerated and considered in this chapter.

It is a curious and important fact that patients whose general condition is unsatisfactory are usually far more tolerant of a comparatively light anæsthesia than vigorous subjects. Whilst a healthy child or adult may require large quantities of a given anæsthetic in order that inconvenient reflex movement or abdominal rigidity may be prevented, the chronic invalid, the bronchitic or asthmatic sufferer, or the patient with advanced morbus cordis and a degenerated vascular system, will often remain completely passive to surgical procedures even though a brisk lid-reflex be present.

A. SEX AND AGE

Sex.—Sex has a distinct, though probably only an indirect, influence upon the effects produced by general anæsthetics. Women certainly pass more easily than men into deep anæsthesia—a fact which may be explained by their physique being, as a rule, inferior to that of men (*vide infra* **D**). Men with feebly developed muscular systems take anæsthetics very much in the same manner as women, and women of masculine type display similar symptoms to those of men. Emotional disturbances are commoner in women than in men.

Age.—Similarly, age has of itself no intrinsic influence in modifying the effects produced by anæsthetics. It is rather the presence, at different periods of life, of different physical and other conditions which must be considered. The invariable use of chloroform, for example, for patients between certain ages, and of ether for patients at other periods of life, cannot be regarded as rational. General anæsthetics may be given to patients of all ages. Infants but a few hours old may be safely anæsthetised; and anæsthetics have been successfully administered to centenarians.

Boys are often very difficult subjects for anæsthesia for laparotomy, and particularly boys in good or moderately good health and with some degree of nasal obstruction from past or present adenoids. Their nervous systems are highly sensitive; they are often alarmed by their relatives; they have rarely been dieted properly; and it is quite difficult in some cases to secure an oral air-way owing to a powerful tongue pressing spasmodically against the soft palate and pharynx. Ether often produces considerable difficulty in breathing even when given by the purely open system. It is difficult to say what is the best anæsthetic for such cases—probably C.E. mixture with additional ether if need be.

A few words may not be out of place concerning the general **management of children** about to be anæsthetised. Kindness, gentleness, and good temper are important elements in the success of an administration. Children should never be deceived or entrapped. The less said to them by their relatives and friends the better. The alarm sometimes displayed by these little subjects is almost invariably due to the misguided action of sympathetic parents and friends who, by their unusual conduct and expressions, have betrayed their apprehension. On the day of the operation there should be as little deviation as possible from the child's usual routine. If the relatives and friends can be persuaded to adopt such a course they should altogether absent themselves immediately before and during the administration. A little "wholesome neglect" is often an excellent prescription, both before and after anæsthesia. When, as sometimes happens immediately before an anæsthetic is given, a child is surrounded by an agitated crowd of relations, all speaking at the same time, a state of alarm is not unlikely to arise. It is generally quite unnecessary to tell children beforehand that anything unusual is about to happen; but with intelligent children of six and upwards, it is often a good plan to say that they "are going to have something to smell which will make them better" or "take away their pain," as the case may be. Generally speaking, the administration may be begun whilst the little patient is lying in bed (p. 246), and it is often useful to first spray some eau-de-Cologne on the Skinner's mask and gradually add the C.E. mixture whilst the child counts aloud. In this way most small children may be anæsthetised without distress.

The upper air-passages of **infants and young children** are so sensitive that ether often causes some irritation and reflex "holding of breath." This has led many to prefer chloroform, which is certainly inhaled with comparative ease by children.

It is a mistake, however, to suppose that children are not so susceptible as adults to the toxic effects of this agent, and that with them fatalities are practically unknown. It is true that children inhale chloroform freely, and that they are not so liable as adults to certain forms of respiratory embarrassment. It is certain also that children may be rescued from conditions of respiratory and circulatory depression which in adults would be attended by more immediate risk to life. Children are, however, occasionally placed in considerable peril by chloroform, and more fatalities under this anæsthetic have been recorded than might be imagined.[1] Although chloroform is apparently better borne than ether by children, it nevertheless possesses certain special disadvantages in these subjects. It not unfrequently induces an extremely tranquil and sleep-like respiration which deprives the administrator of the most important means of knowing how deeply his patient is anæsthetised. This reason is alone sufficient to warrant us in the use of ether in some form or another for very young subjects. Moreover, the experience of recent years would seem to indicate that chloroform is far more liable than ether to be followed by certain peculiar toxic after-effects to be subsequently discussed (p. 634). Nitrous oxide is not an appropriate anæsthetic for children under three or four years of age, although, if given with suitable percentages of oxygen, it answers far better than when otherwise administered. The fragile thoracic parietes seem to be unable, in many cases, to meet the demands made upon them by the necessary valves and other parts of the inhaler. Pure nitrous oxide may rapidly bring about, in a small child, a very undesirable state of asphyxia. For **infants in arms** the method of etherisation described on p. 335 answers admirably. The directions there given should be closely followed. If the C.E. mixture be preferred—and it is perhaps preferable for operations of over ten or fifteen minutes' duration — it should be administered from a Skinner's mask (p. 401). If chloroform be used, it must be given in drops from a Skinner's mask; or by means of a Junker's inhaler,

[1] Comte, who has collected records of 232 chloroform fatalities, found that, of this number, 21 occurred in children. Weir stated (1890) that no death had been recorded under ether given to patients under twelve years of age. *New York Med. Journ.*, 1st March 1890.

the flannel mask of which should never be closely applied. The administration of chloroform to children during natural sleep will be subsequently considered (p. 418). For children of from **eighteen months to four years** the C.E.-ether sequence may be employed as described on p. 483 with good results, and is particularly appropriate for comparatively short operations such as that of circumcision. For comparatively protracted operations upon patients of this class the C.E.-ether-C.E. sequence (p. 502) may be employed, or the C.E. mixture, sprinkled upon a Skinner's mask, may be used throughout. Children over four years of age may generally be induced to count aloud during the slow administration of the C.E. mixture. As there is no objection (p. 144) to transferring small children, when partially anæsthetised, from one spot to another, the administration may with advantage be started whilst the little patient is lying in bed. The time taken to induce anæsthesia in children is often unexpectedly long, owing to the frequency of breath-holding. Crying children are, for obvious reasons, quickly anæsthetised. When once anæsthesia has become established, it may, as a rule, be maintained by comparatively small quantities of anæsthetic, always provided that the act of vomiting (which is very liable to accompany light degrees of anæsthesia in children) would in no way inconvenience the surgeon. Children of **five, six, or seven years** of age may also be anæsthetised whilst lying in bed, and in such circumstances all complicated sequences should be avoided as likely to cause alarm. A Skinner's mask and a drop bottle containing C.E. mixture can easily be carried in the pocket, and these simple appliances will be all that is necessary, at all events, for inducing anæsthesia. Should another anæsthetic be subsequently required, it can be substituted when the child has been carried to the operating table.

Children of **eight years** and upwards may generally be successfully anæsthetised upon the operating table, and under these circumstances nitrous oxide and oxygen may be used. One great advantage of nitrous oxide in anæsthetising children is that, if properly administered, it is generally breathed without resistance, and very rapidly destroys consciousness. Ethyl chloride has a much more distinct odour than nitrous oxide, and has not, in the author's hands, proved quite so satisfactory as an induction agent, at all events from the point of view of the patient. If the child be actually crying or hopelessly recalcitrant when the moment of administration arrives, ethyl chloride seems to be specially serviceable. As regards the routine use of this anæsthetic for brief operations upon children of the age in question, the results in expert hands are good. Many surgeons, however, prefer nitrous oxide or C.E. mixture even for such operations as those for the removal of tonsils and adenoids.

When, as in **abdominal operations**, it is essential to maintain deep chloroform, C.E. or so-called "open ether" narcosis in order to avoid all chances of "straining," the resources of the anæsthetist may be severely taxed. The skill of the administrator may, in fact, be gauged by the percentage of abdominal cases in children which he can carry through without straining or vomiting occurring (see pp. 211 and 540). Boys with adenoids, large tonsils, or catarrh of the upper air-passages are specially liable to give trouble.

Children appear to be more liable than adults to "**post-anæsthetic toxæmia**" or "**acidosis**"—a state which occasionally arises after a general anæsthetic and particularly after chloroform (Chap. XXI. p. 634). When, from the presence of an excess of acetone in the urine or from other symptoms such as a history of "cyclical vomiting," it is thought that "acid-intoxication" is likely to arise as an after-effect, ether should be given in preference to chloroform.

Children are usually regarded as unsuited for **spinal anæsthesia**; but Mr. H. T. M. Gray reports enthusiastically on a series of several hundred consecutive cases of children anæsthetised by this method.

Patients advanced in years generally take anæsthetics better than middle-aged or more vigorous subjects. They are less prone to muscular spasm; they usually require smaller quantities of the drug employed to produce desired effects; and, by reason of the frequency with which their teeth are defective, an oral air-way is usually readily obtainable for respiratory purposes. Elderly patients are far less liable to after-vomiting than younger subjects. Nitrous oxide may be administered to very elderly people, but care must be exercised. It should not be pushed quite so far as in younger subjects, otherwise, when the inhaler is removed, respiration may not recover itself as quickly as is desirable. The use of oxygen with nitrous oxide is specially indicated in senile subjects (see p. 315). As a general rule ether should not be given to patients over sixty years of age. For operations, however, upon patients about sixty years of age, whose general condition is good, the C.E.-ether sequence, administered as described on p. 483, will answer well. The best anæsthetic for routine use in old people is the C.E. mixture. Should a senile patient be alcoholic or obese, it is advisable in the course of the C.E. administration to employ ether for a minute or two during the rigid stage.

B. TEMPERAMENT AND ATTITUDE OF MIND

Patients of a **placid and equable** temperament are, as a rule, easier to anæsthetise than **excitable** and **neurotic** persons. Nitrous oxide and ethyl chloride are excellent anæsthetics for patients of the latter class, for by their means excitement—at all events during the administration—may usually be abolished. When longer anæsthesia is required, nitrous oxide may be followed by ether with the best results. Reflex actions are, for the most part, more marked and more difficult to subdue in neurotic and hysterical persons than in those of a non-excitable temperament. As pointed out by Snow, hysterical subjects may display an absence of corneal reflex even though anæsthesia be not fully established. Muscular rigidity is sometimes a troublesome phenomenon in neurotic patients; and, when very sensitive parts are being operated upon or manipulated, there is often a tendency, even during deep anæsthesia, for slight movement or some other reflex effect to manifest itself. Screaming, sobbing, and other emotional disturbances during recovery, are much more common in hysterical and nervous persons than in those of an opposite temperament. In anæsthetising sensitive and fastidious subjects considerable judgment and tact may be needed; in some cases one method will be appreciated, whilst in others another must be adopted. The very gradual administration of chloroform from the drop bottle shown in Fig. 59 (p. 402) or alternate inspirations of nitrous oxide and air may be advantageously resorted to in such cases for the induction period.

The influences of mental emotion and fear will be more particularly considered when dealing with chloroform (p. 421), under which anæsthetic such influences are most likely to be detrimental. But whatever the anæsthetic may be the effects which it produces will depend, to some extent at least, upon the patient's attitude of mind at the commencement of inhalation. Mental disquietude may affect both respiration and circulation and leave its imprint, so to speak, upon these functions after consciousness has been abolished. In some cases it would seem as if emotional disturbances are capable of throwing the whole nervous system into such a state of tension that definite insusceptibility to the anæsthetic is engendered. The author has observed this state of things in a healthy girl of nervous temperament who had had unfortunate experiences with anæsthetics on previous occasions. She was unusually distressed during slow chloroformisation, though she controlled her emotions in a remarkable degree. When anæsthetised for the operation (intra-nasal) her blood-pressure was high, and inordinate quantities of chloroform were needed to control reflex movements. This class of case differs from that in which fear and apprehension bring about a fall of blood-pressure and an indifferent colour before the administration begins. In this latter class the feeble pulse and pallor may persist throughout the administration in association with shallow breathing and eccentric ocular phenomena.

As will be pointed out when discussing preliminary narcotisation (Chap. IX.), this line of treatment is specially useful in highly nervous and apprehensive subjects.

C. HABITS OF LIFE

Patients whose nervous systems have become undermined by alcoholic indulgence, the morphine habit, the excessive use of tobacco, chloral, or other narcotics, may display abnormal symptoms during or after anæsthetisation.

The behaviour of **alcoholic subjects** under anæsthetics is generally perfectly characteristic. Large quantities of the agent employed may be required to produce the requisite degree of quietude. The author once had to administer $5\frac{1}{2}$ ounces of chloroform, in $1\frac{1}{4}$ hour, to an alcoholic man of fifty-six. It is occasionally difficult, if not impossible, to secure total muscular relaxation in patients of this class, and reflex movements during operations upon sensitive parts may obstinately persist, even though dangerously large quantities of the anæsthetic be administered. In confirmed alcoholics the stage of muscular excitement is usually prolonged, and, at all events with chloroform, there is great need for caution during the rigidity and irregular respiration (see p. 423). In certain exceptional cases nitrous oxide seems incapable of producing anything more than an analgesic state. If the gas be given without oxygen, clonic and tonic spasm come about abnormally early and cut short the administration; whilst if oxygen be mixed with nitrous oxide, the anæsthetic element may be insufficient to induce true narcosis. It is in such cases as these that ethyl chloride is often of great service, either alone or in succession to nitrous oxide. Alcoholic subjects usually recover quickly and abruptly from anæsthesia, and nausea and vomiting are rare. It is quite a common event for an alcoholic patient who has been anæsthetised for half an hour to regain coherent speech and co-ordinated movement within two or three minutes after the withdrawal of the anæsthetic, even though corneal insensibility and stertor have been present up to the very end of the administration. There are a great many people, especially fashionable ladies and business men "in the city," who drink champagne regularly and freely. Though not alcoholics in the ordinary sense, these subjects often present the usual alcoholic difficulties.

The habitual use of **morphine** may render patients comparatively insusceptible to the influence of anæsthetics,[1] although morphia injected shortly before an operation has an opposite effect (see pp. 265 *et seq.*).

[1] The late Dr. R. J. Carter kindly furnished the author with details of a case in which the patient, a morphinomaniac, showed extraordinary immunity to the effects of chloroform. An hour and three-quarters were spent in inducing anæsthesia, and eight ounces of chloroform were expended.

The excessive use of **tobacco** may lead to an irritable condition of the pharynx and larynx, and to troublesome coughing during the administration. Hesitating breathing, widely dilated pupils, and tonic or even clonic spasm over most of the body may be met with in great smokers. It is said to be a useful precaution with patients of this type to spray the fauces with a weak solution of cocaine before commencing the administration.

Some of the most difficult subjects that the author has had to anæsthetise have been heavy smokers. One man, a patient at the London Hospital, admitted smoking 1 oz. of "plug" tobacco daily. His heart-sounds were very distant and his pulse slow, but no evidence of intrathoracic disease was detected. Ether was given, but it was taken very badly, so chloroform was substituted with little or no improvement. The breathing was much embarrassed, the jaws so rigid that they could hardly be separated by the strongest gag, there was profuse secretion of (?) laryngeal and tracheal mucus, with a moist expiratory râle, and the abdomen was so rigid that the operation could hardly be performed. It was, in fact, with the greatest difficulty that anæsthesia was maintained.

The author has notes of several other cases in which somewhat similar symptoms have arisen. The chief difficulties met with are apparently due to exaggerated spasm of muscles about the floor of the mouth, jaws, and neck. It is quite conceivable that in excessive smokers these muscles may be abnormally developed, and, in consequence of this, inconvenient spasm may arise. Heavy smokers who display great insusceptibility to nitrous oxide may generally be successfully anæsthetised by ethyl chloride administered alone or in conjunction with nitrous oxide (p. 504). The difficulties which may arise in anæsthetising excessive smokers are well exemplified in Illustrative Case, No. 41*a* (Chap. XIX. p. 560).

Patients who have been **surgically anæsthetised on several previous occasions** may become less and less susceptible to the influence of anæsthetics. A tendency to vomiting at the first few inhalations, swallowing movements, and obstructed breathing, are liable to arise in such cases.

The **ether** or **chloroform habit** is sometimes acquired; but as the amount of anæsthetic inhaled on each occasion is necessarily small, no marked insusceptibility to these drugs may result.[1]

High living, more especially if associated with want of exercise, leads to obesity, plethora, and other conditions, which, as will be presently shown, are capable of modifying the effects of anæsthetics (*vide infra* and p. 154).

D. GENERAL PHYSIQUE

The **healthy, vigorous, and stalwart** subject does not pass so easily into anæsthesia as the weaker and more **fragile** patient. This would seem to be principally due to the stage of excitement being more marked, and to muscular spasm, interfering with respiration, being more pronounced than in feeble subjects. The amount of anæsthetic needed to produce narcosis will be found to vary with the general physique of the patient, the total quantity of blood within the vascular system constituting an important factor. For example, a man of six feet in robust health may require from eight to ten gallons, or possibly more, of nitrous oxide, before he is completely anæsthetised; whereas an ill-nourished young woman of short stature may exhibit all the signs of complete anæsthesia from this gas after inhaling from one to two gallons. Emaciated children need remarkably small doses of anæsthetic.

Patients with much **hair about the face**, particularly if they be edentulous, are unsatisfactory subjects for methods of anæsthetisation the success of which is dependent upon an accurate coaptation of the face-piece. This fact is exemplified, to a certain extent when employing nitrous oxide or ether; but it is often more strikingly apparent when employing nitrous oxide and oxygen or the nitrous oxide-ether sequence. In general surgical practice, indeed, such patients should, as a rule, be anæsthetised with the C.E. mixture or with the C.E.-ether sequence, and not with nitrous oxide and oxygen or with nitrous oxide and ether.

Patients who are the subjects of extreme **obesity** usually exhibit phenomena differing somewhat from those met with

[1] An interesting fatal case of the chloroform habit is recorded by Mr. Percy Court, *Lancet*, vol. ii., 18th July 1903, p. 54.

in thin and spare individuals. As a general rule they are intolerant of any anæsthetic which, by reason of the method of administration employed, limits the supply of air to any considerable extent. Ethyl chloride is not a satisfactory anæsthetic for such subjects. The C.E. mixture and chloroform are usually better borne than nitrous oxide, ether, or ethyl chloride. There are, however, certain exceptional cases amongst obese and alcoholic men in which chloroform, when administered to the full surgical degree, produces obstructed respiration, and in these a change to ether may advantageously be effected.

Patients with **large abdominal tumours** may be unable to assume the dorsal posture, and it may be necessary to anæsthetise them in the lateral, semi-recumbent, or even the sitting posture (see Illust. Case, No. 21, p. 479). Such patients generally display some degree of respiratory embarrassment during the induction stages, particularly if the dorsal posture be adopted. As in the case of obese subjects, air deprivation should be avoided as much as possible. A bulky abdominal tumour may not only lead to considerable respiratory embarrassment during anæsthetisation by limiting thoracic and diaphragmatic action, but it may also interfere with circulation. In many cases the circulatory depression which is observed is doubtless dependent upon respiratory embarrassment, but in others it may be due to the simple mechanical pressure of the tumour upon the great abdominal venous trunks. Thus, during the anæsthetisation of a healthy woman for **Cæsarian section,** the patient being in the dorsal posture and moderately deeply under chloroform, it was noticed that up to the point at which the fœtus was removed, the face remained rather pale and the pulse hardly palpable at the radial, temporal, and superior coronary arteries. Immediately, however, the fœtus had been removed the colour markedly improved, and all the arteries mentioned became properly filled with blood. Whether the freer pulmonary circulation or the removal of the pressure from the vena cava and other veins was the chief factor in the improvement it is difficult to say. Probably both factors contributed.

Patients with a **florid colour**, as well as those who are distinctly **plethoric**, require more anæsthetic than anæmic and sallow persons. The parts constituting the boundaries of the upper air-passages may, in vascular subjects, become so engorged as to lessen the capacity of those passages. This vascular turgescence and consequent swelling is most pronounced under nitrous oxide or ether, but it may also be observed under other anæsthetics, and appears to be often partly dependent upon the degree to which air-limitation is practised. The tongue of a plethoric, short-necked patient under nitrous oxide may, for example, become noticeably increased in size. The so-called "falling back of the tongue" is often partly or wholly the outcome of an increased size of that organ. Mucus and saliva are usually freely secreted during the administration of ether to young patients, more especially young women of good colour. When the face of the patient is very florid it will rapidly become dusky or cyanosed, should the air-supply be purposely or accidentally restricted. Thus, under nitrous oxide or "close" ether, red-faced patients may assume an appearance which to the onlooker may cause alarm; but moderate duskiness of the features is not of itself indicative of any dangerous condition in such cases.

Anæmic patients take anæsthetics very well, small quantities being required to secure tranquil anæsthesia. When, however, the anæmia has been induced by loss of blood, as, for example, during the progress of some uterine affection, it may happen that no unusual diminution in the quantity of anæsthetic will be distinguishable. Air-limitation should be practised as little as possible with these subjects, for they are intolerant of any asphyxial state. Nitrous oxide mixed with oxygen is hence a better anæsthetic than the former gas alone. Anæmic subjects have, in fact, a special susceptibility to pure nitrous oxide, so that the effects produced by this gas constitute, so to speak, a test for anæmia. Epileptiform movements coming on very early in a nitrous oxide administration generally indicate anæmia. The most marked illustration of this fact which has come under the author's observation occurred in the case of a lady who was the subject of pernicious anæmia. Epileptiform movements arose after three respirations of pure nitrous oxide, and air had then to be admitted to check the convulsive phenomena. In cachectic and very feeble persons undergoing rather formidable operations it is usually best to secure a fairly deep anæsthesia for the *commencement* of the operation, and then to allow the patient to pass into a condition of light anæsthesia for the *remainder* of the time. The influence of chloroform upon anæmic patients has been carefully investigated by R. T. Sutherland.[1] This observer concludes that anæmia of any kind contra-indicates chloroform, and that ether should be given instead. He finds that the danger of chloroformisation is greatest in the anæmic, and in proportion to their degree of anæmia. The cause of this is probably the state of chronic malnutrition and oxygen starvation of the anæmic tissues, whereby the toxicity of chloroform is ill-resisted. The heart and the cells of the nervous system are thus rendered especially vulnerable. It has been shown that the red cells carry most of the chloroform in the circulating blood,[2] so that the total quantity of chloroform in the circulation can hardly be itself excessive.

The so-called "Status Lymphaticus."—The terms **status lymphaticus, status thymicus,** and **lymphatism** are used to denote a condition which in extreme cases having a fatal issue is characterised by the following pathological changes. Undue persistence or enlargement of the thymus gland; hyperplasia of the lymphatic glands, especially the mesenteric, retro-peritoneal, and cervical, and of lymphoid tissue in general, such as that of Peyer's patches, and of the follicles at the base of the tongue; enlargement of the tonsils, faucial and pharyngeal; enlargement of the spleen; hypoplasia of the aorta; and degeneration of the heart-muscle.[3] To these some observers add[4] enlargement of the liver, enlargement of the circumvallate papillæ of the tongue, and dilatation of the pupils. Hyperplasia of the bone marrow and thyroid enlargement are also described.

The ætiology of this syndrome is quite obscure: by some it is regarded as a developmental error, or series of errors;

[1] *Intercolonial Medical Journal of Australasia,* 20th Jan. 1909.
[2] See p. 113.
[3] W. J. McCardie, *Lancet,* 21st Dec. 1907, ii. 1763.
[4] R. E. Humphry, *ibid.*, 9th Jan. 1909.

others regard the condition as more probably due to toxæmia or to infection. On this point, which is a problem for clinicians and pathologists rather than anæsthetists, any definite decision at present is premature. As to the frequency of status lymphaticus opinions vary. The milder forms, which do not end fatally, and are recovered from, though seldom discovered, may be less rare than is generally supposed. But the fully developed typical form is considered by most authorities to be extremely rare. Some authors, however, hold different views: thus six fatal cases in two and a half years are described by one observer,[1] and fifteen cases are mentioned by another.[2] It has been found at all ages; in a series of thirty collected [3] cases the average age was sixteen years, the youngest six months, and the oldest fifty-five years. The incidence upon the two sexes is the same.

The symptoms by which this symptom-complex may be recognised during life are unfortunately vague and easily overlooked. Enlarged glands are usually most prominent in the neck and abdomen, but may also be present in the axillæ and groins. Enlargement of the thymus is very difficult to detect with any certainty, though theoretically it causes dulness to percussion of the manubrium sterni. It has however been maintained that a pushing downwards of the upper border of the superficial cardiac dulness is, in the absence of any other obvious reason for it, the surest sign of thymic enlargement. Thyroid enlargement is, in conjunction with lymphatic hyperplasia, an important sign. The spleen is seldom actually palpable clinically. The presence of adenoids and of enlarged tonsils is too common in patients generally to be allowed much weight in forming a diagnosis. The heart sounds are said to be often muffled and distant, and the pulse weak, soft, and ill-sustained. Anæmia with lymphocytosis is the rule: indeed Paltauf, who in 1889 first gave a full description of the status lymphaticus, called it the "lymphatico-chlorotic constitution." Lymphatic subjects are said to be especially liable to infections; and resemblances have been traced between lymphatism and myasthenia gravis.

[1] R. E. Humphry, *Lancet*, 9th Jan. 1909.
[2] D. J. Munro, *ibid.*, 4th Dec. 1907, p. 1703.
[3] McCardie, *loc. cit.*

Notwithstanding this list of definite signs, the status lymphaticus is seldom diagnosed before death, which occurs as a rule suddenly, and primarily from acute cardiac failure. Numerous instances are now on record of sudden death for no apparent reason, where a post-mortem examination has shown the signs of lymphatism and nothing more. Apart from anæsthesia, it would seem that in genuine cases of this symptom-complex, very slight and even trivial circumstances may excite a fatal issue; as for instance sitting up in bed, bathing, etc. But why such actions, part of every-day life, should determine a fatality at one moment rather than another remains mysterious.

Anæsthesia is said to be particularly dangerous to the subjects of the status lymphaticus; for in the majority of the cases reported during the last five years, the administration of an anæsthetic is believed to have precipitated death. Many authorities go so far, indeed, as to assert that normal anæsthesia, free from all suspicion of overdose, asphyxia, or other complication, may cause sudden death in those affected by lymphatism. Admitting all this, there is, nevertheless, little doubt that a great many of the disasters during anæsthesia which have been ascribed to the status lymphaticus have been susceptible of explanation on other grounds; and that the status lymphaticus has been asserted to exist in many of these cases on quite inadequate evidence. On this account some authorities are highly sceptical concerning deaths ascribed to this cause. There is, however, as little to be said for such scepticism as there is for attributing every death during anæsthesia to the rare syndrome of lymphatism. Several of the lesions which constitute the clinical picture of lymphatism may easily contribute to difficulties in anæsthetisation. Enlargement of the thymus, the thyroid, and the mediastinal lymph nodes may possibly compress the trachea or bronchi and thus introduce an asphyxial element. Anæmia itself renders the patient more susceptible to the action of anæsthetics; and cardiac degeneration, in association with hypoplasia of the arteries, may possibly also render him a less favourable subject for anæsthesia. Finally, the important influence of the presence of adenoids and enlarged tonsils must not be omitted. It need hardly be pointed out that patients thus affected are particularly liable to respiratory difficulties, and that such difficulties may come about so insidiously that their true nature may readily be overlooked.

Many of the recorded fatalities have occurred during very light anæsthesia, and hence it has been supposed that the operative procedure has been the actual cause of the catastrophe. But in several of the reported cases death took place during the induction, or before the beginning of the operation; so that it is clear that the latter is not the only factor to be considered. As a general rule chloroform has been the anæsthetic employed; but nitrous oxide, ethyl chloride, and ether have all been followed by calamity. In McCardie's 30 cases there were 17 of chloroform, 5 of chloroform and ether mixed, 6 of ether, and 2 of nitrous oxide.

Operations of all sorts should not lightly be undertaken upon the subjects of this disorder. Spinal anæsthesia has been followed by death in this condition, and is not preferable to general anæsthesia. When a general anæsthetic is to be administered, "gas and oxygen" may be used; or ether by the "open" method may be employed. If chloroform or any mixture containing it must be given, a preliminary hypodermic injection of atropine may be administered. In any case the induction and maintenance of anæsthesia must be attended to with extraordinary caution and vigilance. The presence of explicit signs of lymphatism need not absolutely contra-indicate anæsthesia. Thus a case is related[1] in which narcosis was induced in spite of the diagnosis of status lymphaticus, and quite successfully. A few weeks later the patient, when convalescent, died suddenly from some trivial cause, thus demonstrating the correctness of the diagnosis. As in other morbid conditions, early and accurate diagnosis is the best guarantee of success in dealing with the status lymphaticus. In conclusion it may be said that it is still open to question whether the risk of general anæsthesia in patients suffering from lymphatism is anything more than the risk of auto-asphyxia, which risk, owing to the

[1] *Brit. Med. Journ.*, 8th Jan. 1910, p. 103.

pathological conditions present, is obviously greater than in other subjects.

E. THE RESPIRATORY SYSTEM

The State of the Upper Air-Passages.—This is one of the most important of the numerous factors which are capable of determining the effects produced by general anæsthetics. Certain symptoms during anæsthetisation will be found to be dependent upon the manner in which the **teeth** of the lower jaw engage those of the upper. Patients with powerful jaws and irregular and interdigitating teeth, as well as those with perfect teeth which meet accurately, will be liable to exhibit a greater tendency to hampered breathing than patients with feeble jaw muscles and teeth which do not tend to interlock. Moreover, when the upper and lower teeth engage one another in such a manner as to render it difficult to push the lower jaw forwards upon the upper, some embarrassment in breathing may arise. Difficulties are also not uncommon in anæsthetising patients with ill-developed and receding lower jaws; whilst those with high, arched palates almost invariably display some degree of respiratory embarrassment, particularly during the use of "close" methods.

Should the patient be wholly **edentulous** it may be necessary to keep the gums and lips apart, in order to maintain respiration. Such patients are not only difficult through contact of the lips and gums; but also because the base of the tongue may occlude the glottis. The anæsthetist may easily be deceived as to breathing taking place, unless he be particularly on the alert. Doyen's gag (Fig. 10, p. 188) is usually the best appliance for keeping the gums and lips apart; but even with this in position it may be necessary to sponge out the fauces at intervals, to keep up tongue traction, or to use Longhurst's tongue retractor continuously.

Fixity or lessened mobility of the lower jaw, from disease of its articulations (see Illust. Case, No. 44, p. 564), from local inflammatory conditions, or from the presence in the submaxillary or cervical regions of glandular or other tumours (see Illust. Case, No. 45. p. 565), is particularly liable to give rise to asphyxial difficulties.[1]

If the nasal air-way be free, breathing will usually take place either partly or wholly through it when the patient is unconscious. If it be more or less obstructed, even by ordinary catarrh, the anæsthetist should insert a small prop between the teeth before the use of any "close" method. In patients with complete nasal obstruction special care must be exercised. Mouth-props should be inserted roller-wise (Fig. 68). It must be remembered that although this precaution generally allows of free oral respiration it does not necessarily ensure it, for the tongue may persistently remain in contact with the palate. The presence of a mouth-prop, however, allows of the mouth being quickly opened at any moment, and of the introduction of the "oral air-way" (Fig. 20, p. 258) if necessary.

Patients suffering from **nasal or naso-pharyngeal catarrh** are liable to retch or vomit even during apparently well-established anæsthesia. The author believes this to be owing to the presence within the stomach of swallowed mucus. Similarly, after-vomiting is common in patients, especially children, with naso-pharyngeal affections attended by much mucous secretion. Sometimes the presence of mucus within and above the larynx, as in children with adenoid growths, may bring about an eccentric form of anæsthesia, characterised by stridor, rigidity, curious movements of the arms, hands, and fingers (pp. 74 and 416), and dilatation of pupils. Such phenomena may be met with during the induction stage and may be very disconcerting to the anæsthetist. They appear to be of reflex origin dependent upon the presence of mucus, and though the cornea may be insensitive to touch during their incidence, there may be considerable reflex response if a cutaneous incision be made. It must be borne in mind that mucous secretion under anæsthetics is often extraordinarily viscid and "stringy," and is therefore likely to constitute a formidable obstacle to breathing if present above or within the larnyx.

[1] See an interesting case (*Lancet*, 8th April 1899, p. 959), in which nitrous oxide caused fatal asphyxia.

Morbid growths of the tongue, soft palate, tonsils, pharynx, epiglottis, and adjacent parts may, from vascular turgescence or alteration in position, interfere with free respiration during anæsthesia. Any deprivation of oxygen is especially liable to lead to this increase in size. Muscular spasm about the neck and jaws, such, for example, as that which often accompanies the use of pure nitrous oxide or ethyl chloride, may readily lead to respiratory arrest in these subjects. Both these anæsthetics, indeed, are contra-indicated when any marked narrowing of the upper air-passages is present. Patients with enlarged tonsils will be found to take nitrous oxide with oxygen far better than nitrous oxide administered in the ordinary manner, *i.e.* without any oxygen. With the former system respiration at most becomes snoring; whereas, when nitrous oxide free from oxygen is fully administered to a patient with very large tonsils, embarrassed and obstructed respiration (usually only temporary) will result. But even with non-asphyxial methods, difficulties from enlarged tonsils are likely to occur. Mr. Bellamy Gardner has found the lateral or semi-prone posture advantageous in cases of extreme enlargement. Again, glandular, lipomatous, and other tumours of the neck, including thyroid growths, may, during vascular engorgment, lessen the capacity of the air-way, and thus favour obstructed breathing. Should the patient whose air-way has become narrowed suffer from even occasional or slight difficulty in breathing, the advisability of preliminary tracheotomy should be discussed.

When **dyspnœa from laryngeal disease, narrowing of the trachea, or similar conditions** is present, great care must be exercised.[1] Chloroform has hitherto been the best available general anæsthetic for these cases; but ether by the intravenous system (p. 357) may possibly supplant it in the future. Patients with slight narrowing of the air-tract generally tolerate the anæsthetic state remarkably well; but when the dyspnœa is considerable, the patient somewhat cyanosed and unable to lie down, and sleep hardly possible, the risks of giving a general anæsthetic are great. The extraordinary

[1] Mr. Bellamy Gardner, in an interesting paper (*Lancet*, 11th June 1898), has discussed the use of anæsthetics in patients with laryngeal paralyses and morbid growths.

muscles of respiration upon which the patient has become dependent are thrown out of action during unconsciousness, the result being that respiration is left to the care of muscles which are incapable of overcoming the difficulties present. In this way respiratory arrest may readily arise even though the corneal reflex be brisk. In anæsthetising patients with laryngeal affections, a careful consideration of the precise nature of the disease is essential. In cases of abductor paralysis, for example, it may be necessary to keep the chin forcibly pulled away from the sternum throughout the administration, otherwise dangerous approximation of the lax cords may result. The use of anæsthetics during operations for papilloma of the larynx will be discussed in the following chapter.

There are, perhaps, no cases demanding greater care and experience on the part of the anæsthetist than those in which extensive **cellulitis of the submaxillary and cervical regions** is present (**Angina Ludovici**). When this inflammatory state attacks an obese, or thick-necked and muscular man, when the infiltration of the cellular tissues is so extensive that the outline of the lower jaw is lost, and when, as is not uncommon, the patient's habits, as regards alcohol and tobacco, are intemperate, no worse subject for a general anæsthetic exists. If there be no other course than to induce general anæsthesia, the lateral posture should be chosen, a closed Mason's gag introduced between the teeth, the C.E. mixture slowly given, to partial anæsthesia, the tongue forceps applied if necessary, and every provision made for immediate laryngotomy or tracheotomy should breathing become seriously embarrassed. Nitrous oxide, "close" ether, and ethyl chloride are all strongly contra-indicated in these cases (see Illust. Case, No. 20, p. 478 and footnote thereto). **Lymphadenoma** is another condition in which unsuspected tracheal compression by enlarged glands may occur and cause grave complications during anæsthesia.

Bronchial, Pulmonary, and Pleural Diseases.—So far as the use of anæsthetics is concerned, old-standing lung or pleural affections are of less importance than those more recently acquired. In the former the respiratory mechanism has, by constant use, become adapted to circumstances; whilst in the latter such adaptation is in process of establishment. Patients with **chronic bronchitis, marked emphysema, chronic phthisis, old pleural disease**, and similar conditions take anæsthetics well when care is exercised and the most appropriate agent administered. Speaking generally, ether by closed methods should be avoided in cases of this group. Its use is not only likely to be attended by strained and difficult expiration with cyanosis, but to be followed by an aggravation of the respiratory affection. C.E. mixture or the C.E.-chloroform sequence usually gives good results in chronic cases; and "open ether" preceded by atropine is also often very successful. It is hardly necessary to point out that the greater the embarrassment to respiration, the lighter should be the anæsthesia, and the more careful should the administrator be to allow a free supply of air and to prevent all conditions likely to impede breathing. It is a fortunate circumstance that patients with respiratory affections are, as a rule, singularly free from those inconvenient reflex manifestations which generally attend a light form of anæsthesia. Should the bronchial, pulmonary, or pleural affection under which the patient is labouring be of recent origin and of sufficient intensity to cause distress in breathing, much caution must be exercised and a deep anæsthesia studiously avoided. The most hazardous cases are those in which respiratory embarrassment from **recent pleurisy or pleuro-pneumonia** coexists with quick and hampered cardiac action. When the patient is dusky, his temperature elevated, his breathing rapid, and his pulse quickened, the use of any general anæsthetic is attended by considerable risk. The risk is greater in patients with fatty and dilated hearts than in others. Numerous deaths have, in fact, occurred in such subjects from syncope during or immediately after transient struggling. It is in such cases as these, in which the risk is from the cardiac side, that the author finds it best to employ "open ether." He therefore uses the C.E.-ether sequence, applying the ether *before* the rigid stage and maintaining only a light anæsthesia.

Nitrous oxide may be safely used in persons with chronic lung affections, but it should not be pushed quite so far as in healthier subjects. When mixed with oxygen the anæsthesia is of a much more satisfactory nature than when the pure gas is given.

In certain desperate cases in which respiratory embarrassment, with more or less cyanosis, is associated with cardiac disease or with marked depression of the circulation arising from other causes, it is advisable to administer **oxygen** in conjunction with the anæsthetic, care being taken to introduce this gas to the lungs in such a way as to throw no additional work upon the muscular mechanism of breathing (see Fig. 45, p. 346).[1]

Wholly Thoracic or wholly Abdominal Respiration.—There are various conditions which may give rise to wholly thoracic or wholly abdominal respiration. The former is most frequently met with as the result of peritonitis, or of extreme abdominal distension from intestinal obstruction, ascites, ovarian disease, etc. The latter is most commonly due to advanced emphysema or other affections of the lungs or pleuræ. Should the breathing be wholly thoracic[2] or wholly abdominal, the administrator will, of course, meet with more exaggerated respiratory movement than usual. If a patient, from some acute condition, be obliged to use his thorax or abdomen only, and if the new form of respiration be somewhat difficult for him to acquire by reason of pre-existing conditions, such as emphysema or obesity, anæsthetics must be used with great caution. When the **abdomen** is **greatly distended** from ascitic fluid, only a light anæsthesia is necessary during its removal (see Illust. Case, No 21, p. 479), and the administrator will find that both respiration and circulation will markedly improve as the fluid is evacuated and the lungs become able to expand more freely. Reference has already been made (p. 153) to the anæsthetisation of patients with large abdominal tumours.

[1] The arrangement of apparatus in Fig. 45 is quite as applicable for chloroform and oxygen or for the C.E. mixture and oxygen as for ether and oxygen.

[2] In a case reported by the author in the *Lancet*, 19th March 1896, p. 772, the diaphragmatic paralysis which was present was probably due to peripheral neuritis (see Illust. Case, No. 15, p. 380).

F. THE CIRCULATORY SYSTEM

Of the numerous misconceptions which still exist concerning the effects of general anæsthetics, that of gauging the risk of anæsthesia by the state of the patient's circulation is perhaps the most conspicuous. It is often erroneously supposed that the possession of a vigorous vascular system affords a guarantee of safety, but that the existence of organic cardiac disease or of a so-called weak heart almost contra-indicates surgical anæsthesia. As a matter of fact, a precisely opposite view more nearly approaches the truth. With the most vigorous type of circulation there is usually associated a vigorous physique, and, as we have already seen, powerfully built subjects are often difficult to anæsthetise, and not unfrequently give considerable trouble or even anxiety to the anæsthetist. On the other hand, patients with organic or functional circulatory derangements usually possess comparatively feeble muscular systems and pass into deep anæsthesia with little or no excitement or difficulty. At the same time, there are of course many cases in which, by reason of the state of the circulation, special lines of treatment are indicated, and unless such lines be followed, serious consequences directly dependent upon the cardio-vascular conditions may result. Other things being equal, the more vigorous and adaptable the circulation, the better will it be able to withstand any strain, asphyxial or otherwise, to which it may be subjected during anæsthesia.

The circulation may be of the most efficient type; or it may be so feeble as to render it questionable whether any operation should be performed. The pulse may be so rapid that it can hardly be counted, or it may be abnormally slow.

Abnormally **rapid cardiac action (tachycardia)** is most frequently due to nervousness. When this is the cause of the quickening a considerable slowing will invariably occur during anæsthesia; but when the rapid pulse is due to shock or exhaustion, an increase in rate will usually take place (see Illust. Case, No. 74, p. 614). In a patient with Graves's disease to whom the author administered chloroform after ether, the tachycardia was practically unaffected during anæsthesia, the pulse rate during an operation lasting an hour and a half being about 180 per minute. Patients suffering from actual **Graves' disease (exophthalmic goitre)** require special care and management. Nitrous oxide and oxygen may be safely administered for minor operations; but chloroform and chloroform mixtures must be used with great caution. Speaking generally, atropine, with or without morphine according to circumstances, is advantageous as a preliminary to anæsthesia. Should no respiratory embarrassment be present, the chloroform-C.E.-ether sequence (p. 489) may be employed. If the state of the patient or the particular operation to be performed indicate chloroform or a chloroform mixture, it will generally be found possible to substitute ether on an open mask temporarily during the latter part of the induction process. In some cases oxygen may be advantageously administered with the anæsthetic. If the contemplated operation be upon the actual thyroid gland itself, the further considerations detailed on p. 201 must be taken into account.

Patients with an **abnormally slow pulse (bradycardia)**, especially middle-aged and elderly persons, may display, during deep chloroform anæsthesia, a somewhat disconcerting degree of circulatory depression together with halting Cheyne-Stokes, or even arrested breathing (see p. 587).

Valvular and other Cardiac Affections.—Patients with these affections may be anæsthetised with safety if care be taken to select the anæsthetic most appropriate to the case, and to administer it in such a manner that no undue strain is thrown upon the heart. When the cardiac affection is but slight, and, by reason of compensatory changes, the general circulation is good, little or no alteration need be made in the anæsthetist's usual practice. There are one or two points, however, which should be borne in mind in dealing with **advanced cases.** Unless orthopnœa exist, the recumbent posture should be enforced; no marked or prolonged deprivation of oxygen permitted; and any interference with respiratory rhythm prevented. The anæsthesia of nitrous oxide followed by ether is not to be recommended in these cases. A well-marked instance of the ill effect of employing a "close" and asphyxiating method of administration in a patient with mitral obstruction and aortic regurgitation occurred at the London Hospital in 1897; cardiac rapidity and irregularity, with dusky pallor of the face and failing pulse, were observed after a short inhalation of ether by means of Clover's inhaler. Dr. Guthrie records the case of a fat baby, five months old, with congenital pulmonary stenosis, in whom chloroform caused early cessation of breathing, with cyanosis, and finally pallor. All methods should be gradually conducted, and the slightest respiratory embarrassment assiduously avoided. Speaking generally, the C.E. mixture is an excellent anæsthetic for patients with advanced morbus cordis (see Illust. Cases, Nos. 23 and 24, pp. 480 and 481). Ether (preceded by a small quantity of the C.E. mixture to prevent its disagreeable odour) may be used in cases in which **orthopnœa** is present, and only a short unconsciousness is required (p. 479). By the gradual administration of the C.E. mixture to a patient with an intermittent or irregular pulse, the heart's action generally becomes steadier, and remains so for a considerable time. The anæsthetist must not, however, shut his eyes to the fact that after the withdrawal of the anæsthetic, or during a serious operation, this improvement may, and often does become replaced by irregularity and feebleness in excess of the original condition.

The remarks here made with regard to valvular cardiac affections apply with equal force to cases in which **fatty or other degenerative changes** are present in the myocardium. Provided that the respiration be kept free from embarrassment and that a deep anæsthesia be avoided, the "fatty heart" is not injuriously affected by anæsthetics. Any asphyxial strain, however, may quickly impair its action and lead to syncope (p. 41). Moreover, surgical shock is more likely to assume grave proportions in cases of advanced cardiac degeneration than in others.

For patients with **pericarditis**, who are very ill, with quick feeble pulse, the C.E. mixture given only to moderate anæsthesia answers well. The pulse may be observed to improve when a distended pericardium is incised and the fluid removed.

Atheroma.—In extremely atheromatous subjects there is a slight risk [1] of cerebral hæmorrhage during anæsthesia. This

[1] See *Canadian Med. and Surg. Journ.*, March 1888, p. 309.

risk may, however, be minimised by selecting the C.E. mixture or chloroform in preference to ether; and by avoiding, as far as possible, excitement, holding of breath, coughing, and struggling during the administration. The morphine-atropine-C.E. sequence is generally indicated for these cases. Some years ago a man of sixty-two died at the London Hospital from cerebral hæmorrhage, which took place while he was under the influence of ether. The operation was a short one; Clover's inhaler was used, and there was but little struggling. The man never became thoroughly conscious after the operation, was hemiplegic, and died in a few days. From Glasgow two such cases are reported within two months.[1] One was that of a man being anæsthetised for the third instalment of some extensive skin grafting. Death took place under the anæsthetic (chloroform) and was shown at autopsy to have been due to extensive cerebral hæmorrhage. There were excitement and violent struggling during the induction stage, and these are thought to have caused the rupture of an artery. The other patient was a woman, anæsthetised with chloroform for an exploratory laparotomy. Preparation of the abdominal skin was begun before consciousness had quite disappeared, and this caused straining and holding the breath. After two drachms of the anæsthetic had been given, respiration ceased and cyanosis developed. After artificial respiration for seven minutes, an attempt was made to continue with "open ether," but the same symptoms supervened. The patient was sent back to bed, but cerebration was slow, and three days later hemiplegia with unconsciousness set in. Eventually the patient went home, still hemiplegic.

Should arterial degeneration have led to the formation of an **aneurysm**, the same caution as to the avoidance of struggling, straining, coughing, etc., must be exercised. It is true that ether has very frequently been given to patients with large aneurysms without rupture having occurred; but when there is any evidence of rapid increase in size, and more particularly when the aneurysm is intrathoracic, the C.E. mixture or chloroform (preceded by morphine and atropine) should be used in preference to ether.

[1] H. P. Fairlie, *Lancet*, 12th Nov. 1910, p. 1415.

Venous Thrombosis.—Patients with venous thrombosis must be carefully treated. They should be moved as little as possible, and special precautions should be taken to avoid struggling and excitement. An interesting case, in which fatal syncope arose under ether in consequence of a clot from the common iliac vein becoming dislodged and entangled in the tricuspid orifice, is given on p. 595. An almost identical case is reported[1] from abroad, the patient, who was suffering from long-standing suppuration, having died during the first few inhalations of chloroform. It is by no means improbable that some of the sudden deaths which have occurred under anæsthetics, and which have been ascribed to their action, have in reality arisen from cardiac or pulmonary embolism. For such patients the morphine-atropine-ether, or morphine-atropine-C.E. method is particularly useful.

Exhaustion: Shock: Collapse.—One is often called upon, more particularly in hospital practice, to anæsthetise patients whose circulation has become much enfeebled, either from some long-standing disease or from some recently acquired but prostrating malady. As illustrations may be mentioned—cases of suppurating hip disease in children, cases of advanced stricture of the pylorus, cases of strangulated hernia, and cases of collapse from railway or other injuries. Such patients are very susceptible to anæsthetics, small quantities only being necessary to induce and maintain anæsthesia. As a general rule, the pulse of the exhausted patient improves in volume when anæsthesia is established; but, when the anæsthetic is withdrawn, some depression of the circulation may follow. Moreover, this initial improvement does not, as a rule, last long; and any loss of blood, prolonged exposure, or severe surgical procedure will soon give rise to signs of circulatory depression. The administrator must do all in his power to sustain the strength of his patient. If the heart's action be very feeble, no method of administration should be employed by which the supply of air is greatly restricted, and all mechanical or other hindrances to free respiration must be avoided. Ether is, as a rule, the best anæsthetic and should be administered by the so-called "open method." The

[1] *Brit. Med. Journ.*, 31st March 1906 (p. 46 of epitome).

administration of nitrous oxide should be avoided in these cases. Exhausted and collapsed subjects are liable to display a peculiar state of the eyes during anæsthesia, and more particularly during deep anæsthesia, the lids failing to close and the globes turning upwards so that the sclerotics only are visible. Profuse sweating is also common in these subjects, and is another indication of exhaustion. The administrator must be on his guard with reference to the rosy cheeks of **hectic subjects** and of those artificially stimulated by alcohol or opium. This florid colour may co-exist with a circulation totally unable to withstand any very prolonged surgical interference (see Illust. Case, No. 74, p. 614). It is in cases of this group that the preliminary injection of atropine (with or without morphine, according to circumstances), the envelopment of the body in cotton wool, the employment of a water-warmed operating table, and the use of continuous saline infusion during the operation are specially indicated.

Cases of **intestinal obstruction** are, perhaps, appropriately referred to under this heading, seeing that syncope of the worst type may occur during anæsthesia. The abdomen is usually distended, and the diaphragm unable to act efficiently; the stomach frequently contains fluid or semi-fluid material; the patient is, in many instances, partly under the influence of an opiate; and the circulation, though often artificially stimulated by alcohol, may be unable to withstand any strain. When vomiting is frequent, the abdomen distended and inactive, the pulse quick and feeble, the extremities clammy and dusky, the features pinched and the lids half open, general anæsthesia will be hazardous. "Open ether," with oxygen if necessary, is the anæsthetic of choice for such patients. Many authorities regard it as good practice to wash out the stomach before the surgeon is allowed to begin the operation, and again at the conclusion of the latter. It is in such cases as these that the advantages of local or spinal over general anæsthesia (pp. 517 and 524) become of considerable importance. In less advanced cases an anæsthetic may generally be safely given. For further remarks the reader is referred to pp. 208 and 213, and to Illust. Case, No. 22 (p. 480).

G. THE NERVOUS SYSTEM

Should the patient be **drowsy** or **half-conscious** at the time of operation, very small quantities of the anæsthetic will be needed. When well-established **coma** is present, the services of an anæsthetist will not, of course, be required. The subjects of **depressed fracture of the skull, intracranial hæmorrhage, cerebral abscess, or cerebral tumour** may, at the time of operation, be so lethargic that a few inhalations of the anæsthetic will readily produce the quietude desired. It must be remembered that patients with cerebral or cerebellar tumours may, apart from the use of anæsthetics, display symptoms of primary respiratory failure from increased intracranial tension; and when any tendency in this direction exists, the induction of even light anæsthesia may completely suspend breathing.[1] These patients are most susceptible to the very slightest air limitation, and to small variations in the strength of the vapour offered them. Induction is best accomplished with chloroform in a regulating inhaler such as the Vernon Harcourt, or Dubois; but if such an instrument be not available this anæsthetic must be cautiously administered, drop by drop, from a Skinner's mask. When the various arm- and head-rests, sandbags, and other surgical arrangements are complete, the anæsthetist may find the patient's head in a very awkward position for the administration. In spinal cases (laminectomy and others) it is sometimes a help to let down the head of the table altogether and support the patient's head on a towel spread on one's lap. In cerebral cases the anæsthetist will often find his patient's face and his own hands buried in sterilised towels; in such an event a Vernon Harcourt inhaler provided with a long tube connecting the face-piece with the chloroform chamber is now generally used. Anæsthesia must be maintained at the lowest pitch consistent with the performance of the operation; a slight amount of phonation or reflex movement is no great detriment.[2]

Patients whose perceptive faculties have become blunted

[1] The author has related a case of this kind (*Practitioner*, 1887, vol. xxxix. p. 93), and Dr. E. T. Fison of Salisbury (*Lancet*, 4th August, 1900, p. 329) records another. In both artificial respiration was maintained for four hours.

[2] See also Sir V. Horsley, *Brit. Med. Journ.*, 25th August, 1906, p. 411.

by the absorption of poisonous products during the course of intestinal, vesical, renal, or similar affections, often pass into anæsthesia with a marked absence of excitement and rigidity; and display a florid colour and good pulse throughout the administration, provided that the corneal reflex be not completely abolished. Very deep anæsthesia is unnecessary in such cases. The author has often been struck by the fact that patients of this kind behave in much the same way as if a preliminary injection of morphine had been given.

Patients who are the subjects of chronic nervous affections may exhibit peculiar respiratory phenomena during anæsthesia. Thus, the author has notes of two cases—one patient had **disseminated sclerosis**, and the other advanced **tabes dorsalis**—in which, during the use of an anæsthetic (ether), breathing was jerky, catchy, halting, and split up, as it were, by long pauses. In the ataxic patient some degree of laryngeal obstruction, with prolonged expirations, was noted, and caused some trouble.[1]

The subjects of **epilepsy** may be safely anæsthetised. In some cases a more or less distinct attack occurs during the exhibition of the anæsthetic. The author has, on one or two occasions, noticed in these subjects a greater tendency than usual to tonic and clonic spasm during the administration of nitrous oxide.[2] In only one case has the author known a distinct and characteristic epileptic seizure to arise, and in this the attack began after a few breaths of the gas, *i.e.* before the occurrence of the usual asphyxial phenomena.

The administration of anæsthetics to patients with a history of previous **insanity** is liable to be followed by a fresh attack. According to Sir George Savage,[3] patients subject to recurrent seizures of mental disorder are particularly liable to be thus affected. There is, apparently, no special objection to anæsthetising patients already insane, except, of course, in the case of maniacal subjects. The author has met with one or

[1] A similar case is recorded by Dr. Lamb (*Lancet*, 16th May 1903).

[2] The late Mr. Woodhouse Braine believed (*Med. Soc. Proc.* vol. viii., 1885, p. 64) that there is greater risk of an epileptic attack being brought about by tooth extraction without an anæsthetic than when one is used.

[3] See an interesting and important paper by Sir George Savage—"The Relationship between the Use of Anæsthetics and Insanity" (*Lancet*, 11th November 1899).

two cases of exaggerated excitement in patients with a family history of insanity.

Lastly, cases occasionally, though rarely, present themselves, in which, owing to **some peculiarities in the nervous system,** of whose nature we are ignorant, the induction and recovery period are characterised by violent struggling or maniacal excitement. The author has on more than one occasion met with these eccentric states in members of the same family. Certain patients behave as if they had drunk freely, although no evidence can be obtained of alcoholism. The so-called "neurotic" subjects, and those whose nervous systems are peculiarly unstable or hypersensitive, seem to be most liable to these uncontrollable outbreaks. The treatment most likely to be successful in such cases is the administration, some hours before the anæsthetic, of sedatives, such as potassium bromide and chloral (see Illust. Case, No. 32, p. 538).

H. RENAL DISEASE

Opinions are still divided as to the choice of anæsthetics in patients suffering from renal disease. The fact that very contradictory results have been arrived at by observers who have investigated the relative influences of ether and chloroform upon the urinary functions would seem to indicate that there is not that objection to the use of ether that was formerly held to exist. At the same time, it is obviously important, when anæsthetising patients with advanced forms of kidney disease, to employ methods which will throw as little strain as possible upon the circulatory and respiratory functions. The C.E. mixture and ether, given by "open" methods, may both be regarded as suitable for these cases. The liability of such patients to respiratory complications should be specially borne in mind. For further remarks see pp. 75, 96, 123, 383, and 440.

I. DIABETES MELLITUS

The presence of diabetes in a patient about to be anæsthetised must always be regarded with some degree of anxiety. Numerous cases, indeed, have been recorded in which fatal **diabetic coma** has been initiated by anæsthetisation. Unfortunately our knowledge as to the rôle played by the anæsthetic in such cases is very inadequate. Some observers believe that the presence of **acetone** in the urine of a diabetic patient renders that patient particularly liable to fatal coma. This view has been urged by Becker,[1] who has reported three fatalities after anæsthesia in patients whose urine contained acetone at the time of operation. Becker also found records of twelve other fatalities after anæsthesia in diabetic subjects. Gerhardt and others state that the urine and blood of diabetics frequently contain, in addition to acetone, both diacetic acid and β-oxybutyric acid. We know that the administration of ether or chloroform occasionally brings about a state of acid-intoxication characterised by the presence of these three substances within the blood (p. 634), and the administration of an anæsthetic to a diabetic patient whose blood already contains these bodies may induce fatal coma. There would seem to be a distinct connection between the condition of "post-anæsthetic toxæmia" and the coma which is liable to follow the administration of an anæsthetic to a diabetic subject.

The late Dr. Pavy, whose contributions to the subject of diabetes are so well known, very kindly furnished the author with his views as to the influence of anæsthetics upon patients suffering from this affection. In cases "under control," in which sugar is at the time either absent from the urine or present only to a slight extent, he thought that general anæsthesia is unattended by risk. But when the quantity of sugar in transit through the system is abnormally large, any profound disturbance of the vital processes, such as that attendant upon the use of an anæsthetic, especially for a protracted operation, may upset the balance, and lead to fatal diabetic coma.

With the above considerations before us it is clear that in the event of a diabetic patient requiring a surgical operation—(1) special attention should be paid to the diet for some time before the administration, with the object of reducing the quantity of sugar in the circulation; (2) free purgation and

[1] For these references to Becker and Gerhardt I am indebted to Dr. J. A. Kelly, of New York. See *Annals of Surgery*, February 1905, p. 171, "Acid Intoxication: its Significance in Surgical Conditions."

skin action should be obtained before anæsthetisation; (3) the anæsthetic should be very carefully chosen in order that the general after-effects may be reduced as far as possible; and (4) the anæsthesia should be as short as is compatible with the needs of the surgeon, and no more of the anæsthetic given than is necessary for the particular operation in hand. According to recent observations, the presence of diacetic acid in the urine would seem to indicate the selection of ether in preference to chloroform.

Although the author has not himself met with a case of diabetic coma after anæsthesia, he has been given brief notes of such a case. The patient suffered from diabetic boils, several of which had been incised without the employment of an anæsthetic. At 9.30 one morning, ether, preceded by nitrous oxide, was administered for further incisions; but the patient never recovered consciousness, and died at 4 P.M. the same day.[1] The author was, however, consulted some time ago as to the desirability of general anæsthesia in a patient at St. George's Hospital who was suffering from diabetic gangrene. It was proposed to amputate the leg. The risks of anæsthesia were explained to the patient and he decided to incur them. Anæsthesia was skilfully conducted but the patient died of coma. In such cases as these there is probably less risk in spinal than in general anæsthesia, and in the light of recent knowledge it would probably have been better to have advised spinal anæsthesia for the last-mentioned case.

J. MENSTRUATION. PREGNANCY. LACTATION

Opinions are still divided as to the advisability of performing operations during the **menstrual period.** In cases of any urgency the question will not, of course, arise. In other cases the anæsthetist is often consulted as to the propriety of giving an anæsthetic. Speaking generally, it may be said that if the case be not urgent it is better to postpone the administration and operation. In some patients the nervous system is distinctly unstable at the menstrual periods, so that even a slight operation under a general anæsthetic may

[1] See also Kauch, *Centralblatt für Chirurgie*, No. 27.

be accompanied or followed by unusual symptoms. Moreover, it is not an uncommon event for hysterical and other patients to ascribe erroneously a multitude of unusual after-effects to the circumstance that the anæsthetic was given during menstruation. Hæmorrhage after tooth extraction is said to be greater during menstruation than at other times; but this is doubtful. The author once observed very considerable hæmorrhage during and immediately after a nasal operation in a young woman in whom menstruation had been proceeding for forty-eight hours.

If an operation has to be performed during **pregnancy**, an anæsthetic may unhesitatingly be given. No departure from ordinary rules is necessary during the earlier months. The diet should be cautiously regulated in order to avoid retching or vomiting after the administration. Nitrous oxide may be given with safety till the sixth or seventh month; but after that time it is probably better not to administer this anæsthetic, or, at all events, not to administer it in such a manner as to excite clonic muscular movements. The author has given nitrous oxide and oxygen to a patient about thirty-five years of age who was within seven to ten days of her confinement. She experienced no after-effects of any kind from the anæsthetic. Laffont, quoted by Dr. Buxton, refers to a case of a female aged thirty-seven who was eighteen weeks pregnant when nitrous oxide was administered to her. Abortion followed, which he believed was due to the gas having produced some asphyxial changes in the blood.[1] Chloroform, as is well known, is taken comfortably by pregnant women, when the pains of labour have to be relieved (see p. 218). In the event of a surgical operation being required during the latter months of pregnancy, the safety of the patient will probably best be consulted by using the C.E.-ether sequence, the C.E. mixture, or so-called "open ether" throughout. Should ether produce respiratory difficulty, cough, etc., it should not be persisted in; but the mixture or chloroform substituted.

The use of anæsthetics during **lactation** in no way interferes with that process.[2]

[1] *Brit. Journ. of Dent. Science*, 15th October 1898, 917.
[2] *Med. Chir. Trans.* vol. xlvii., 1864, p. 435.

CHAPTER VII

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR CASES (*continued*)

PART II.—THE SURGICAL OPERATION OR PROCEDURE AS A FACTOR

Although the selection of the anæsthetic should be chiefly regulated by the general state of the patient, the nature of the operation, procedure, or condition for which anæsthesia is to be induced should be carefully taken into consideration. There are, for example, certain operations which should unquestionably be performed under certain anæsthetics. Again, there is a tendency during some surgical procedures for circulation or respiration to become injuriously affected, and, unless the administrator be aware of such contingencies, he may erroneously attribute the phenomena to the action of the anæsthetic. Lastly, when certain parts of the body are being manipulated or operated upon, there is need for a somewhat deeper or lighter anæsthesia, as the case may be, than is requisite under other circumstances.

A. OPERATIONS WITHIN OR ABOUT THE MOUTH, NOSE, PHARYNX, AND LARYNX (EXCLUDING THE EXTRACTION OF TEETH, SEPARATELY CONSIDERED)

The procedures of the surgeon and those of the anæsthetist are so intimately associated in this branch of surgery that a clear mutual understanding, coupled with a feeling of "give-and-take," should always exist before the administration commences. It is highly probable that many a fatality has arisen in connection with operations of this group, from the association for the first time of surgeons and anæsthetists totally unfamiliar with one another's principles and methods. On the one hand, the anæsthetist should ascertain the precise nature and probable duration of the operation; the order in which its different stages will be performed; the requirements of the surgeon as regards the avoidance of hæmorrhage, depth of anæsthesia, etc.; and the posture in which the operator wishes his patient to be placed. On the other hand, the surgeon should know the capabilities of the anæsthetist and the lines upon which the latter proposes to secure the anæsthesia required; whilst he should also endeavour, so far as may be possible, to meet any special views of the practitioner in charge of the anæsthetic as to the posture, depth of anæsthesia, etc., which, in the particular case, would give the best results.

It is in cases of this group that the administrator of the anæsthetic should be particularly careful as to the cleanliness of the apparatus he employs and the sterilisation of his gags, mouth-tubes, etc. (p. 262).

Operations upon the Lips, Cheeks, Jaws, Tongue, Floor of the Mouth, Palate, Tonsils, Naso-pharynx, and Nose.—With our present methods it is possible safely and satisfactorily to anæsthetise all patients requiring these operations, provided attention be paid to certain important details which may now be conveniently considered.

(1) **Selection of Anæsthetic; Depth of Anæsthesia.**—One of the most important considerations in this connection is the influence which the selected anæsthetic may have in favouring hæmorrhage during the operation. There can be no doubt that ether, even though used only during the induction period, distinctly favours bleeding. In those cases in which moderate or free hæmorrhage would in no way embarrass the operator there is, of course, no objection to this agent. But for many of the modern nasal, naso-oral, and laryngeal operations, prior to which the surgeon often uses adrenalin and cocaine with the object of securing bloodlessness of the parts, there is obviously considerable objection to ether. It hence happens that for such operations as submucous resection, enucleation

of tonsils, etc., the C.E.-chloroform sequence (p. 502), preceded by atropine and possibly by morphine, should be employed.

For operations not exceeding 30 to 40 seconds, nitrous oxide (p. 283), nitrous oxide and air (p. 306), or nitrous oxide and oxygen (p. 315) will answer well. For those of from 30 to 90 seconds an administration of ethyl chloride (p. 444), the C.E. mixture (p. 471), or nitrous oxide, followed by a small quantity of ether (p. 491), according to the type of subject and other circumstances, will meet the case. When a total available unconsciousness of from a minute and a half to three minutes is required, two courses are open to the anæsthetist. He may either employ the nitrous oxide-ether, the C.E.-ether, or the ethyl chloride-ether sequence (pp. 491, 483, and 496), pushing the administration of the last-named anæsthetic till it is judged that a sufficient after-anæsthesia will result; or he may proceed as he would in a more lengthy case, using the nitrous oxide-ether-chloroform, the C.E.-ether-chloroform, the ethyl chloride-ether-chloroform, or the C.E.-chloroform sequence. The former plan has the undoubted disadvantage of favouring inconvenient hæmorrhage, and if it be adopted, special attention must be paid to posture (*vide infra*). In the latter plan a comparatively small quantity of ether passes through the circulation, and, as a general rule, the operation is not attended by undue hæmorrhage.

When a continuous and protracted anæsthesia is desired, one of the four sequences just mentioned may be chosen, chloroform anæsthesia being maintained till the termination of the operation. Or advantage may be taken of the nasal system of etherisation (p. 356). In certain cases of this group the recently introduced infusion method of anæsthesia is certainly advantageous, and will probably secure a permanent position in hospital practice.

The late Mr. J. Mills[1] was, the author believes, the first to use Junker's inhaler (p. 392) for maintaining chloroform anæsthesia in these cases. Before changing from ether to chloroform, the anæsthetist should ascertain whether respiration

[1] *Lancet*, 14th December 1878, p. 839. Mr. Mills found, and the author can corroborate his statement, that it is not always easy to keep up anæsthesia by this means in alcoholic subjects.

is taking place through the mouth or nose. It is obviously next to useless to insert the tube of Junker's apparatus into, or place a mask sprinkled with chloroform over, the mouth, when respiration is taking place through the nose. Should circumstances permit it is a good plan to pass a flexible rubber catheter of fairly large bore through the anterior nares so that its free end may be felt just beyond the soft palate. It is easier to maintain anæsthesia by this means than by the use of a mouth tube. Very often, however, a nasal tube is inadmissible, and a mouth tube must be used, under which circumstances the anæsthetist must be careful to see that respiration is oral, and if necessary the anterior nares should be plugged with lint.

Patients requiring these operations may either be suffering from respiratory embarrassment or may be in such a condition that respiratory embarrassment will almost certainly arise during the induction period. The selection of anæsthetics in such cases has already been fully discussed (p. 159).

With regard to the depth of anæsthesia which is advisable, this must depend, to a certain extent, upon the patient's general condition, the posture, and the exigencies of the particular operation. Provided the general condition be satisfactory and the air-passages not seriously obstructed, a fairly deep anæsthesia may be secured at the outset, in order to allow of the proper adjustment of the gag, etc. When once the operation has been begun it is usually advisable to attempt to retain swallowing and coughing movements without the occurrence of body movements. A deeper anæsthesia than usual may be permitted when the posture is one in which blood cannot enter the larynx. Speaking generally, the greater the hæmorrhage the lighter should be the anæsthesia. In those operations in which coughing or other indications of moderate anæsthesia might be detrimental to the surgeon, *e.g.* cleft palate and intra-laryngeal operations, deep anæsthesia will be essential.

When the actual or the galvano-cautery has to be used, ether and ethyl chloride must be avoided owing to the inflammable character of their respective vapours. There is, however, no objection to placing the patient under ether and then changing to chloroform, but the cautery should not be used till two or three minutes after the change.

(2) **Posture; Avoidance of Blood entering the Larynx and Trachea.**—A smooth and successful anæsthesia cannot be secured in cases of this group except by careful attention to the posture of the patient. In addition to the remarks made on pp. 238 *et seq.*, there are certain special considerations which apply to mouth, nose, and throat operations. The following are the postures in which these operations may be and are performed:—

(i.) *The dorsal, with the head neither flexed nor extended;*

(ii.) *The dorsal, with the head completely extended over the end of the table or couch;*

(iii.) *The dorsal, with the head turned to one side;*

(iv.) *The dorso-lateral, with one shoulder raised, and with the head turned to the opposite side;*

(v.) *The purely lateral;*

(vi.) *The latero-prone, with the face turned downwards towards the floor;*

(vii.) *The semi-recumbent or "propped-up" posture, with the head in the body axis,* i.e. *neither flexed nor extended;*

(viii.) *The semi-recumbent or "propped-up" posture, with the head extended over the pillow;*

(ix.) *The sitting;*

(x.) *The "bent-forwards"; and*

(xi.) *The Trendelenburg posture.*

Most of these are figured in Chap. VIII. (p. 239). If posture (i.) be adopted, care must be taken to have at hand several honeycomb (not Turkey) sponges, unattached to holders, for keeping the fauces free from blood. These sponges should be round in shape and when moist about the size of a tangerine orange. The anæsthesia should not be profound. If the hæmorrhage be excessive, the head must be frequently turned to one side. Posture (ii.), in the author's experience and opinion, should be proscribed in throat operations. It renders swallowing and coughing difficult or impossible, so that the larynx may readily be invaded; it increases hæmorrhage by retarding the flow of venous blood from the head; and if the nasal channels be blocked, it does not always provide that free drainage for blood which is the avowed object of the posture. Posture (iii.) is not so satisfactory as posture (v.). Seeing that in each case the head is on its side, there is no advantage in the body being supine. In other words, if the operator can operate with the head on its side, the trunk should be placed upon its side also. Some surgeons favour the fourth posture, especially for cases in which it is important that a good view of the palate, tongue, or fauces should be obtained, and it is certainly very useful when the purely lateral posture would be inconvenient. Of all postures, however, the (v.) or purely lateral is undoubtedly the best so far as the anæsthetist is concerned. The patient should be placed strictly upon his side, with his legs flexed and with one cheek resting on the pillow, the open mouth being turned so that it directly faces a window, if daylight is to be used. Owing to the facility with which all blood flows out of the mouth, sponging is generally unnecessary: and it is possible to keep up a deep and uninterrupted anæsthesia throughout by means of Junker's inhaler. The next posture (vi.) is usually inconvenient to the surgeon, and has no advantage over the purely lateral. Of the two semi-recumbent or "propped-up" postures (vii. and viii.) that in which the head is not extended is the better, but both are open to objection from the anæsthetist's point of view, for when patients are thus placed, all blood must, of necessity, drain backwards towards the laryngeal orifice, and turning the head to one side does not permit the blood to escape as it would if the patient were flat. So far as the surgeon is concerned, posture (viii.) is an admirable one in tongue, jaw, and other cases; but it is practically impossible with this posture for the anæsthetist, however skilled he may be, to maintain that unembarrassed form of anæsthesia which may be depended upon in other postures. With regard to (ix.), the sitting posture, there can be no doubt that for many rhinological and other operations of this group it is, from the operator's standpoint, exceedingly convenient. There is certainly no special risk of administering nitrous oxide, ether or ethyl chloride to sitting patients, but the question arises, Are we justified in employing chloroform? The author believes that the proper answer to this question is to be found in the following considerations, viz.: (1) It is certainly unwise for any one to administer chloroform *ab initio* to patients thus placed (p. 122), although there are certain exceptional cases in which this plan must be followed;[1] (2) Unless the administrator has had a large experience in giving anæsthetics, it is not advisable for him to give any other anæsthetic than nitrous oxide, ether, or ethyl chloride to sitting patients; but (3) Provided the anæsthetist be thoroughly experienced, there is no objection to his first placing a sitting patient well under ether in the manner already described (p. 179) and continuing the anæsthesia by means of chloroform. In conducting such cases he should keep the patient's head, as far as possible, in a line with the body; maintaining only moderately deep anæsthesia, *i.e.* not completely abolishing the corneal reflex; and sponging out the fauces with small coarse sponges from time to time. For these operations a comfortable arm-chair with a slightly sloping back is advisable, and it is well to have at hand two or three sofa cushions, or folded bath towels as pillows, in order to obtain the proper head adjustment. As satisfactory anæsthesia becomes established it will be found that the relation of the head to the trunk alters, so that an extra pillow behind the head will be necessary in order to bring the latter into the body line. Great care will be required in anæsthetising patients with a comparatively insensitive larynx. Coughing and swallowing are the two safeguards in these cases; and if, as sometimes happens, one has to anæsthetise a patient who does not clear the larynx by cough, even though quite lightly anæsthetised, repeated sponging must be relied upon. Although the author has anæsthetised a large number of patients in the sitting posture for throat and nose operations, he has only on two occasions been obliged to place the patient horizontally. In neither case, however, was this necessary by reason of any circulatory phenomena. The patients were thick-necked, heavily built, fat, florid, and bronchitic men with narrow air-passages and sensitive nervous systems, and it was difficult or impossible to keep respiration unembarrassed and the air-way free during operations involving the nose and throat. Both patients were successfully

[1] As in operating for laryngeal growths in children. See p. 194.

anæsthetised in the dorsal or dorso-lateral posture. The "bent-forwards" posture (x.) may be employed when the natural or artificial nail is used for removing post-nasal vegetations. The patient is first placed under ether in the dorsal or sitting posture, and bent forwards during the scraping process. Sir William Dalby[1] advocated this position, and it certainly has the merit of preventing blood from embarrassing respiration; but as this can be equally well accomplished in the side posture, the latter is generally preferred by surgeons. The last posture (xi.) to be considered is that known as Trendelenburg's. Its advantage in these cases is that it provides for the flow of blood away from the larynx, but it has the drawback that it undoubtedly favours hæmorrhage. It is, however, useful in hare-lip cases in children; and some surgeons speak well of it for cleft-palate operations.[2] It is inadmissible when the patient is even slightly dyspnœic beforehand, or when the manipulations of the surgeon necessarily involve some degree of dyspnœa during the administration; for in a patient thus placed, any intercurrent asphyxia is liable to become intensified. The author has seen one or two remarkable examples of this faulty practice, the patient's face and scalp becoming œdematous from the accumulation of blood in the venous system, whilst his radial pulse has become gradually imperceptible as the result of the pulmonary stasis.

The entry of blood into the larynx and trachea during these operations may be easily avoided by attention to the following simple rules:—(*a*) When practicable, the posture should be such that blood can easily flow out of the mouth; (*b*) the head should be kept, as far as possible, in a line with the body, so that coughing and swallowing movements may effectually take place; (*c*) the anæsthesia should not be profound, otherwise the pharyngeal and laryngeal reflexes will be abolished; and (*d*) the anæsthetist should have at hand several small, round, coarse sponges unattached to holders, so that, in the event of it being impracticable to adopt a posture favourable for the escape of blood, this fluid may be repeatedly removed by sponging. The cases in which asphyxial complications from blood are most to

[1] "Adenoid Growths in the Pharynx," *Lancet*, Oct. 1886, p. 618.

[2] Keen of Philadelphia advises this posture for operations upon the naso-pharynx (*Annals of Surgery*, 1897, p. 97).

be feared are those in which the larynx has become, during the course of chronic throat or nose disease, comparatively insensitive. In such cases coughing and swallowing may not take place even during a light anæsthesia, and if the posture be faulty, a fine, moist, expiratory râle will become audible, indicating that blood is present in the larynx, trachea, or large bronchi. The treatment of this condition is considered on p. 568. For operations in the dorsal, the semi-recumbent, or the sitting posture, and for certain operations in the lateral or the latero-prone posture, a widely-opening Mason's gag (Fig. 15, p. 257) generally answers well enough; and one fitted with tubes for transmitting chloroform vapour (Fig. 53, p. 397) may be employed if desired. For certain operations, however, in the lateral or latero-prone posture a Mason's gag may be inconvenient to the surgeon, and the anæsthetist must, therefore, either insert a Doyen's gag (Fig. 10, p. 188), an O'Dwyer's gag (Fig. 11, p. 189) or the chloroform-prop (Fig. 56, p. 398) between the teeth of the side away from the pillow, or introduce a dental mouth-prop (Fig. 23, p. 260) or the long screw-gag (Fig. 55, p. 398) between the teeth of the side next the pillow. Difficulty may be experienced in maintaining breathing with the mouth widely open, for the tongue may be thus thrown against the pharyngeal wall. By forcing the chin away from the sternum and relaxing the gag slightly, such difficulties usually disappear. After operations of this group the gag should be relaxed but not removed; and the patient should then be placed in the lateral posture, and carefully watched till signs of semi-consciousness appear (p. 626).

(3) **The Exigences of the Particular Operation.**—In operations upon the **lips** and **cheeks** the lateral or dorso-lateral posture will give the best results. The "propped-up" position, with the head extended, is likely to lead to difficulties. For **hare-lip** operations the infant's body should either be placed in Trendelenburg's posture or it should be semi-inverted by means of pillows, chloroform anæsthesia being kept up either by pumping the vapour through the tube of a Junker's inhaler held several inches away from the mouth, or by a Skinner's mask or lint held horizontally above the site of operation. Crile's method of nasal etherisation, and the

infusion method, are both well adapted to the requirements of these cases. It is well to keep a finger upon the radial pulse in these cases, unless other indications are present as to the depth of anæsthesia.

For operations upon the **jaws** the lateral or dorso-lateral posture is again to be recommended. The author has on more than one occasion known the superior maxilla to be removed from a patient lying upon the side without it being once necessary to sponge out the fauces. Operations upon **the antrum** are certainly conveniently performed with the patient lying upon his non-affected side in the strictly lateral posture, facing a good light. The mouth should be kept slightly open by means of one of the dental mouth-props shown in Fig. 23, p. 260, or by the chloroform prop of Fig. 56, p. 398, as Mason's gag is inapplicable. When the prop has been inserted the operation may be begun, and if swallowing and slight coughing be not abolished, sponging will be rarely if ever needed, even though hæmorrhage be free. There is often a good deal of bleeding in these cases, and if the dorsal posture be adopted, difficulties will almost certainly arise.

For operations upon the **tongue** the lateral or latero-prone posture is the best, although the "propped-up" position is still used by many surgeons. Deep anæsthesia should be secured before the gag and nose tube are inserted. When the first part of the operation consists of tying the lingual arteries or removing affected glands, the anæsthetist's task will be easier than under other circumstances; for there will be no inconvenient tendency for the patient to recover from the effects of the anæsthetic during the insertion of the gag, etc. When a considerable portion or the whole of the tongue has been removed, the breathing may become embarrassed by the stump of the tongue and epiglottis covering the opening of the larynx. Many surgeons follow the plan of passing a ligature through the base of the organ and epiglottis before excision, in order to avert this danger; and the anæsthetist will probably be excused for suggesting the precaution, should it have been omitted. In connection with these operations it may be well to say a few words as to the advisability of tracheotomy, for the anæsthetist may be consulted upon this point. Generally speaking, this measure is unnecessary if the lateral posture be adopted. But should the patient display any considerable embarrassment in breathing when the mouth is first opened to the requisite extent by the gag, it is, as a rule, advisable to open the trachea at this juncture, for such embarrassment to breathing will be liable to increase during the course of the case. The infusion method of ether anæsthesia will probably solve many of the difficulties of the anæsthetist in these cases.

In **staphylorrhaphy** and other operations upon the **palate** the administration of ether before chloroform is, by some surgeons, regarded as open to objection, owing to the inconvenient hæmorrhage which may result. To meet this objection the C.E. mixture may, if desired, be used to precede chloroform, or the latter may be employed throughout. The dorso-lateral posture with the head slightly extended answers very well. Many operators, however, require the patient to be placed in the semi-recumbent position with the head thrown back. Arbuthnot Lane's special gag for this operation (Fig. 9) will be found extremely useful when anæsthetising infants in whom the teeth have not yet appeared. Generally speaking, the anæsthesia must be profound, in order to avoid retching, coughing, or movement. In the earlier stages of staphylorrhaphy, however, when hæmorrhage is free, it is usually advisable to maintain only a moderate degree of anæsthesia. One advantage of the dorso-lateral posture is that the head can be occasionally turned well to the side for the escape of blood, should bleeding be profuse. It is necessary to watch the pulse when working with a profound narcosis. As already mentioned (p. 40), there is often a considerable degree of intercurrent asphyxia in these cases. Many of the symptoms met

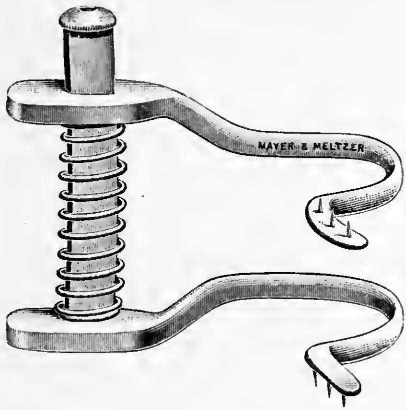

FIG. 9.—Arbuthnot Lane's Gag for Cleft Palate Operations.

with, indeed, such as cyanosis, pallor, feeble pulse, coldness of the face and extremities, and half-open lids, may be dependent upon the embarrassed breathing.

The successful removal of **tonsils** is largely dependent upon the anæsthetist. Surgeons differ so widely in their requirements, that it is difficult to lay down any definite rules of procedure. When only one tonsil requires removal; when it is of such size and shape that it may with certainty be encircled by the guillotine; and when the patient is of sufficient age to permit the preliminary insertion of a mouth-prop (Fig. 23, p. 260) or Doyen's gag, here figured, nitrous oxide and oxygen will give the best results. Doyen's gag must be used with great care, as the leverage it brings to bear upon the teeth is

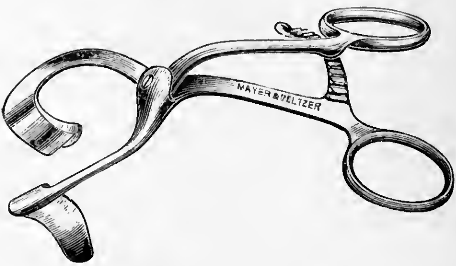

Fig. 10.—Doyen's Gag.

considerable, and as it is liable, unless properly adjusted, to injure the lips. Pure nitrous oxide is not so satisfactory as nitrous oxide and oxygen, because of its tendency to produce muscular spasm, head-movement, and general venous engorgement of the tongue and adjacent parts.

Within recent years ethyl chloride has been extensively used for tonsillotomy. It produces a longer anæsthesia than nitrous oxide; there is little or no venous congestion under its influence; and it is specially applicable in the case of crying or recalcitrant children. Both tonsils may usually be successfully removed under a single administration of this anæsthetic. O'Dwyer's gag (Fig. 11) is particularly useful, as it allows of the removal of the second tonsil without readjustment, and does not get in the operator's way. When surgical difficulties are likely to arise, or when it is proposed to take some time over the operation, it is often a good plan to place the patient in front of a window with a strong light, and to charge him up, so to speak, with ether. In this way a clear view of the tonsils may be obtained and a perfectly quiet anæsthesia, free from movement, relied upon. Under these particular circumstances frequent sponging may be needed, and if the hæmorrhage be free, the head must be tilted forwards from time to time. When the tonsils are very large, the C.E. mixture or chloroform may be the only permissible anæsthetic, as other agents would cause difficulties in breathing. Under such circumstances the lateral posture is the best.

For the modern operation of **tonsillectomy** the C.E. mixture followed by chloroform answers well. An O'Dwyer's

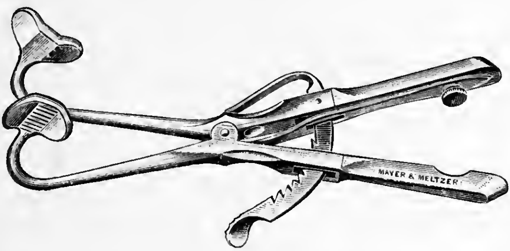

FIG. 11.—O'Dwyer's Gag.

or a Doyen's gag should be inserted; the anterior nares temporarily plugged; the small bent mouth-tube of a Junker's inhaler introduced into the mouth; and a moderately deep anæsthesia maintained. The supine or the lateral position is here indicated.

The part played by the anæsthetist in operations for the **removal of post-nasal adenoid growths** is also one of considerable importance. As the most divergent views exist not only with regard to the means which should be adopted for inducing and maintaining anæsthesia, but as to the posture in which patients should be placed, the subject deserves special consideration. With the actual surgical details of the operation we are not, of course, concerned. It may be said, however, that from the anæsthetist's point of view surgeons divide themselves into two classes—those who perform the operation as quickly as possible; and those who see no necessity for or advantage in this rapidity. It would be out of place to express an opinion on the respective merits of these two schools, but speaking purely as an anæsthetist, the author must confess that the deeper and more persistent anæsthesia required by the latter system is more in harmony with the general principles which should guide us. It is certainly more satisfactory to the administrator of the anæsthetic to induce moderately deep anæsthesia and to maintain this condition till the operation has been completed (which can be done with safety) than to adopt methods which may favour the occurrence of screaming, inconvenient movement, and other unpleasant or even distressing symptoms. The author regrets to say that he knows of instances in which patients have become perfectly conscious before the completion of the operation—a state of things which, with our present knowledge, hardly admits of excuse. It must, of course, be admitted that the transient and light anæsthesia which many surgeons prefer has the advantage of leaving the patient with little or no after-effects. But the inconvenience of this inadequate anæsthesia, and the distress to the friends which it may occasion, are certainly open to great objection. Were there any real danger in keeping up satisfactory anæsthesia, the whole aspect of the question would be changed, but this is not the case. The selection of the anæsthetic will necessarily largely depend upon whether the operation is to be rapid or deliberate. If it is to be the former, ethyl chloride is probably the best anæsthetic, particularly in hospital practice, although nitrous oxide still has its advocates. The nitrous oxide-ether sequence, the C.E. mixture, and chloroform itself, are also applicable for brief naso-pharyngeal operations. With nitrous oxide or ethyl chloride, either a small dental mouth-prop should be placed between the teeth during the inhalation, so that no delay need arise in subsequently opening the mouth by the Mason's gag; or the Doyen's gag shown in Fig. 10, p. 188, may be inserted before the inhalation commences. For more deliberate operations, and for children under four or five years of age, the author prefers the C.E. mixture or the C.E.-chloroform sequence (p. 502), according to the duration of the operation. With regard to the vexed question of posture the reader is referred to what has been said above (p. 181). The purely dorsal posture, although regarded by many as dangerous, is in reality a good one provided that the depth of anæsthesia be adjusted as recommended; that blood be repeatedly sponged away by small, coarse, unattached sponges; and that the head be turned occasionally to the side for drainage. The dorsal posture with the head extended over the end of the table, although still used, is not so satisfactory as other positions (p. 181). The dorso-lateral posture, with one shoulder raised and with the head turned to one side and slightly extended, is employed by many surgeons, and is certainly preferable to the last mentioned. The semi-recumbent or "propped up" posture with the head neither flexed nor extended is not a good one for reasons already given (p. 182). The "propped-up" posture with the head extended is so unsatisfactory that nothing need be said about it. There are, however, certain points in favour of the sitting posture in these cases. It is certainly a very convenient one for the surgeon; and so long as the principles already laid down (p. 183) are followed, a skilful anæsthetist will be able to steer his patient perfectly through even a protracted operation. The "bent-forwards" position is only applicable under the circumstances already referred to on p. 184. Trendelenburg's position is open to the objection that it is inconvenient to the surgeon, and is liable to lead to unusual hæmorrhage. Whatever posture be adopted, the patient should be placed upon his side immediately the operation is finished; his mouth should be kept *slightly* open for a while by a Mason's gag; and he should not be left until distinct evidences of recovery are present.

Patients requiring operations within the **nasal cavities** often possess a partially or wholly occluded nasal air-way; and in such patients it is advisable, if a "close" method is to be used, to place a little mouth-prop (Fig. 16, p. 257) between the teeth before commencing the administration. Should the sitting posture be chosen the nitrous oxide-ether-chloroform sequence may be used provided the corneal, swallowing, and coughing reflexes be retained during the administration of the last-named anæsthetic, and that blood be repeatedly removed by sponging. Most surgeons, however, now prefer the slightly propped up, the horizontal, or the lateral posture, and the avoidance of ether in order to lessen hæmorrhage as far as possible. The C.E.-chloroform sequence, possibly preceded by atropine, or atropine and morphine, is hence generally indicated. It must be remembered that the cocaine and suprarenal extract now so frequently used by surgeons may, and occasionally do, introduce special symptoms of their own into the administration. Thus the author has met with sudden syncope from the solid drug during chloroformisation (see Illus. Case, No. 30, p. 520). Several cases, moreover, are on record in which the injection of suprarenal extract into the septal mucosa has been immediately followed by dangerous or even fatal symptoms. With the ordinary solutions of cocaine and of adrenalin, however, there is little or no danger. If ether has been used, very free hæmorrhage may be met with during the removal of the turbinated bodies or "spurs," so that special care must be taken under such circumstances to prevent blood entering the larynx (p. 184). In all intra-nasal operations the mouth should be kept open, at all events to a slight extent, in order that the tube of the Junker's inhaler may properly deliver its vapour and that blood may be sponged out of the pharynx, if necessary. Some surgeons plug the posterior nares in these cases—a procedure which is helpful to the anæsthetist in that it prevents blood entering the larynx and secures wholly oral breathing. Should the posterior nares be not plugged, respiration will tend to take place through the nose, the chloroform vapour that is being pumped into the mouth will hence fail to reach the respiratory current, and imperfect anæsthesia will result. To avoid such difficulties the anæsthetist should carefully observe the course the respiratory current is taking, and adopt measures to render it oral throughout. In some cases it is necessary to apply a tongue clip (Fig. 19, p. 258) in order to obtain free oral respiration.

For all other operations within and about the naso-pharynx and pharynx, such, for example, as those for the removal of **naso-pharyngeal polypi** or **tumours of the epiglottis,** the anæsthetist should proceed as has been above indicated, employing the lateral or dorso-lateral posture whenever possible, and regulating the depth of anæsthesia as described.

Operations within and upon the Larynx and Trachea.—The administration of anæsthetics for these operations is often a rather anxious task, because of the condition of the patient at the time. Speaking generally, chloroform is preferable to all other agents; but in cases free from dyspnœa there is no objection to inducing anæsthesia with the C.E. mixture. Nitrous oxide, ether, and ethyl chloride are unsuitable anæsthetics. Preliminary spraying with a local anæsthetic combined with adrenalin is of the greatest assistance to both anæsthetist and surgeon.

For such operations as partial or complete **excision of the larynx, thyrotomy for the removal of laryngeal growths**, etc., the surgeon usually first performs tracheotomy, employing a Hahn's or Trendelenburg's tube with the object of preventing blood passing from the larynx to the trachea. In the author's experience Trendelenburg's plan of cutting off communication with the trachea by the distension of a small air-ball round the tracheotomy tube has given the best results. In one or two cases he has known the sponge surrounding the Hahn's tube permit the passage of blood from above downwards. But whichever plan be chosen, it is certainly a mistake to adapt to the tracheotomy tube the long flexible tubing and funnel generally supplied for maintaining anæsthesia. The addition of this appliance may greatly impede breathing, the tubing becoming blocked by blood and mucus. The simplest plan is to maintain chloroform anæsthesia by a Junker's apparatus, employing a small bent metal tube, the fore end of which is passed a short distance down the tracheotomy tube. Apnœic pauses and almost imperceptible breathing are commonly met with immediately after the introduction of the tracheotomy tube. It is advisable in most of these cases to keep up as deep an anæsthesia as possible in order to prevent reflex cough and movement. Some surgeons employ an ordinary tracheotomy tube in these cases and insert a small sponge, directly the larynx has been opened, in such a way as to prevent blood passing towards the trachea.

There are practically only two postures available for these operations—the dorsal with the shoulders slightly raised and the head somewhat extended, and that of Trendelenburg, already referred to (p. 184). It is well to maintain anæsthesia till the bandages have been applied, when the patient should be immediately turned upon his side. If this be done, mucus and blood will be readily expelled as the cough reflex returns, instead of being driven into the unbandaged wound. Infusion anæsthesia (p. 357), promises to provide the most satisfactory way of dealing with these cases, provided further experience confirms the favourable first impressions which have been formed of it.

Although **intra-laryngeal operations from above** are now generally performed under cocaine, it is occasionally necessary to administer a general anæsthetic, particularly in the case of children; and no other agent than chloroform is applicable. Should the patient be a child, he should be carefully anæsthetised in the dorsal posture, and when moderately deep anæsthesia has been secured, placed in the sitting posture with the head very slightly thrown back. A Mason's gag is next inserted, the mouth-tube of Junker's inhaler introduced, and the operation begun. Considerable experience is needed before cases of this kind can be undertaken; for the anæsthetic has to be given till reflex coughing or movement cannot take place, and yet it must not be pushed to the degree of causing such a fall of blood-pressure as would be hazardous in the sitting posture. It is in these cases that the plan suggested and practised by Dr. Scanes Spicer,[1] of spraying the fauces with a dilute cocaine solution, is of service, for it allows of a lighter general anæsthesia than would otherwise be possible. The cocaine not only lessens irritability but also hæmorrhage and salivation. The pulse should be carefully watched throughout.

The author has only once had to anæsthetise an adult for the removal of an intra-laryngeal growth from above. The patient was a gentleman of about sixty years of age, tall, rather stout, and liable to bronchial attacks. Anæsthesia was induced with the C.E. mixture, the patient sitting in a chair. A change was then effected to chloroform, which was pushed till the laryngeal reflex vanished.

[1] See *Brit. Med. Journal*, vol. ii., 1894, pp. 1171 and 1276.

For **laryngotomy** and **tracheotomy**, chloroform is also the best general anæsthetic. It should be given throughout in all cases in which difficult breathing pre-exists; but when no such difficulty is present there is no objection to inducing anæsthesia by other means. The remarks just made as to the posture of patients for thyrotomy apply in this connection. Apnœic pauses often arise immediately after the introduction of the tube. In adult patients with no inflammatory condition of the tissues the operation is quite possible under local anæsthesia, which, in the opinion of many surgeons, is preferable to any general anæsthetic for these cases (see Illust. Case, No. 29, p. 516).

The plan of administering **morphine in conjunction with chloroform** is regarded by many Continental surgeons as specially advantageous in major operations within and about the mouth or nose, owing to the smaller quantity of anæsthetic needed to keep up anæsthesia, or, more correctly speaking, analgesia. For remarks on this mixed narcosis, see Chap. IX. pp. 265 *et seq.*

Except as the result of hæmorrhage, **surgical shock** primarily circulatory in type is rarely if ever met with in operations of this group. This is exceedingly fortunate, for were it otherwise it would be hazardous to employ chloroform in the sitting posture. The exaggerated breathing necessarily incidental to operations of this class is doubtless a powerful factor in maintaining good circulation.

B. DENTAL OPERATIONS

Choice of Anæsthetics, etc.—The anæsthesia produced by **nitrous oxide with small percentages of oxygen** is the best with which we are acquainted for dental operations. Its chief merits are that it is practically free from risk to life and that it is applicable, with the rarest possible exceptions, to all subjects. When the diet has been regulated, all constricting clothing unfastened, a proper posture secured, and the administration conducted as described on p. 318, an almost ideal form of anæsthesia may usually be obtained. The average available duration of this anæsthesia, for a dental operation, is

44 seconds. As the anæsthesia is of a deeper character than that obtainable by other methods of administering nitrous oxide, patients' relatives and friends who may be present or within earshot are not distressed by reflex screaming or movement. Stertor and lividity, moreover, are conspicuously absent in the vast majority of cases. As regards after-effects, these are very rarely met with when attention has been paid to the diet. The chief, one might almost say the only, disadvantage of this form of anæsthesia is that it is of insufficient duration when it is desired to remove numerous firmly rooted teeth at one sitting.

When it is impracticable to administer nitrous oxide as above described, it must either be given **with air** (p. 306) or in a state of **purity** (p. 283). The anæsthesia from nitrous oxide and air is of a better type than that produced by the undiluted agent; but in neither case is it possible to secure such good results as when oxygen is mixed with the nitrous oxide.

Various means have been devised for **prolonging nitrous oxide anæsthesia** in dental surgery. Thus, the face-piece of an apparatus supplying nitrous oxide and oxygen or pure nitrous oxide may be reapplied as the patient begins to emerge from anæsthesia, care being taken that the body is nearly vertical and that the head is not extended when the face-piece is reapplied. Should this precaution be not observed, respiratory embarrassment from blood, tooth fragments, or the swollen tongue may occur. When properly managed, the reapplication of nitrous oxide and oxygen or nitrous oxide itself often proves of great service to the operator. In the case of nitrous oxide and oxygen the apparatus should be reapplied with the oxygen indicator at "0," "1," or "2," and the oxygen percentage should then be quickly increased. In this way several teeth may be removed at one sitting, and when the diet has been carefully regulated, very good results, so far as the patient is concerned, may be obtained. Another plan of prolonging nitrous oxide anæsthesia, and one which is spoken of highly by many anæsthetists, is first to induce nitrous-oxide anæsthesia in the usual way, and to continue the administration by means of the nose-piece (p. 309). It must be remembered, however, that all these methods of prolonging nitrous oxide anæsthesia are open to the objection that they may be attended by stertor, obstructed breathing, cyanosis, and the usual reflex accompaniments of light nitrous oxide anæsthesia. From the point of view of patients requiring the removal of many teeth at one sitting, prolongation methods are certainly a great boon; but they must be applied with discretion and caution if good results from all points of view are desired. In private practice the removal of one, two, or three firmly rooted teeth at one sitting is all that is generally required, and as this can almost invariably be accomplished under nitrous oxide and oxygen without any unpleasant sensations, so far as the patient is concerned, during or after the administration, and without any distress to relations or friends who may be present, this line of procedure leaves little or nothing to be desired.

During the last few years **ethyl chloride** and mixtures consisting largely of this substance have come into extensive use as anæsthetics for dental operations. Ethyl chloride is certainly an exceedingly portable and convenient anæsthetic; its vapour is not unpleasant to inhale; it is easy to administer; and it rapidly produces a deep anæsthesia half as long again as that obtainable by nitrous oxide. Recovery from its influence, however, is more often associated with nausea, vomiting, and headache than the recovery from nitrous oxide. But beyond all doubt ethyl chloride is greatly inferior to nitrous oxide in point of safety. The important question to consider is: To what extent are we justified in availing ourselves of the special advantages of this anæsthetic when we have at our disposal in nitrous oxide one which is far safer, rather more pleasant to inhale, and certainly less liable to be followed by unpleasant after-effects? Ethyl chloride is undoubtedly useful in busy hospital practice and in country private practice; and when administered with a proper knowledge of the principles of anæsthetisation, and by one who has had experience in its use, there is nothing to be said against its employment for the ordinary run of dental operations. But when nitrous oxide is available, and when not more than two firmly-rooted teeth have to be removed at one sitting, this anæsthetic is, as a general rule, unquestionably preferable to ethyl chloride. At the same time there are certain special cases in which ethyl chloride is to be preferred to nitrous oxide. Thus, when a few temporary teeth require removal from a crying or recalcitrant child, or when previous experience has shown that a particular patient is an unsatisfactory subject for nitrous oxide, ethyl chloride may, in skilled hands, be the appropriate agent. The sequence of nitrous oxide and ethyl chloride is also useful in certain circumstances (p. 504).

For **difficult or prolonged dental operations,** *i.e.* for those which do not admit of performance under an ordinary administration of nitrous oxide, nitrous oxide and air, nitrous oxide and oxygen, or ethyl chloride, the anæsthetist must either employ the nasal method of administering nitrous oxide (p. 309), or he must resort to the routine methods of anæsthetisation which are suitable in general surgical practice. Patients with more or less complete trismus fall into this category even though only one tooth has to be removed. As regards the choice between a prolonged nitrous oxide administration on the one hand and ordinary surgical methods on the other, much must depend upon the experience and aptitude of the anæsthetist. Nasal anæsthetisation by means of nitrous oxide is not invariably successful, at all events from the points of view of the operator and anæsthetist. Reflex movement, loud phonation, obstructed breathing, and rigidity are not uncommon, so that it is generally preferable to place patients requiring these operations well under ether. The perfect quietude thus obtainable is often essential to a successful operation. After a little practice the anæsthetist will find that he can, by regulating the length and degree of etherisation, provide the surgeon with an available anæsthesia of the desired duration, so that no reapplication of the inhaler will be needed. It is a good plan, in these major dental operations (1) to remove first the lower and upper teeth of one side; (2) to wedge a large sponge between the gums of that side; (3) to complete the operation; and (4) to plug the other side of the mouth. In this way loss of blood may be largely prevented. As regards after-effects in these cases, it is worthy of note that by arranging the early morning or 1 P.M. for the administration, the patient in the former case having had nothing to eat or drink since the preceding evening, and in the latter having had only tea and toast at 8 A.M., remarkably little discomfort will follow the use of ether. If the anæsthetist be experienced, the best results, in major dental operations, will be obtained with the nitrous oxide-ether-chloroform sequence, which may be safely employed, for suitable patients, even though the sitting posture be adopted (p. 182). Although chloroform is not a suitable routine anæsthetic in dental surgery when given *ab initio*, it may be used *after ether*, provided the special precautions already referred to when dealing with throat operations be followed. In this way the author has anæsthetised a considerable number of patients, not only for major dental operations but for the excavation of sensitive teeth prior to stopping. Although he has usually employed only a moderate anæsthesia in these cases, he has never seen any indication of reflex circulatory shock. It is often convenient to use a Junker's inhaler with a nasal tube during lengthy dental operations. Patients who, by reason of visceral or other affections, are suitable only for chloroform or its mixtures, should be anæsthetised in the dorsal posture and turned to one or other side for the operation.

Children are rapidly affected by pure nitrous oxide and rapidly recover from its influence. They are liable to inconvenient epileptiform movement and to reflex phonation. Much better results are obtainable by nitrous oxide and oxygen; but it is important, when using this mixture, to diet the patient carefully. Boys and girls of from ten to sixteen seem specially liable to nausea after a full administration of nitrous oxide and oxygen. As already mentioned, ethyl chloride is very useful in small children.

Posture.—The posture during anæsthetisation for dental operations is important. The body should be nearly but not quite vertical; the head in the body-line, *i.e.* neither flexed nor extended; the legs straight; and the feet projecting over the foot-rest in such a way that the tendo Achillis of each foot rests upon the rail. Should the operator wish the patient's body to be nearer the horizontal plane, the chair should be thrown back immediately before the face-piece is removed.

Similarly, should he desire the head extended, extension may be effected just as the administration terminates. It must be borne in mind that there is a risk, during operations upon semi-recumbent patients and upon patients with the head extended, of extracted teeth or roots falling backwards. Reference has been made above to the use of chloroform when the patient is in the sitting posture, and to the necessity for the dorsal or lateral posture when this anæsthetic is given *ab initio*.

Mouth-props.—All mouth-props should be sterilised by boiling. The best form of prop is shown in Fig. 23, p. 260. When trismus exists, a small prop should, if possible, be placed between the front teeth in order that the mouth may be opened without delay by the Mason's gag when anæsthesia is complete. When ether or chloroform anæsthesia is to be induced, no prop need be used during the induction stage unless the nasal air-way be inadequate (p. 159).

C. OPERATIONS IN THE REGION OF THE NECK NOT INVOLVING THE AIR-PASSAGES

In administering anæsthetics for operations **involving the great vessels and nerves** of the neck the following points must be borne in mind:—

(1) Any embarrassment in respiration will be quickly followed by venous turgescence, which may inconvenience the operator. It is hence desirable to avoid all coughing, straining, and hampered respiration, by maintaining a deep anæsthesia.

(2) Ether leads to greater vascularity than chloroform. When, however, ether is administered by the so-called "open" system, and respiration is regular and unembarrassed, there is very little difference between the effects of the two anæsthetics. Infusion anæsthesia may prove to be valuable for these operations.

(3) In some cases considerable surgical shock may arise during the operation, either from loss of blood or from interference with important nerves. In addition to Illust. Cases, Nos. 58, 59, 60, pp. 605, 606, in which chloroform was used, the author has notes of one other in which considerable

circulatory depression took place under ether after the internal jugular vein had been tied, and whilst the internal carotid was being exposed for ligature.

(4) There is a distinct though slight risk of air entering veins during these operations (see p. 615). Sternberg[1] has recorded two instances in which gurgling cardiac sounds, due to the presence of air within the heart cavities, were audible after the accident had occurred.

The selection of anæsthetics for operations upon the **thyroid gland** is a matter of no small importance. Speaking generally atropine (with or without morphine according to the circumstances present) should be injected prior to anæsthesia (p. 275). The so-called "open" system of etherisation is particularly useful in these cases. The ether may be preceded by chloroform or the C.E. mixture as described on pp. 487 and 483. Nitrous oxide, ether by "closed" methods, and ethyl chloride are inadmissible. In patients with pressure symptoms even "open" ether may be contra-indicated and the anæsthetist must fall back upon either C.E. mixture or chloroform. Whatever anæsthetic be chosen, however, it is exceedingly important to remember that the safety of the patient largely depends upon the maintenance of a comparatively light anæsthesia. The greater the pressure symptoms the more forcibly does this principle apply. When bronchial catarrh or chronic bronchitis co-exists with a narrowed trachea, extraordinary care will be needed. The risk is that mucus may be coughed up to the narrow part of the trachea and there remain, becoming the immediate cause of respiratory failure. Cyanosis during anæsthetisation must be regarded as indicating the need for a lighter anæsthesia. On the Continent there is a strong preference for local anæsthesia for these operations, especially when symptoms of **hyperthyroidism** exist. Crile adopts a different plan, which he calls "stealing" the thyroid. At a fixed time of day a mask is held over the patient's face; upon the mask eau-de-Cologne or other scent is dropped. This is pretended to be part of the treatment and is carried out for three or four consecutive days. The patient is not told the date of operation, and when the day fixed arrives, the eau-de-Cologne

[1] *Centralbl. f. Chir.* No. 11, 1899.

is once more produced and dropped on. Gradually chloroform or C.E. is substituted, and the patient is thus anæsthetised. It is claimed that thus the effect of fear, so formidable in these patients, can be totally eliminated.

Patients requiring operations for **mastoid** disease are best anæsthetised, as a rule, by C.E., or by "open" ether. The anæsthetist should maintain purely *oral* breathing in these cases: otherwise inconvenient vascularity of the parts may be met with. The author has never seen surgical shock in connection with any operation upon the mastoid process.

Reference has already been made (p. 162) to the anæsthetisation of patients suffering from **angina Ludovici**, and to the special care which is necessary in such cases.

Recovery from the effects of the anæsthetic may be more tardy than usual after neck operations, owing to the tight bandaging which is often necessary. The anæsthetist should not leave his patient till distinct signs of returning consciousness have been manifested.

D. OPERATIONS INVOLVING THE PLEURA OR LUNG

Patients requiring operations for **empyema** or for other affections of the pleuræ or lungs are, as a rule, suffering at the time from respiratory difficulties more or less pronounced. The reader is therefore referred to the previous chapter (p. 162) for remarks bearing upon the use of anæsthetics in persons thus affected.

The **posture of the patient** in these cases is a matter of importance. Should the lateral position be necessary, the affected or more affected side should, if possible, be lowermost, in order to allow of the free expansion of the healthier lung. Unfortunately, many operations upon the pleura or ribs cannot be performed unless the affected side be uppermost, or the patient be lying almost prone. The prone, or semi-prone, position is an unsatisfactory one under any circumstances, as it is liable to interfere with respiration; but it is more especially hazardous when a considerable proportion of the trunk-weight is allowed to tell upon the only efficient lung. A favourite plan with some surgeons is to adjust the patient's thorax so that it projects over the edge of the operating table, and to operate from below. This is certainly safer than to allow the patient to lie on the unaffected side, which has been the determining cause of many tragedies. In chronic cases, in which the healthier lung has become enlarged and accustomed to increased work, posture is not of so much importance as in more acute cases.

When a **purulent or gangrenous cavity** of the lung or pleura communicates with the bronchi, special attention must be paid to posture; otherwise respiration may become embarrassed by pus, gangrenous matter, or blood obstructing the air-ways (see p. 566).

During the **withdrawal of fluid** from the pleural cavity the circulation of the patient should be watched, and any signs of failure reported to the operator. Syncope is said to have occurred from the sudden return of the heart to its proper position. The author has never witnessed any symptoms of this nature.

Operations upon the lung may be attended by **hæmoptysis** during the administration, and it is hence desirable, in such operations, to keep the patient upon his affected side, so that the bronchi of the unaffected lung may remain as free as possible for respiratory purposes (see Illust. Case, No. 46, p. 568).

With regard to the **most appropriate anæsthetic**, it is difficult to lay down definite rules. The condition of the patient must be the chief guide (see p. 163).

E. ABDOMINAL OPERATIONS

When an anæsthetic is required for an **abdominal examination** it must be administered to the full surgical degree. The subjoined remarks, which more particularly apply to anæsthesia for abdominal section, are hence applicable. In selecting an anæsthetic for a simple examination, the type of subject is the paramount factor. Nitrous oxide and ethyl chloride are inadmissible by reason of the muscular rigidity they so often induce. Ether, if chosen, must be used freely: either by a so-called "open" method, with or without preliminary narcotisation; or by a "close" method, in which case nitrous oxide or ethyl chloride may precede it. For reasons to be subsequently given methods involving rapid induction are not so suitable as gradual methods. Caution is necessary with chloroform or a chloroform mixture lest in attempting to obtain muscular relaxation the bounds of safety be overstepped. Muscular patients in a good state of health, and particularly florid boys, may require such a profound degree of anæsthesia in order to abolish inconvenient rigidity, that if chloroform or a chloroform mixture be the anæsthetic chosen, the greatest caution must be exercised. Boys and girls suffering from naso-pharyngeal catarrh are specially liable to give trouble (p. 160). Such patients should be carefully prepared and kept without food for many hours before the administration.

The successful performance of abdominal operations depends in no small degree upon the skill, judgment, and self-possession of the anæsthetist. In the first place, patients requiring these operations are often in a very unsatisfactory condition. Secondly, abdominal operations are specially liable to be attended by surgical shock (p. 69). Thirdly, unless the level of anæsthesia be properly adjusted—and there are, perhaps, no cases in which there is such a need for what may be termed the fine adjustment of anæsthesia—there may be on the one hand such inconvenient phenomena as reflex movement, abdominal rigidity, retching and vomiting, or on the other, such threatening phenomena as pallor, pulselessness, or arrested breathing. Lastly, unless care be taken in the selection and use of anæsthetics for abdominal cases, the after-effects may be such as to retard or possibly prevent the recovery of the patient. As will be subsequently pointed out (pp. 377 *et seq.*), patients who have undergone abdominal operations are specially liable to respiratory sequelæ.

In order that the best results may be obtained, attention must be paid to (*a*) the preparation of the patient; (*b*) the selection of the anæsthetic and method of administration; (*c*) the posture; (*d*) the depth of anæsthesia; and (*e*) the particular operation and its tendency to produce surgical shock.

(*a*) **Preparation of Patient.**—Unless special circumstances be present, the **diet** should be carefully regulated, as described on p. 225.

When the **stomach is distended with fluid**, as may be the case in patients suffering from intestinal obstruction, pyloric disease, etc., general anæsthesia may be hazardous owing to the risk of vomited fluid entering the larynx and trachea, and producing asphyxial symptoms upon the table, or fatal pneumonia subsequently. In these circumstances it is generally considered advisable either to wash out the stomach before the administration, or to do this after the induction stage. The latter course is generally preferable. The patient must be kept upon his side during the process.[1] In the author's hands the procedures recommended below in connection with cases of acute intestinal obstruction (p. 213) have answered quite as well as preliminary lavage. (See also Chap. VI. **F.**).

Special care should be taken to **wrap the patient up warmly**. For long operations a warm-water bed may with advantage be used, but care must be taken that its temperature does not exceed the normal body heat. The temperature of the room should be from 65° to 70° Fahr., and there should be no draughts of cold air. The anæsthetist should not commence the administration until he is satisfied that the surgeon will be ready to begin as soon as the patient is sufficiently "under."

(*b*) **Selection of Anæsthetic and Method.** — Putting on one side for the moment those exceptional cases in which the patient's general condition is such that some particular procedure is indicated (*vide* Chap. VI.), the question arises: Is there any plan of anæsthetisation specially adapted for routine use in abdominal operations? Until quite recently this question hardly admitted of any other than a negative answer. But owing to certain recent noteworthy developments in preliminary narcotisation, and to the establishment of so-called "open ether" upon a scientific basis, there can be no doubt whatever that we are now in a position to answer this question more or less positively, and to say that ether, when administered by this modern system, is the best anæsthetic for the majority of operations within the abdomen. For many years chloroform has enjoyed a great reputation as

[1] *Vide* Greig Smith, *Brit. Med. Journ.*, 12th March 1892; *vide* also *Lancet*, 25th September 1897, p. 786.

the anæsthetic *par excellence* in abdominal surgery. There is now no room for doubt, however, that if chloroform be used in this branch of surgery special precautions must be taken to avoid difficulties and accidents directly or indirectly attributable to its action. By entrusting the administration to a highly skilled administrator, by employing a percentage inhaler, by the preliminary use of atropine as a prophylactic against cardio-inhibitory shock, or by placing the patient in the Trendelenburg posture, the risks of chloroform may doubtless be largely reduced. But as it is often impossible to adopt such precautions, it is a singularly fortunate circumstance that this new system of etherisation furnishes us with an anæsthesia which does not call for such precautions and is quite as satisfactory in abdominal section as chloroform anæsthesia. Many surgeons will doubtless be prejudiced for a time against ether in intra-abdominal procedures, recalling the laboured breathing, muscular rigidity, and venous engorgement which have so often embarrassed them when operating with this anæsthetic. But the close etherisation of Clover and his disciples and the recently introduced "open" etherisation constitute two totally different clinical pictures; and it is this fact which must be borne in mind in the present connection. When an appropriate preliminary narcotic has been used, when a slow induction by chloroform or the C.E. mixture (p. 471) has been practised, and when strict attention is paid to the maintenance of a free air-way, the new system of etherisation may generally be applied in abdominal surgery, so as to secure the muscular resolution, respiratory quiet, and freedom from excessive vascularity which are so essential to surgical success. It must not be forgotten, however, that ether, particularly when administered for very prolonged periods, is more liable than chloroform to be followed by pulmonary complications.

Whilst "open" etherisation after preliminary narcotisation is generally applicable and highly satisfactory as a routine procedure in abdominal surgery, there are many cases in which the judicious blending of ether and chloroform after such narcotisation is preferable to ether itself. This is often seen in cases in which the Trendelenburg posture is to be employed; the comparatively high blood-pressure incidental to that posture renders the anæsthesia of the C.E. mixture, for example, nearly if not quite as satisfactory, so far as respiration and circulation are concerned, as the anæsthesia of ether. In a considerable number of abdominal cases, indeed, the C.E. mixture may be used practically throughout, ether being added to the mask only when circumstances indicate such a course. For short-necked, obese, or elderly subjects who are about to undergo some lengthy operation there is perhaps no better line of practice than this. In other cases the C.E. mixture and ether may be used more or less alternately, the preponderance of ether over the mixture, or of the mixture over ether being determined by the symptoms observed from time to time (p. 473). In other cases, again, the C.E. mixture may with advantage be substituted more or less permanently for "open" ether. Thus, when it is difficult to obtain or maintain full ether anæsthesia by the so-called open system, when ether appears to produce respiratory distress, particularly during expiration, when this anæsthetic causes laryngeal irritation or mucorrhœa, or when a very prolonged operation is in prospect, such a substitution may often be advantageously effected. Similarly if it be proposed to start the operation in the horizontal posture, and to continue it in the Trendelenburg posture, ether may generally be employed for the first part of the operation and replaced by the C.E. mixture when the change of posture takes place. On the other hand there are many occasions when the C.E. mixture should be suspended and ether sprinkled upon the open mask. Thus, should respiration or circulation show signs of depression from surgical shock, hæmorrhage, or prolonged anæsthetisation, a temporary or permanent change of this nature should be made. Again, should a change from the Trendelenburg to the horizontal posture be necessary during the operation, and should any signs of exhaustion be present, the replacement of the C.E. mixture by ether will similarly be called for. By such judicious alternations as these it will often be found possible to carry to a successful termination cases which, if otherwise treated, would almost inevitably display unsatisfactory or even threatening symptoms.

The remarks already made concerning the selection of anæsthetics for operations upon children apply in the present connection (Chap. VI. pp. 144 and 147). If so-called "open ether" be used in these subjects the encircling collar of Fig. 35, p. 339 need not be employed. When any throat affection is present and the child is presumably swallowing mucus in considerable quantities, anæsthesia may with advantage be induced by chloroform followed by the C.E. mixture (p. 503). When anæsthesia has become nearly established the fauces should be stimulated till vomiting occurs, after which the throat should be sponged out and the oral air-way (Fig. 20, p. 263) introduced. For the remainder of the administration the C.E. mixture and ether may be used alternately by the purely open system. The author, who has tried a large number of methods for these somewhat difficult subjects, has obtained the best results by this procedure.

The anæsthetisation of **infants**, and particularly of infants but a few weeks old, for intra-abdominal operations is not an easy task. The successful performance, for example, of such an operation as pyloroplasty is in no small degree dependent upon the anæsthetist.[1] In some cases in which it has been necessary to secure a profound degree of anæsthesia for a comparatively short time, *e.g.* half an hour, the author has used ether in preference to any other agent, and has been very pleased with the result. The rapid respiration is but a trifling disadvantage as compared with the great advantage of obtaining abdominal relaxation with safety. Gray claims that spinal anæsthesia is especially valuable for these cases.

For patients **desperately ill**, through some intra-abdominal condition for which laparotomy has to be performed, the author generally finds the C.E.-ether sequence advisable. The latter anæsthetic should be commenced before any excitement occurs and as a general rule a strictly open plan of anæsthetisation is indicated. When the patient is already poisoned by septic absorption, remarkably small quantities of anæsthetic will generally be needed.

[1] See a paper by Dr. Edmund Cautley and Mr. Clinton Dent (*Trans. Royal Med. Chir. Soc.* vol. lxxxvi.). The authors say "it would be difficult to imagine a class of cases in which more depends upon the skill and judgment of the anæsthetist."

Patients about to undergo abdominal operations are sometimes well under the influence of **opium** or **morphine**, in which case general anæsthetics must be given sparingly.

Finally there are certain abdominal operations for which **spinal anæsthesia** is permissible and even advantageous. Thus prostatectomy in old men enfeebled by chronic cystitis and pyelitis and suffering perhaps from some intrathoracic complication, strangulated hernia with the patient *in extremis*, and similar desperate states in which a general anæsthetic is exceptionally dangerous, rightly come within the scope of spinal anæsthesia. **Infusion** anæsthesia is also of value in dealing with these difficult and desperate cases. Exactly what the limitations of, and indications for, this newly introduced method may ultimately prove to be cannot yet be determined. But it seems certain that for some of these cases it offers a valuable alternative to spinal anæsthesia.

(*c*) **Posture.**—The reader is referred to the following chapter for remarks on this important subject (p. 238). Should the dorsal position be chosen, the head should be placed so that one cheek rests upon the pillow. The chief point in connection with posture during abdominal operations is that the Trendelenburg position is an exceedingly satisfactory one, so far as the anæsthetist is concerned. Provided that the patient's head be kept in a line with the body, and that a free air-way be maintained, respiration will remain unembarrassed, whilst reflex surgical shock of the circulatory type will be far less likely to arise in this than in the horizontal posture, even though the patient be deeply under chloroform (p. 243). Whilst the author has notes of a considerable number of cases in which surgical shock (from traction upon or manipulation of the abdominal contents) has arisen during the use of chloroform in the dorsal posture, he has met with few, if any, instances in which this condition has occurred during similar operations under chloroform in the Trendelenburg posture. (See remarks, pp. 212 and 242). The second point is that, unless care be taken in the adjustment of the arms during protracted abdominal operations, certain posture paralyses will be liable to occur (p. 248). The third point is that the surgeon sometimes finds it necessary, particularly for operations upon the gall-bladder, to place a sand-bag or hard pillow under the lower part of the thorax, with the result that some respiratory embarrassment takes place. Lastly, in extreme abdominal distension, it may be necessary to anæsthetise the patient in the sitting or semi-recumbent posture, and to lower the body gradually as the distension is relieved (p. 164).

(*d*) **Depth of Anæsthesia.**—Whilst the general principle may be accepted that full anæsthesia is essential in intra-abdominal surgery this principle must not be applied on all occasions. A comparatively light anæsthesia is often possible and indeed indicated.

(*a*) when preliminary narcotisation has been practised,
(*b*) towards the termination of a prolonged operation, and
(*c*) in comparatively feeble subjects.

If preliminary narcotisation be practised, and especially if scopolamine be used, the persistence of slight or even distinct corneal reflex may often be permitted in abdominal cases without any inconvenient movement or rigidity on the part of the patient. One of the most striking features, indeed, of the recently introduced plan of following up preliminary narcotisation by slowly induced anæsthesia (p. 337) is the ease with which it is possible to secure abdominal relaxation with comparatively small quantities of anæsthetic. This is of course most noticeable in feeble subjects. Vigorous, muscular men, particularly if addicted to alcohol or tobacco, necessarily require a deeper anæsthesia than other patients. In all subjects the maintenance of a free oral air-way is of paramount importance in preserving a proper depth and type of anæsthesia.

In the absence of preliminary narcotisation the task of the anæsthetist may be distinctly more difficult, particularly in the case of thick-necked vigorous men and of others who, from causes referred to in the preceding chapter, are comparatively insusceptible to anæsthetics. Rapid induction methods are particularly liable to be followed by difficulties in maintaining the proper heat of anæsthesia. Generally speaking, full narcosis must be secured, at all events for the earlier stages of the operation. Whilst most surgeons require this complete narcosis there are still some who are content with a light form of anæsthesia. Certainly light anæsthesia has the advantage that the patient is less likely to display symptoms of surgical shock *of a primarily circulatory type* than when deeply anæsthetised (p. 42). It may, indeed, be said that provided a corneal reflex be retained, and watchful attention be paid to the respiration (which, as we have seen, is more liable to become deranged in light than in deep anæsthesia), the patient's general condition will usually remain satisfactory, unless, of course, excessive hæmorrhage take place, or the operation be very prolonged. But the accompaniments of a light anæsthesia are often so inconvenient to the surgeon that delicate intra-abdominal operations may be well-nigh impossible. The result is that a very important task often devolves upon the anæsthetist—that of providing the surgeon with the requisite degree of abdominal relaxation, and of safely steering the patient through the deeper levels of anæsthesia. This task may be specially difficult with chloroform as the anæsthetic, and with the patient in the horizontal posture. As a general rule, however, it may be safely accomplished by carefully observing the numerous guides as to the depth of anæsthesia. In most cases an almost imperceptible degree of lid-reflex in one eye (the reflex of the other eye having vanished) indicates the proper level. With the C.E. mixture and *a fortiori* with ether, a deeper anæsthesia than this may be secured in horizontally placed patients without that risk of surgical shock which undoubtedly obtains in abdominal operations when chloroform is freely pushed. Should the Trendelenburg posture be adopted full anæsthesia may generally be safely secured by chloroform or the C.E mixture.

(*e*) **The particular Operation: Surgical Shock.**—Intra-abdominal operations have a special interest for the anæsthetist in that they frequently produce reflex respiratory and circulatory phenomena, thus converting what would otherwise be simple surgical anæsthesia into the complex state (pp. 39 and 65). Few, if any, abdominal sections are performed without the surgical procedure in some way or another thus modifying the anæsthesia. The modification may be so slight as to escape attention; it may be so grave as to threaten life. It may come into play during the lightest anæsthesia; it may manifest itself during the most profound narcosis. Reflex respiratory phenomena are most common during the earlier stages of anæsthesia; whilst reflex circulatory phenomena are most frequently met with when the full effects of the anæsthetic have been secured. Manipulations within the upper part of the abdominal cavity have a tendency to bring about a somewhat strained and rapid type of respiration with tense muscles. An almost characteristic expiratory "catch," sometimes phonated, is common during manipulations in the region of the liver. Traction upon the peritoneum, omentum, uterus, or ovary frequently excites reflex laryngeal spasm, resulting, perhaps, in some embarrassment to breathing. Sponging out Douglas's pouch, and other procedures of a similar character, may also induce respiratory modifications likely to interfere temporarily with the convenience of the surgeon. Traction on the rectovaginal septum, as during perineorrhaphy or abdominal hysterectomy, nearly always produces some degree of laryngeal reflex, even when the patient is profoundly narcotised. Should the respiratory derangement assume grave proportions, the state to which the term "respiratory shock" has been given will arise. The most important of the intercurrent conditions, however, which may be met with during abdominal operations and modify the phenomena of deep anæsthesia, is undoubtedly circulatory shock. A variable degree of this form of shock is common in abdominal sections under chloroform, when the anæsthesia is profound and when the patient is horizontal. If the chloroform anæsthesia be not profound, or if it be profound and the patient be in the Trendelenburg posture, primary circulatory shock is exceptional. The complication, moreover, is less common under C.E. mixture (and less common still under ether) than under chloroform. When the conditions are favourable to the occurrence of this form of shock, manipulations in the neighbourhood of the solar plexus, evisceration in the course of appendicectomy, traction upon the uterus, ovary, or omentum, and similar procedures, may readily cause sudden circulatory depression, the symptoms of which are very likely to be erroneously referred wholly to the anæsthetic. The clinical aspects of surgical shock will be specially discussed in the following chapter (p. 254).

Patients with acute **intestinal obstruction** are not good subjects for general anæsthesia, chiefly because of the risk of vomited fluid entering the larynx during the administration. Reference has above been made (p. 205) to the practice of washing out the stomach in these cases. In any circumstances the administrator should make it a rule to keep the head turned well to one side throughout; for vomiting may come on very quietly, and if he be not on the watch he may suddenly find his patient verging on asphyxiation. In desperate cases, and especially in those in which the patient is very obese, the author generally places a pillow under one shoulder, turns the head well to the opposite side, inserts a Mason's gag between the teeth or gums, and has at hand small sponges for keeping the pharynx clear of fluid. He once anæsthetised, for the relief of acute obstruction, a patient who weighed over twenty stone: she had a dilated, fatty, and very irregular heart, and was vomiting blood every ten minutes. In this case the surgeon kindly consented to operate whilst the patient was lying almost in the lateral posture, and the author ascribes the successful issue of the administration to this fact. The patient died some hours afterwards, but without any signs of fluid having passed into the trachea. Spinal anæsthesia is especially valuable in this class of case.

It is usually taught that there is some risk of heart failure during the **evacuation of fluid** from a distended abdomen. It is probably more correct to say that if the patient be deeply under chloroform, vaso-motor syncope from a sudden fall in the intra-abdominal tension may result. The anæsthesia should be light during such operations. With this precaution it will generally be found that the respiration improves, and that the circulation is thereby benefited during, and immediately after, the evacuation of the fluid (see Illust. Case, No. 21, p. 479).

Flushing out the abdomen with hot water usually improves the respiration, the pulse, and the colour of the patient, whilst it not uncommonly sets up a reflex crowing condition of breathing. After the flushing is over, however, the pulse is apt to flag.

F. OPERATIONS UPON THE GENITO-URINARY ORGANS AND RECTUM

It has already been pointed out (p. 72) that the genito-urinary and rectal reflexes are amongst the latest to disappear, so that a **profound anæsthesia** is necessary during operations of this class. Unless the patient be fully anæsthetised, inconvenient or even threatening symptoms of a respiratory, and not, as is often supposed, of a circulatory, nature may be reflexly excited. General movement, laryngeal stridor, stertor from tongue retraction, and respiratory spasm may thus complicate the administration in certain subjects, if the operation be begun before full narcosis has become established (see Illust. Case, No. 42, p. 562). This point becomes of vital importance in patients whose circulatory system is so feeble or degenerate as to be unable to withstand a slight asphyxial strain. Patients suffering from affections of this group are often highly nervous, peculiarly sensitive, and prostrated by continued pain and sleeplessness. They hence require considerate and careful management. Whenever practicable, **ether** should be used in preference to other anæsthetics, for it may be safely pushed to that point at which little or no reflex response will follow the commencement of the operation.

It is generally believed that the operation of **castration** is liable to be attended by grave shock; but although the author has watched for this condition in a large number of cases, he has never seen it. He has, however, once or twice observed a distinct change of pulse, undoubtedly due to the exposure or removal of the testis, the rate becoming abruptly slower, or some intermission taking place. Such changes are probably more common under chloroform than under ether—the anæsthetic which the author has generally administered (see remarks, p. 254). Crile observed a considerable fall of blood pressure during **amputation of the penis** in an old man.[1]

[1] See Mummery's "Lectures on Surgical Shock," *Lancet*, 18th March 1905, p. 698.

Patients suffering from **bladder affections** are usually elderly, and are not infrequently the subjects of obesity, emphysema, and chronic bronchitis. Distension of the bladder in a patient whose breathing is principally diaphragmatic will at once increase the rate and depth of respiration. There is, perhaps, no greater problem in the administration of anæsthetics than that of keeping the breathing of an emphysematous patient sufficiently quiet to meet the requirements of the operator, when the bladder, and possibly the rectum, have been artificially distended preparatory to a supra-pubic operation. Ether is therefore often contra-indicated, and to obtain a deep anæsthesia with the C.E. mixture or chloroform considerable skill may be required. Reference has already been made (p. 209) to the anæsthetisation of bad subjects for prostatectomy.

In operations upon the **kidney** there is often considerable surgical shock, and as a general rule ether is therefore preferable to chloroform. The shock is likely to be greater in feeble than in moderately healthy persons (see Illust. Cases, Nos. 69 and 70, p. 611). The question of posture in these operations will be discussed in the following chapter.

Full-blooded, well-nourished patients and those in average health generally pass through **rectal operations** without giving any anxiety to the anæsthetist, always provided that deep ether anæsthesia be secured. Reflex laryngeal stridor, of a pitch which is almost characteristic of rectal manipulation, is very common in these cases, particularly whilst the sphincter is being dilated. During the more extensive procedures, in which numerous nerves are divided, some degree of circulatory shock may appear, even under ether. This complication is most frequently observed in over-worked, sparely built, and anæmic subjects. There is usually a considerable degree of surgical shock in connection with excision of the rectum and with Kraske's operation. During the removal of a portion of the sacrum in the course of the latter procedure the author has known both radial pulses to disappear and to remain absent for twenty minutes. In this particular case the patient was in what may be termed the prone-Trendelenburg posture, which doubtless accounted for the fact that respiration continued in spite of the profound shock. A further interesting feature of the case is that although no remedial measures whatever were adopted, the shock—which was in a sense conservative—had completely passed off by the time the patient was put back to bed. In these operations the anæsthetist must guard against intercurrent asphyxia, due to the prone posture (p. 241). The C.E.-ether sequence after preliminary narcotisation answers well in these cases.

G. OPERATIONS UPON THE BREAST

There is a greater liability to **surgical shock** during breast operations than is generally believed, and the anæsthetist should therefore do all in his power to aid the surgeon in preventing and treating this condition. Signs of circulatory depression may appear as the immediate result of the skin incision, muscle traction, or muscle division, as a sequel to hæmorrhage, or as the consequence of the exposure of a large raw surface. The patients most liable to surgical shock are those whose general condition is unsatisfactory, and those who are subject to attacks of fainting. One of the most acute cases of surgical shock that the author ever witnessed took place in connection with a breast operation (see Illust. Case, No. 56, p. 604), but in this case the symptoms were due to forcible muscle-traction. In cases of shock the state of the patient almost invariably begins to improve immediately the removal of the breast has taken place. The reader is referred to the following chapter for further remarks on this subject (p. 254).

With regard to the **most appropriate anæsthetic,** this must be decided by a careful consideration of the patient's general state of health. "Open ether," with preliminary narcotisation, answers admirably in most cases, but the C.E. mixture with occasional additions of ether to the mask is more appropriate for elderly subjects. As in abdominal surgery, there is greater liability to reflex circulatory shock under chloroform or a chloroform containing mixture than under ether; but such shock in mammary surgery is in a sense conservative, for it limits hæmorrhage. When it begins to show itself, the depth of anæsthesia should be lessened, and in severe cases ether substituted for C.E. mixture. In cases of slight shock it is best to do nothing more than reduce the depth of anæsthesia. The anæsthetist should see that the patient's body is not more exposed than is absolutely necessary, and the room should be kept as warm as for an abdominal section.

Should the surgeon require the patient's shoulders raised, the head should be raised also. If this be not done, the neck-extension with abducted arm may give rise to embarrassed breathing with laryngeal stridor, cyanosis, and other symptoms. The asphyxial difficulties thus initiated may readily be mistaken for true surgical shock. They are in reality due to faulty **posture.** Reference will be made in the following chapter to certain posture-paralyses which may follow breast operations (p. 248).

H. OPERATIONS INVOLVING THE BRAIN OR SPINAL CORD

Patients about to be subjected to operations upon the brain or its membranes are sometimes more or less **drowsy or comatose** at the time of administration. The greater the tendency in this direction the smaller must be the quantity of anæsthetic given. In any event, after the preliminary incision, a light chloroform anæsthesia is indicated. Those anæsthetists who have had most experience in this branch of surgery have obtained the best results with the Vernon Harcourt inhaler, with a continuous supply of oxygen. The whole face-piece with the anæsthetist's hands can usually be enveloped in sterile towels, which procedure keeps the field of operation clear of interference. The mixed narcosis of chloroform and morphine, which was for some time employed in these cases, is now rarely used (see Chap. IX.). Should a preliminary injection of morphine have been given, the anæsthetist must administer chloroform very sparingly, and attempt to secure an analgesic rather than a true anæsthetic state. Considerable surgical shock may be met with during these operations.

The chief point concerning operations upon the spinal column and cord is that the prone or almost prone posture may introduce respiratory complications. In some cases, moreover, there may be no thoracic breathing; and the position of the thoracic viscera may be greatly altered by the spinal deformity. A variable degree of surgical shock is common in these operations. Generally speaking, deep anæsthesia should be avoided in the prone posture, and a careful watch kept upon respiration and circulation. The choice of anæsthetic must be regulated by the general circumstances of the case. Although chloroform may be preferable from the surgeon's point of view, the anæsthetist may find it advisable in bad cases to employ ether, either alone or in mixture with chloroform. Operations for spina bifida in infants are best performed under ether administered by the strictly open system (p. 334).

I. PARTURITION AND OBSTETRIC OPERATIONS

In the early stages of **natural labour**, when the pains are short and not very frequent, no general anæsthetic is advisable. The **scopolamine-morphine** method of producing analgesia is useful at this stage (see p. 270). The patient is semi-somnolent between the pains, though she can converse rationally if roused. Each pain penetrates to the threshold of consciousness, as it were, and may produce a slight moan or other response. Yet the sensorium is so dulled that no recollection of the pains is retained afterwards, or indeed of any other incident of the period covered by the narcosis. When the second stage is reached, and the true expulsive pains begin, the administration of **chloroform** in small quantities is desirable. (In America **ether** is generally used at this stage of labour.) When the patient shows by her movements that a "pain" is approaching, chloroform should be applied; as little as possible given; and even before the "pain" has actually passed off the anæsthetic should be withdrawn. The patient should be allowed to recover completely from the analgesic effects of the drug between the "pains," except when the fœtal head is actually down on the perineum; then a somewhat deeper anæsthesia is permissible and also advantageous to the obstetrician by enabling him to preserve the perineum intact. Most authorities agree that if chloroform be given more deeply than is here suggested there is a risk not only of uterine inertia, and a prolongation of the labour ensuing, but of *post-partum* hæmorrhage, more especially in persons predisposed to this condition. **Chloroform should not be employed** when the uterine contractions are feeble, when small doses of the drug appear to retard labour, or when any great respiratory difficulty is present.

When **true surgical anæsthesia** is required, as for turning, instrumental delivery, craniotomy, and other operations, ether should, as a general rule, be given. Though the use of chloroform in analgesic doses during labour may be said to be free from risk, there is no reason to suppose that when this anæsthetic is pushed to its fullest degree this almost absolute immunity from danger is to be relied upon.[1] But as chloroform has been very largely used for obstetric operations requiring deep anæsthesia, and as very few fatalities have occurred, it would seem that there must be some reason of this freedom from accident. When fatalities under this anæsthetic have occurred in surgical practice at the very outset of the inhalation, *i.e.* before consciousness has been lost, the factors of fright and apprehension have possibly been at work. These factors are, as a rule, wholly absent when chloroform is given to relieve the pains of labour. The patient is occupied with her suffering, and the prospect of speedy relief from pain gives rise to a feeling of comfort rather than to one of alarm. The view that the physiological hypertrophy of the heart enables this organ to cope with any undue strain which may be imposed upon it is probably quite erroneous. A very large proportion of those who have succumbed under chloroform have had healthy and vigorous hearts. Moreover, the clinical fact is established beyond doubt that, in surgical practice, the best subjects for chloro-

[1] It is a mistake to suppose that chloroform accidents during child-birth are unknown. See a fatal case, *Lancet*, 2nd Feb. 1889, p. 249. The administrator had given chloroform four hundred times before. See also an article by Dr. Ballantyne (*Scot. Med. and Surg. Journ.*, Jan. 1897), who has collected eight deaths during labour under chloroform.

form are those whose general vital functions are somewhat impaired by illness. In the comparatively few cases in which the author has administered chloroform to its full extent during or immediately after labour, the patients have certainly taken this anæsthetic remarkably well. There has apparently been a fuller and better circulation and respiration than in ordinary cases. Dr. Lombe Atthill,[1] after forty years' experience with chloroform in obstetric practice, suggested the possibility of the safety being due to the fact that "in these cases the involuntary expulsive efforts seldom entirely cease, and as at the expiration of each of these, comparatively deep inspiration follows, it may tend to prevent asphyxia. . . ." There can be no doubt that in many cases in which chloroform produces unsatisfactory effects, the difficulty seems to be one arising in the first instance from feeble or hampered respiratory movements, and consequently an inadequate pulmonary circulation. The deep respirations of labour would obviate this sluggish pulmonary circulation by emptying the right heart more efficiently. Dr. Galabin believes that the high abdominal pressure which is necessarily caused by the distension of pregnancy prevents that undue vaso-motor dilatation which might otherwise arise under chloroform.[2]

J. OPHTHALMIC OPERATIONS

The vast majority of ophthalmic operations are conducted under local anæsthesia, which is to be regarded as the best by far for routine cases. There are certain special operations, however, such as enucleation, and glaucoma operations, for which general anæsthesia is preferable. There are special reasons why the maintenance of a perfectly tranquil anæsthesia during ophthalmic operations is a matter of comparative difficulty. In the first place, the head is usually adjusted face upwards and slightly extended; so that mucus and saliva tend to flow backwards and to induce

[1] *Brit. Med. Journ.*, 16th Jan. 1892.

[2] For further information see an interesting *résumé* of the whole subject by Mr. H. Bellamy Gardner (*Brit. Gynæcolog. Journ.*, May 1896). This author points out that there is no decided evidence to show that anæsthesia has any injurious influence on the fœtus.

reflex disturbances, whilst the tongue may obstruct breathing. Secondly, the depth of anæsthesia is liable to considerable fluctuations, by reason of the anæsthetist having to discontinue the administration from time to time, in order to meet the requirements of the surgeon. And thirdly, the eyes are often unavailable as guides. There have been a large number of chloroform fatalities in ophthalmic practice, and the explanation of the fact is probably to be found in these considerations. As a general rule the C.E. mixture, followed by chloroform if the mask gets in the way of the operator, may be recommended. The anæsthetic, whatever it may be, must be administered to the proper surgical degree. For strabismus operations in children, ether is unquestionably preferable to chloroform.[1] For the operation of enucleation the choice of the anæsthetic must depend upon the state of the patient.

Infusion ether anæsthesia, if it fulfils the hopes that have been formed, may prove extremely useful for ophthalmic operations.

K. OPERATIONS UPON THE EXTREMITIES

Complete **muscular flaccidity** is essential for the examination of stiff and painful joints, the reduction of dislocations, and the setting of fractures. Ether is the best anæsthetic for the reduction of dislocations of the shoulder: curiously enough, chloroform has proved particularly lethal during these operations.[2]

[1] Mr. Brudenell Carter, in a very able letter to the *Lancet* (7th August 1875, p. 227), strongly advocates the use of ether in preference to chloroform in ophthalmic practice, and refers to a surgeon who lost sixteen patients under chloroform administered for operations upon the eye.

[2] Lisfranc, Verneuil, Böckel, and Guillon have all drawn attention to this fact. They believe the fatalities to have arisen in consequence of the "unfavourable position of the patient" during the administration, by which they probably mean that respiration is likely to be interfered with during the necessary manipulations. We must remember, too, that complete relaxation is always essential—in other words, that the anæsthetic has to be pushed very freely; that the subjects of dislocated shoulder are often men who have met with the accident whilst under the influence of alcohol; that food is often present in the stomach when anæsthesia is induced; and lastly, that the administration is not unfrequently placed in unskilled hands. These facts, together with the suggestion made by the above observers, seem to the author to point to the necessity for considerable caution in administering chloroform for the reduction of a dislocated shoulder.

For orthopædic operations deep ether anæsthesia is also generally advisable. The legs and feet are particularly liable to move reflexly at the moment of operation. This is noticeably so in the case of nitrous oxide. Even if this anæsthetic be administered with oxygen till as deep an anæsthesia as possible is procured, there is almost invariably a reflex twitch when an incision about the leg or foot is made. Ethyl chloride is useful in short cases.

Children requiring orthopœdic operations are not uncommonly somewhat defective intellectually and are liable to display eccentric symptoms, particularly in the direction of insusceptibility during the induction and maintenance of anæsthesia.

L. OTHER OPERATIONS, PROCEDURES, OR CONDITIONS FOR WHICH ANÆSTHETICS MAY BE REQUIRED

General anæsthetics, and more particularly chloroform, are sometimes employed in **renal colic**, **biliary colic**, and **other acutely painful seizures**. In such cases the selected agent should be administered in analgesic rather than in anæsthetic doses, and, as when exhibiting chloroform in normal labour (p. 218), pain should be relieved without wholly destroying consciousness.

Chloroform has been extensively used in the treatment of **puerperal eclampsia**. In these cases it is necessary to push the administration somewhat more freely than when the mere relief of pain is desired. Dr. Galabin[1] makes the following practical remarks:—

"At first the patient may be brought pretty fully under the influence of the drug, but afterwards it may be given only from time to time and in partial degree. Any premonitory signs of a paroxysm, such as increased muscular restlessness, more rapid breathing, or contraction of the pupils, are indications for giving more of the chloroform, and so, *a fortiori*, is the recurrence of a fit. When chloroform is given judiciously, in this partial degree, the administration may be continued for hours together, without danger."

[1] *A Manual of Midwifery*, 4th edition.

The late Dr. Playfair[1] pointed out that chloroform occasionally fails to control the paroxysms. The same author stated that the use of an anæsthetic is contra-indicated when the patient is cyanosed. Spiegelberg[2] refers to a case in which sudden death took place during the use of chloroform for puerperal eclampsia.

Chloroform quickly relieves the spasms of **strychnine poisoning.** In some of the recorded cases it was only necessary to give the drug in analgesic doses;[3] whilst in others deep anæsthesia was produced.[4] In one case[5] chloroform was administered, almost without intermission, for seven hours.

In the treatment of **tetanus**, chloroform has also been found distinctly advantageous.[6] As in strychnine poisoning, muscular spasm subsides before true anæsthesia is reached; so that it is not necessary to push the chloroform very far. Sometimes a considerable interval of freedom from spasm may elapse after the inhalation, in which case no more of the anæsthetic need be given till the tetanic rigidity recommences. Should the spasms, however, be nearly continuous the administration may be maintained. One case is recorded in which a child was kept more or less under the influence of chloroform for thirteen consecutive days, 100 oz. being used. In extreme cases, in which there is intense spasm of the jaws, neck, thorax, and abdomen, it may be difficult or impossible to administer chloroform without intensifying the existing condition.[7]

[1] *Science and Practice of Midwifery*, vol. ii. 6th edition.
[2] *A Text-Book of Midwifery* (Sydenham Society), p. 220.
[3] *Brit. Med. Journ.*, 22nd April 1882, p. 575.
[4] *Lancet*, vol. ii., 1875, p. 310. [5] *Ibid.* vol. ii., 1867, p. 118.
[6] See *Braithwaite's Retrospect*, vol. ii., 1877, p. 59—"On the state of Therapeutics in Tetanus." See also *Medical Record*, 15th June 1879, p. 243; and *Lancet*, 31st July 1880, p. 171.
[7] A case occurred at the London Hospital in March 1899, in which several attempts were made to relax the tetanic spasm which was threatening the life of the patient by asphyxia. On each occasion the chloroform vapour, even though very carefully given, seemed to aggravate the condition, and artificial respiration became necessary in re-establishing breathing. Eventually, however, the tetanic spasm got the upper hand, and the patient died.

CHAPTER VIII

THE EXTRANEOUS CIRCUMSTANCES OF ANÆSTHETISATION

In order to ensure, as far as possible, successful anæsthetisation, it is essential that attention should be paid to numerous points prior to and during the actual administration.

Experience shows that patients who are subjected to the *régime* of a nursing home for a few days before a surgical operation usually pass into and out of general anæsthesia more smoothly than those who are operated upon without any such preparation. Whenever practicable, therefore, it is important that attention should be paid to the diet, the state of the bowels, the avoidance of tobacco-smoking, etc., during the twenty-four or forty-eight hours immediately preceding a major surgical operation. Even in the case of so-called minor operations the patient should be prepared for anæsthetisation as far as circumstances will permit.

Some years ago, at a surgical home in London, the author anæsthetised a little boy on about sixty separate occasions, each time employing the nitrous oxide-ether-chloroform sequence. The operations necessitating the anæsthesia were in three batches, so to speak, separated by intervals of a few months. During these intervals the little patient went home. The operations themselves took place at intervals of a few days. After the first administration in each batch, *i.e.* soon after the patient had arrived in London, there was a good deal of nausea and vomiting; after the second administration the after-effects were less; after the third they were very trifling; and after the remaining administrations of the batch they were practically nil.

It is always advisable to have a third person in the room during the administration of an anæsthetic (see also p. 644).

A. HOUR OF ADMINISTRATION: REGULATION OF DIET: ETC.

It is hardly necessary to point out that as patients are usually in a state of nervous tension before operations they should not be kept waiting a moment beyond the hour that has been arranged. Some considerate surgeons, indeed, make a practice of naming to the patient a somewhat later time than that actually fixed with their colleagues and nurses. By this simple device the suspense before an operation may be reduced to a minimum.

It is an accepted fact that the **early morning (8–9.30 a.m.)** is the best time for the administration of a general anæsthetic for a surgical operation. Putting exceptional cases aside, patients are brighter and fresher in the morning than in the after-part of the day. But the most important reason for choosing the time indicated is that the stomach is then generally empty and in a state of quiescence. Adult patients in good health may be allowed their usual meals the day before the operation, provided that nothing be taken after 7 or 8 P.M. A light and nutritious meal at or about 7 o'clock on the previous evening is generally to be recommended. The author has known patients who have had an exceptionally good dinner the night before the operation, and children who have eaten heartily of pudding before going to bed, to eject a considerable quantity of semi-digested food after the anæsthetic on the following morning. He has also known milk taken "the last thing at night" to cause post-anæsthetic vomiting after an operation performed early the following morning. The practice of giving beef-tea, soup, tea, coffee, an egg beaten up in milk, or an egg with brandy during the night or early hours of the morning, is open to much objection. Digestion is not always so rapidly performed as is generally believed, and when nourishment is taken at unusual times, the process may be greatly retarded. Moreover, even though beef-tea may have been given several hours beforehand, so that the stomach is empty at the time of the administration, considerable gastric irritability may remain as the result of recent digestion. Milk is particularly prejudicial. It requires such a length of time to become digested and to disappear from the stomach, and leaves the stomach so irritable after it has disappeared, that it is, in the author's judgment, the worst of all forms of nourishment either before or after anæsthesia. In one week the author met with two cases of congestive hæmatemesis in patients—both boys—to whom milk had been given several hours before their operations. The best results, so far as the avoidance of gastric disturbance during anæsthesia is concerned, are undoubtedly met with in cases in which nothing whatever has been taken since the previous evening. In the prophylaxis of vomiting and of post-anæsthetic toxæmia, some observers praise glucose given in drachm doses (for adults) four hourly for two days beforehand: the last dose to be taken four hours before operation (*vide* p. 639).

When the operation cannot be arranged for the early morning, the next best time, so far as anæsthesia is concerned, is either about 1 P.M. or 2 P.M., or 5 P.M. or 6 P.M. Administrations conducted in the middle of the morning or in the middle of the afternoon, *e.g.* at about 11 A.M. or 3 P.M., are often unsatisfactory owing to the difficulty of regulating the diet for operations at these times.

As a general rule an **interval of five hours** should have elapsed between the last meal and the administration of a general anæsthetic for a surgical operation.

In the accompanying table will be found suitable dietaries for patients about to be operated upon at the hours specified:—

[TABLE.

Operation.	Diet.
8 A.M. .	No food or drink since previous evening.
9 ,, .	No food or drink since previous evening.
10 ,, .	No food or drink since previous evening.
11 ,, . .	*If patient awake*, cup of tea or coffee (according to habit) with biscuit or toast, or cup of clear soup, not later than 6 A.M.
12 Noon . .	Cup of weak tea or coffee with biscuit or toast, or cup of clear soup, not later than 7 A.M.
1 P.M. . .	Tea, coffee, or clear soup, with toast, not later than 8 A.M.
2 ,, . .	Light fish breakfast before 8 A.M., or tea, coffee, or clear soup, with toast, before 9 A.M.
3 ,, . .	Light fish breakfast, or simply tea, coffee, or clear soup, with toast, before 9 A.M.
4 ,, . .	Tea or coffee with toast before 7 A.M., and cup of clear soup or broth at 11 A.M.; or (better) fish breakfast at 10 A.M.
5 ,, . .	Tea or coffee with toast before 8 A.M., and cup of clear soup or broth at 12 noon.
6 ,, . .	Fish breakfast at 8 A.M., and cup of clear soup or broth at 1 P.M.

The author has never seen any difficulty attributable to too lengthy a fast; but he has frequently met with difficulties of a respiratory or circulatory character due either to the presence of nourishment within the stomach or to an irritable state of that organ apparently dependent upon recent digestion.[1]

The above rules can hardly be adhered to when we have to deal with **exhausted patients**, or with those who are liable to feel faint after a comparatively short abstinence from food or stimulants. Moreover, patients advanced in years should not be kept so long without food as younger persons; partly because they more readily show signs of exhaustion, and partly because they are far less liable than their juniors to after-nausea and vomiting. Generally speaking, exhausted and asthenic subjects who are to be operated upon in the early morning should be allowed some clear soup during the night; and in extreme cases a little wine, brandy, or whisky may at

[1] Some anæsthetists hold views which diverge considerably from those of the author. Thus Mr. R. W. Collum is disposed to allow food much more liberally than is here suggested (*Brit. Med. Journ.*, 29th October 1910, p. 1302). With his remarks condemning the practice of preparing (in hospital practice) all the patients on a long afternoon's list as if they were to be anæsthetised at the same moment we quite agree; but we remain unconvinced as to the desirability of a slice of bread and butter with unlimited tea at 8 A.M. for a patient to be anæsthetised an hour later.

the same time be taken with advantage. Similar arrangements are indicated when the operation is fixed to take place during the day, *i.e.* some soup should be given about four hours before the administration. Milk, eggs, and ordinary beef-tea are not so suitable as clear soup.

As a general rule **alcohol** should not be given by the mouth before an anæsthetic, as it is liable to interfere with anæsthesia, and in some cases to cause vomiting during the administration.[1] Some writers, however, consider alcohol advantageous.[2]

Should the patient's **circulation** be **extremely feeble**, it is a good plan to give an enema of brandy and water, or brandy and beef-tea, a short time (twenty minutes or so) before the administration.

Although it is unnecessary in the case of nitrous oxide that the diet should be as strictly regulated as in the case of ether or chloroform, it is important that some attention should be paid to this point. When the gas is administered in its pure state, an interval of three hours after the last meal is advisable, although it is exceedingly common for patients who have quite recently taken food to pass through this form of anæsthesia without vomiting. But when nitrous oxide is to be given with oxygen, even for a brief operation, the diet must be carefully regulated, in accordance with the foregoing principles. The same may be said when one administration of pure nitrous oxide is to be immediately followed by another, or when this gas is to be given with air for a lengthy operation.

Patients about to be anæsthetised should be requested to abstain from **smoking** for several hours beforehand. Excessive smokers who are about to undergo operations of some duration, or operations in which throat irritability might be inconvenient, should be requested not to smoke for at least two or three days before the administration.

[1] In one case, in which a patient had taken some champagne two hours before an administration of nitrous oxide and ether for a dental operation, hesitating breathing, masseteric spasm, coarse moist laryngeal sounds, and other inconvenient symptoms arose, and caused delay and difficulty.

[2] See Clover, *Brit. Med. Journ.*, 14th February 1874. See also an interesting letter "On the Value of Alcohol before Chloroform" (*Brit. Med. Journ.*, 20th July 1889). Also *Asclepiad*, January 1892.

B. STATE OF THE BOWELS AND BLADDER

In ordinary surgical cases, the best plan appears to be to give a purgative the night but one before the operation, and an enema on the morning of the operation. If a purgative be given the night before the operation, inconvenience may arise during, or immediately after, the administration. Care should be taken to select purgatives appropriate to the case. The author has on several occasions satisfied himself that certain symptoms of depression[1] which have arisen, during or after the use of an anæsthetic, have been wholly or partly dependent upon the violent purgation to which a somewhat feeble patient has been subjected. There are, of course, certain cases in which the use of strong measures is highly desirable. The so-called "bilious" subjects, those who are generally constipated, and young people (particularly boys) of gluttonous habits, must be freely purged, otherwise after-vomiting will be likely to be troublesome.

The bladder should invariably be emptied before anæsthesia is induced. This rule is particularly necessary in the case of children who are about to be anæsthetised by nitrous oxide free from oxygen, for during the clonic muscular movements micturition is liable to arise.

C. CERTAIN SPECIAL PREPARATIONS

In such operations as those for fæcal fistula, it may be necessary to employ **rectal feeding** for one or two days beforehand.

Some surgeons **wash out the stomach** prior to abdominal section for intestinal obstruction, pyloric or duodenal disease, etc. (pp. 170, 205, and 213).

In cases of extreme exhaustion, nutrient and stimulant enemata, or the **intravenous injection** of **saline fluid** may be indicated. Some surgeons, prior to operations liable to be

[1] Snow believed that free purgation the night before a rectal operation was likely to induce syncope during anæsthesia; and he met with cases which appeared to render this view extremely probable. See Snow, *op. cit.* p. 104.

attended by shock, commence subcutaneous saline infusion immediately after anæsthesia is induced and allow the process to continue throughout the operation.

The employment of **morphine, scopolamine, atropine** and similar drugs in association with general anæsthetics is specially dealt with in Chapter XVI.

The preliminary application of **cocaine**, in the form of spray, to the nose and throat, has been recommended, partly with the object of preventing or lessening the cough, holding of breath, and irritation often produced by ether and chloroform, and partly with the object of averting the early reflex syncope which such irritation is supposed occasionally to induce (p. 118). Rosenberg[1] originally proposed this method; and it has been thoroughly tested by Gerster,[2] Mayer, and Theobald of New York. Whilst there can be no doubt that the irritant effects of anæsthetic vapours may be to a great extent thus averted, experience has shown that the plan is not without its objections, and that symptoms of cocaine poisoning may readily be induced. Moreover, as there are at our disposal numerous methods of administration by which all initial pungency of vapour may be avoided, there is no necessity to resort to this cocainisation of the upper air-tract.

The use of **cocaine and adrenalin** locally is advantageous before certain intra-nasal and intra-laryngeal operations, causing diminution both of hæmorrhage and of laryngeal sensibility (p. 192).

Patients who are already suffering from **acetonuria** (p. 634) require special treatment. When circumstances permit, bicarbonate of soda in appropriate doses and glucose (*vide* p. 639) should be administered for some days before the operation, and the action of the bowels, kidneys, and skin encouraged. In urgent cases there may be little or no time in which to bring the patient under the influence of alkalies; but an attempt should be made whenever practicable.

Lastly, in certain highly excitable subjects the preliminary administration of **bromide of potassium** may be useful (see Illustrative Case, No. 32, p. 538).

[1] See *Berliner klinische Wochenschrift*, Nos. 1 and 2, 1895.
[2] See *Annals of Surgery*, January 1896.

D. INSPECTION AND EXAMINATION OF THE PATIENT

Whenever practicable the patient should be inspected and examined before the administration. Bearing in mind the fact that the phenomena of surgical anæsthesia are largely dependent upon age, temperament, physique, habits of life, quantity and quality of blood, the state of the respiration, the state of the circulation, and other factors (Chap. VI.), we cannot fail to recognise the advantages of ascertaining, as far as circumstances will permit, the general condition of the patient entrusted to our care. Information of value may often be obtained from the patient's usual medical attendant. Every one who has largely administered anæsthetics must be able to call to mind cases which would certainly have gone more smoothly had some particular pre-existing peculiarity or morbid state been recognised before the administration. Aortic disease, mitral stenosis, an extremely slow cardiac action, or emphysema may, for example, be easily overlooked unless care be taken. By considering the condition of the patient, we not only place ourselves in a better position to decide what anæsthetic or anæsthetic mixture should be chosen, but we are often able to anticipate, and possibly to prevent the occurrence of important symptoms during the administration.

A great deal of valuable information, both positive and negative, is afforded by the **general appearance and bearing of the patient.** Let us in a few words consider what may be learnt by simply observing the individual before us. Should he walk to the operating table, couch, or chair, his mode of progression may afford us information. We shall notice whether he moves actively, or whether with considerable hesitation or difficulty. The exertion may be followed by breathlessness. Should the patient be partially or wholly recumbent when we are called upon to anæsthetise him, the precise position in which he lies may afford us information. Those who suffer from chronic bronchitis, emphysema, other affections of the air-passages, or extreme abdominal distension, almost invariably insist upon being propped up to a greater or less degree. Marked dyspnœa will attract attention, and should be regarded as a very important symptom. Patients suffering from unilateral pulmonary or pleural affections will probably be found lying upon the diseased side. The presence of pain, however, may necessitate a precisely opposite position. Whilst observing and drawing our inferences from the walk or posture of the patient, we are able, as a rule, to estimate roughly his age. It must be remembered that the anæsthetist is concerned as much with the apparent as with the real age of his patient. The temperament, too, which plays an important part in determining the manner in which an anæsthetic is taken, usually shows itself on these occasions. This is more particularly the case with hysteria. It must be remembered, however, that women who are liable to outbursts of hysteria sometimes conceal their want of control so cleverly that the observer is deceived. The overworked and the highly-strung patient will be recognised, and should be treated with the utmost gentleness and care. Previous excesses in alcohol, as a rule, present little or no difficulty in their detection. The teeth and breath of the habitual smoker will foreshadow the occurrence of certain difficulties to which reference has already been made. The general physique of the patient will be observed. Gross, flabby individuals, with a large abdomen, muddy complexion, and double chin, will probably not be easy subjects to manage. Nor may florid, muscular young men, who live outdoor lives and enjoy excellent health, be the easiest subjects. Persons affected with extreme obesity will require careful management. On the other hand, patients of slim build, who are more or less anæmic in appearance, generally give no trouble. Florid and more especially dusky-looking and congested patients will show cyanosis under nitrous oxide, or in fact under any anæsthetic, if air be withheld even to a slight degree. The pallor of true anæmia is readily recognised. Apart, however, from this pallor, we must remember that very nervous and apprehensive subjects may be much paler than usual at the time of administration. Their pallor disappears when anæsthesia is established; and, to the surprise of the anæsthetist, to whom such patients may be strangers, they assume a florid colour.

The manner in which **respiration** is performed is specially important, and the reader is referred to preceding remarks upon this subject (p. 160). So-called "nasal" intonation generally indicates an inadequate nasal air-way, and this, as we have seen, is one of the most frequent causes of difficulties in anæsthetisation. The patient should be asked to close the lips and breathe through the nose; to take a deep breath through the mouth; and to give a cough. By these simple procedures it will be possible to estimate the calibre of the nasal channels; to gauge the freedom of lung expansion; to judge whether breathing is principally thoracic or abdominal; and to ascertain the presence or absence of many laryngeal, tracheal, bronchial, or pulmonary affections. An obstructed nasal air-way may call for the preliminary insertion of a mouth-prop. The characteristic cough of chronic bronchial catarrh with little or no secretion may at once point to the C.E. mixture as the best anæsthetic for a short operation; whilst the presence of stridor on deep breathing or of a moist cough may at once indicate that chloroform is the only permissible anæsthetic. The causation of dyspnœa or orthopnœa, particularly if associated with even slight cyanosis, should be most carefully investigated (p. 161).

The state of the **circulation** should be observed. It is always advisable to auscultate the heart; to feel both radial pulses; and to ascertain the cause of any notable pallor or duskiness. Feebleness, irregularity, intermission, or marked slowness of pulse should lead to further inquiry, in order that the most appropriate anæsthetic may be chosen. It is not uncommon, on first applying the stethoscope to the cardiac area of a patient whose heart's action is disturbed by nervous apprehension, to hear a bruit which subsequently disappears, and which is generally regarded as dependent upon a disturbed and irregular action of the chordæ tendineæ.

The **oral cavity should be inspected** and the arch of the palate noted. A very high arch—consequent upon obstruction in, and therefore non-development of, the nasal passages—would indicate a liability to respiratory difficulties, particularly if a "close" method of anæsthetisation be employed. **Artificial teeth**, even though firmly fixed and apparently safe, should always be removed. Careful note should be made of loose natural teeth, lest they become dislodged during anæsthesia, either by jaw spasm, by the insertion of a gag, or by wiping out the mouth. A "quid" of tobacco has been known to lead to asphyxial symptoms during anæsthesia. In the case of children, sweetmeats may possibly be present in the mouth at the time of administration.

E. ATMOSPHERIC CONDITIONS: TEMPERATURE OF ROOM: CLOTHING: MAINTENANCE OF BODILY HEAT

As already pointed out (p. 46) the absorption and elimination of vapours and gases by the blood are directly influenced by the tensions of such gases and vapours within the lungs, so that the **barometric pressure** at the time of administration may be an important factor in anæsthetisation. The best illustration of this is afforded by Paul Bert's system of administering nitrous oxide and oxygen (p. 314). By this system atmospheric pressure is artificially raised and the effects of the anæsthetic are intensified. Although we have no observations bearing upon the point we should expect to find similar effects from anæsthetics when administered at levels considerably below the earth's surface. On the other hand, anæsthetisation at high altitudes, particularly by gases such as nitrous oxide and by very volatile liquids such as ethyl chloride and ether, is attended by delay and difficulty, owing to the tension of such gases or vapours within the blood being too low to produce those results to which we are accustomed at lower levels. With an anæsthetic such as chloroform, however, the vapour of which is dangerous in proportion to its concentration, the low barometric pressure of mountain heights would tend to lessen the chance of overdosage. Whether the fluctuations in barometric pressure which are constantly occurring at or about sea-level are ever sufficient to modify materially the usual phenomena of anæsthesia is questionable. Some observers maintain that such modifications may be observed in the case of nitrous oxide; but the facts which they bring forward to support this contention are not very conclusive, and the author's experience is quite opposed to it.

The **temperature of the air** during the administration of volatile anæsthetics may influence the results obtained, a high temperature being favourable to vaporisation and to subsequent elimination, whilst a low temperature will have an opposite influence. When the temperature is very low delay and difficulty in anæsthetisation may be anticipated.[1] Patients certainly seem to take anæsthetics better when the weather is warm, dry, and bright than when opposite conditions prevail; but we must not forget that catarrhal affections of the nasal, pharyngeal, and laryngeal channels are much more common in cold damp weather, and that these affections, even though slight, may introduce difficulties into the administration (p. 160).

The operating room or theatre should have a temperature of from 65° to 70° Fahr. The higher temperatures insisted upon by some surgeons are of doubtful benefit to patients, whilst they are certainly often detrimental to those engaged in the operation. The author submits that it is more rational for operators and assistants to work in a moderate temperature and to pay special attention to unnecessary exposure of the patient, than to work in a high and enervating temperature and to disregard the extent of cutaneous exposure (*vide infra*). But the question of temperature is probably of secondary importance as compared to that of ventilation. Until quite recently the beneficial effects of efficient ventilation were ascribed to the removal of injurious respiratory products and to the excess of fresh air. But as Leonard Hill has recently shown, the advantages of ventilation are largely dependent upon the actual motion of air over the face, as in fanning; we should therefore endeavour, whatever the temperature of the room or theatre may be, to keep the air gently but constantly in motion. In private houses this air movement is, as a rule, best secured by the presence in the operating room of a good coal fire. In winter-time such a fire will generally produce the desired affects without it being necessary to keep a door

[1] In the *Dental Cosmos* of 1869, p. 659, a case is related in which chloroform anæsthesia could not be induced when the temperature of the room was at 45° Fahr., whereas, on a subsequent occasion, when the temperature was 70° Fahr., the same patient was successfully anæsthetised. The author has met with a somewhat similar case.

or window open. Very often, however, it is advisable either to leave the door ajar or to open a window about half an inch. Even in summer-time a small fire may be advisable. In very hot weather, when a fire is inadmissible windows may often be left widely opened during operations; particularly if some distance away from the operating table. When no open fire is possible, as in most modern operating theatres, special arrangements are of course necessary to secure ventilation.

The detrimental effects of administering chloroform in small rooms heated or lighted by gas or oil lamps have already been considered (p. 33).

A patient who is about to inhale an anæsthetic, whatever that anæsthetic may be, should invariably be **loosely but warmly attired.** Corsets, waist-bands, and collars should be unfastened. If the waist be constricted during the administration of nitrous oxide or nitrous oxide and oxygen, residual air will not be so rapidly expelled as in other circumstances, and imperfect anæsthesia will result. Loose clothing is advisable not only because it allows respiration to take place freely, but because it admits of the immediate application of restorative measures should these become necessary.

In all cases requiring a more or less protracted anæsthesia, the **maintenance of bodily heat** is of great importance. Under ether and chloroform the temperature invariably falls, sometimes to a considerable extent, and it is the duty of the anæsthetist to do his best to prevent and counteract this fall. In the author's opinion, indeed, there is far greater need for attention to the clothing of the patient than for attention to the room temperature. This subject, which is a most important one, has been very thoroughly investigated by S. G. Davis,[1] who has conducted experimental work on dogs as well as clinical observations on patients. His studies support the earlier work of Kappeler, Allen, and Mills, and justify the following conclusions:—

(1) Chloroform produces a loss of body temperature approximately equal to that produced by ether.

(2) Surrounding the field of operation with wet towels

[1] *Johns Hopkins Hospital Bulletin*, April 1909, p. 118.

greatly increases the loss of body temperature and should therefore be studiously avoided.

(3) The loss of temperature produced by ether narcosis is not greatly increased by the previous administration of a moderate dose of morphine.

(4) Excessive application of heat to an individual under the influence of morphine will lessen the usual loss of body temperature from this drug; the additional administration of ether in these circumstances may lead to a rise in body temperature rather than to the expected fall.

(5) Warming of the ether vapour before inhalation will also prevent loss of body temperature, or may actually increase it: undue elevation of body temperature from this source is injurious; the object should be to maintain an even temperature.

(6) Patients should not only be kept dry and warm, but should be anæsthetised in a room free from draughts; and should not be transferred to a cold room after the administration is discontinued.

Patients are often unnecessarily exposed during surgical operations, and this exposure is, in some cases, partly accountable for shock during or after anæsthesia. Feeble persons, infants, and those advanced in years, require special care when about to be subjected to formidable operations; they should, as a rule, be encased in cotton wool except at the immediate site of operation. Indeed, speaking generally, all patients should be protected, as far as possible, from skin exposure by appropriate flannel or other garments, stockings, etc., and should be covered during anæsthetisation by previously warmed blankets. There is no objection to warming the operating table with hot-water bottles, but care should be taken to remove them immediately the patient lies down. If a hot-water bed or tank be employed the anæsthetist should see that its temperature does not exceed that of the human body. A large number of accidental burns have occurred from the absence of these precautions. A notable instance of this occurred in one of the large hospitals of London lately, and an action was brought.[1] It would seem that in this

[1] *The Times*, 30th March 1909.

case some superficial burns of the left arm occurred in this way. The patient ascribed to the same cause extensive paralysis of both arms; he was non-suited on legal grounds before the evidence for the defence was given. At another London hospital a few years ago a baby was accidentally burned by lying on a rubber bottle, filled with boiling water instead of warm water, during the operation of circumcision; a fatal result followed.

Towards the close of lengthy operations, and in cases attended by shock, **hot-water bottles** should be placed in the bed to which the patient will subsequently be transferred, and the bottles should be covered by the bedclothes. Whilst the transference, from the operating room to the warmed bed, is actually taking place the clothes should be momentarily turned back for the reception of the patient, and the hot-water bottles should invariably be removed. A large number of cases have occurred in which hot-water bottles have produced extensive burns during the unconsciousness of the recovery period.

F. POSTURE: CHANGE OF POSTURE: THE TRANSFERENCE OF UNCONSCIOUS PATIENTS: POSTURE PARALYSES

Posture.—The posture of patients during general surgical anæsthesia is a matter of greater importance than is generally imagined. Many of the difficulties encountered by the inexperienced anæsthetist are referable, directly or indirectly, to posture. A faulty posture may introduce undesirable complications into the anæsthesia; render the performance of a surgical operation difficult or even impossible; or lead to inconvenient or dangerous sequelæ. The chief postures now in use are shown in Fig. 12.

Before commencing the administration an endeavour should be made to meet the wishes of the patient, as far as possible, in the matter of posture. Except in the height of summer the operating table should be warmed by means of hot-water bottles which, however, should invariably be removed before the patient is anæsthetised. Patients are often made to lie upon unnecessarily hard surfaces. This discomfort can easily be avoided by the employment of a soft mattress or several blankets beneath the warmed sheet upon which the patient lies. Additional pillows should be at hand for use if required.

The **dorsal** posture is shown in Fig. 12 (A and B). In A the face is turned upwards; in B it is turned to the side. Posture B should be adopted whenever practicable for the induction of anæsthesia. The shoulders should rest upon the table and not upon a pillow; the head should be supported by one or two soft pillows, according to the depth of the chest, so that the head is in the body-line, being neither flexed nor extended. Flexion throws the base of the tongue against the pharynx and encourages stertor and obstructed breathing; extension deprives the larynx of its natural protector the epiglottis, thus rendering swallowing difficult or impossible, and exposing the larynx to the entry of mucus or foreign substances. The face should be turned to one side; the hands with fingers intertwined should rest upon the chest. If the patient be touched or held by bystanders, excitement and struggling will be likely to take place. If, however, all the foregoing points be attended to, the patient may usually be made to pass into deep anæsthesia without the hands becoming separated.

The **propped up or semi-recumbent posture** is not shown in the figure. It is one of the worst positions from the anæsthetist's point of view, owing to the fact that mucus, saliva, vomited matters, blood, or other fluids that may be present within or about the fauces cannot be removed or permitted to escape by turning the head to one side. At the same time there are some patients who cannot breathe comfortably in other positions. This may be the case with the subjects of bronchial, pulmonary, or cardiac disease. Very obese patients, too, usually require several pillows. In all these cases the pillows may be successively removed as anæsthesia deepens, till the dorsal posture is reached. When the semi-recumbent posture is necessary by reason of the presence of ascitic fluid, the trunk may be lowered as the fluid is evacuated.

There is another posture which often causes difficulties during anæsthesia — that in which, by the adjustment of pillows, the **shoulders are raised whilst the head is extended.**

Some surgeons employ this posture for such operations as cleft palate, excision of the tongue, thyroidectomy, and removal of the breast. With some subjects little or no difficulty will arise, particularly if deep anæsthesia be practicable; but with so-called "bad subjects" such a posture may lead to considerable difficulties, and may even have to be changed during the operation. When this posture is required, the patient should first be anæsthetised in the usual position and then carefully moved into the new position. Most operators are gradually becoming aware of the disadvantages of this posture from the point of view of the anæsthetist, and, except for certain cases in which it is essential, it is now rarely used.

The **lateral posture** (Fig. 12, C) is perhaps the most advantageous of all, so far as the anæsthetist is concerned. It is often a good posture when an anæsthetic has to be administered to a patient lying in bed. It is, *par excellence*, the posture for lengthy administrations of nitrous oxide and oxygen. We have seen, moreover, that for those operations within and about the mouth, throat, and nose that admit of performance whilst the patient is thus placed, it is the posture which is least likely to be associated with any respiratory embarrassment from the presence of blood (p. 182). An inclination towards the lateral posture, in other words the **dorso-lateral** posture, is often of advantage in inducing anæsthesia in routine practice. It may be secured upon the operating table by placing a pillow at the patient's back. Many patients prefer this to the purely dorsal posture of Fig. 12 (A and B).

The **latero-prone posture** (Fig. 12, D) is employed for many gynæcological, renal, and rectal operations. It is an excellent one, so far as the anæsthetist is concerned, for those operations within or about the mouth, nose, and throat which admit of being performed with the patient thus placed; for all embarrassment to breathing from blood is avoided. When this posture is required anæsthesia should be induced with the patient in the dorsal or lateral position, and when full anæsthesia has been secured the change should be effected. It is important particularly in the case of heavily built and bronchitic subjects, that anæsthesia should not be too profound,

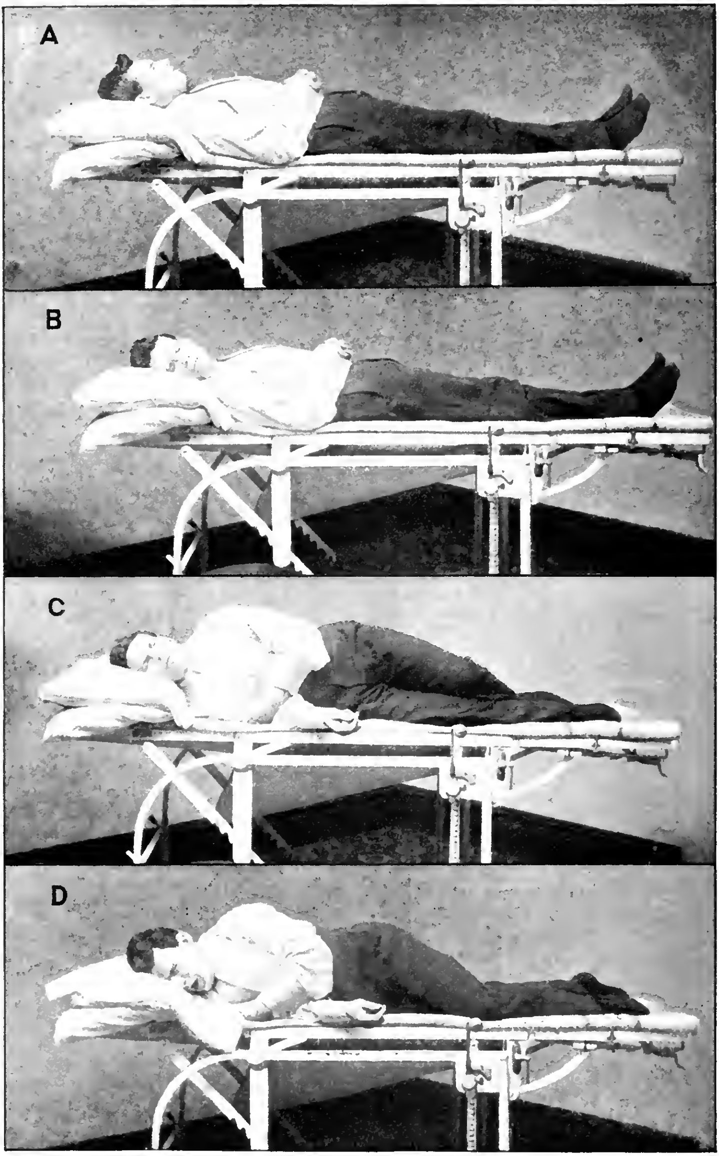

FIG. 12.—The Chief Surgical Postures. A. The Dorsal Posture: face looking upwards. B, The Dorsal Posture: face turned to one side. C, The Lateral Posture. D, The Latero-prone Posture. (Pages 239 and 240.)

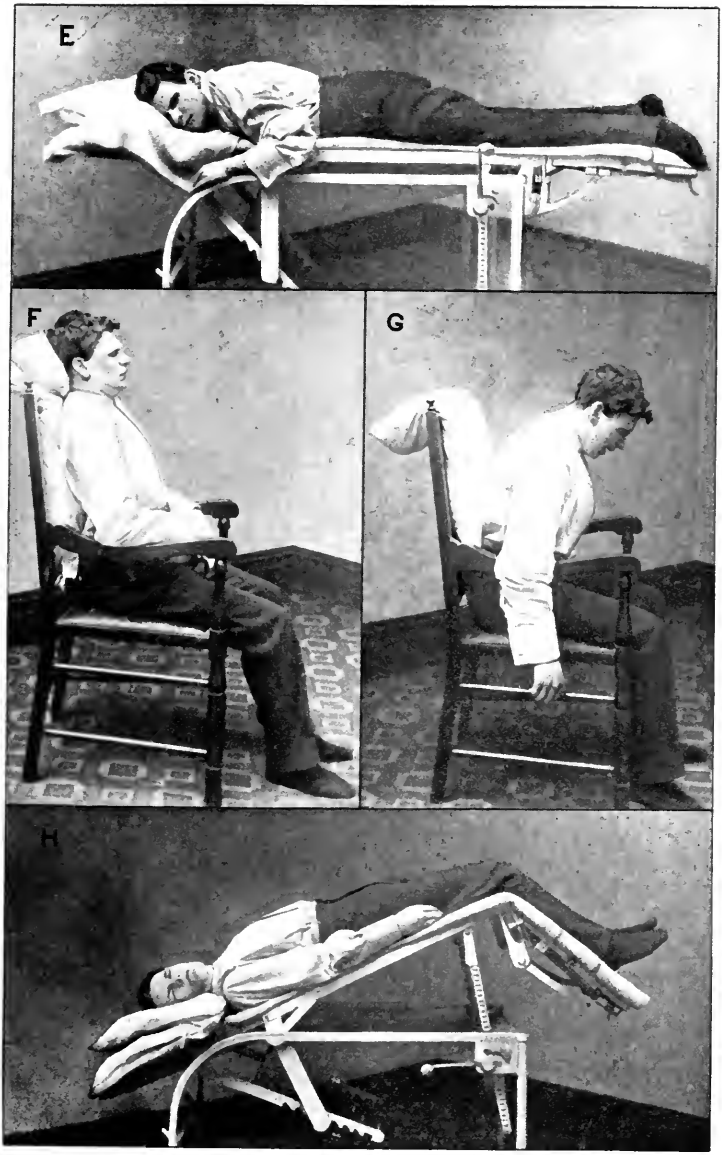

FIG. 12 (*continued*).—E, The Prone Posture. F, The Sitting Posture. G, The Bent-forward Posture. H, Trendelenburg's Posture. (Pages 240-244.)

otherwise the trunk weight may tell injuriously upon lung expansion (p. 578). Should the operation be of considerable length, the upper shoulder and arm should be supported by placing a pillow under the elbow; or Mr. Carter Braine's[1] ingenious arm-support may be used. Should respiratory embarrassment from imperfect lung expansion persist for any length of time, it may induce a state of secondary circulatory depression which may easily be mistaken for true surgical shock. In some operations, as, for example, those upon the kidney, the two states—circulatory depression as the secondary result of the posture, and circulatory depression as the primary result of the operation—may coexist.

The remarks just made apply with even greater force to the purely **prone posture** (Fig. 12, E). When this posture is necessary, as it is for such operations as laminectomy, an endeavour should be made to provide, as far as possible, against respiratory embarrassment. By placing a sand-bag under each shoulder and one under each iliac spine, lung expansion will be facilitated. There is a modification of this posture which is used in Kraske's operation. The patient's trunk is prone; the pelvis is somewhat raised by pillows; the flexed thighs pass downwards over the end of the table; and the knees are supported by a chair. By a little adjustment the whole body may be placed somewhat obliquely, so that the head comes to the side of the table, thus rendering the administration less difficult. As mentioned below, the prone-Trendelenburg posture may also be used in these cases.

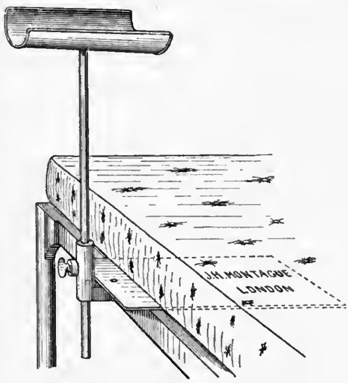

FIG. 13.—Carter Braine's Arm-Support.

The **sitting posture** (Fig. 12, F) has already been discussed when dealing with nose, throat, and dental operations (pp. 182 and 199), and the administration of chloroform to patients in

[1] See *Brit. Med. Journ.*, 15th December 1900, p. 1716.

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this posture has been considered.[1] When the sitting posture is employed for operations other than those mentioned, it will be found easier to keep up a good type of chloroform anæsthesia if a small quantity of mucus be present within the pharynx, than if the air-way be absolutely free. It is therefore advisable so to adjust the preceding ether administration that mucus is somewhat freely secreted. If it be found impracticable to introduce into the administration this trifling but advantageous degree of obstruction, it may be necessary to stimulate respiration from time to time by sponging the fauces. In this way the patient will be prevented from passing into a state of inconveniently light anæsthesia, with pallor and diminished arterial pressure.

The "**bent-forward**" **posture** (Fig. 12, G) is sometimes employed when the naso-pharynx is to be cleared by means of the natural or artificial finger nail. The usual procedure is to anæsthetise the patient in the dorsal posture, to raise him to the sitting position, to insert a Mason's gag, and to tilt the whole body forwards. There is, however, little if anything to be gained by adopting this posture for throat operations.

The **Trendelenburg posture** is an exceedingly interesting one from many points of view (Fig. 12, H). It has already been referred to when dealing with abdominal operations (pp. 209 and 212). Patients who are to be operated upon in this position are generally first anæsthetised in the dorsal posture and then placed as shown in the figure. As the pelvis is being raised, the head should be simultaneously lowered so as to keep the latter in the body-line. If the pelvis be raised without lowering the head, some degree of approximation of the chin towards the sternum will result. On the other hand, it is important that the occiput should not project and drop backwards over the end of the table, otherwise a state of extension will be produced. In either event respiratory

[1] Snow administered chloroform to 949 patients in the sitting posture and without any ill effects. He believed that, provided the ordinary means were adopted for the treatment of faintness, should it arise, there was no great objection to this position. He met with two or three cases, however, in which faintness came on in the sitting posture during recovery from chloroform. Chaldecott has recently (1912) advanced the same opinion, based upon a series of several hundred consecutive administrations.

difficulties might result. As shown in the figure, the head should be turned to one side.

By the use of the Trendelenburg posture in abdominal surgery, the type of chloroform anæsthesia to which we are accustomed during abdominal operations upon horizontally placed patients becomes completely changed. We have already seen that when the patient is horizontal, these operations have a special tendency during deep chloroform anæsthesia to be attended by all degrees of circulatory shock; for cardio-inhibitory and vaso-motor effects produced by traction, etc., are often very considerable owing to the already reduced blood pressure. But when a deeply chloroformed patient is placed in the Trendelenburg posture the blood pressure rises to such an extent as to counteract, more or less completely, any fall that may be occasioned by traumatic stimuli. Although the author has notes of a large number of cases of severe surgical shock in the horizontal posture, he has seen few, if any, in the Trendelenburg position. Another advantage of the position is that mucus and saliva tend to flow away from the laryngeal orifice, so that coughing and straining are uncommon. The chief disadvantage connected with the Trendelenburg position is that free respiration may become somewhat interfered with, particularly in certain subjects, not so much because the abdominal contents press unduly upon the diaphragm, but because, by reason of the accumulation of blood within the veins of the more dependent parts, the tongue and adjacent structures have a tendency to increase in size, so that some degree of narrowing of the air-way results. It is not uncommon for the swollen tongue to protrude between the teeth, and for obstructive stertor to become audible. It may, in fact, be necessary to keep the lower jaw pressed well forwards in order to bring the engorged tongue away from the pharynx (p. 554). The oral air-way (Fig. 20, p. 258) is of great use in these cases. Should the patient be the subject of any condition attended by dyspnœa or likely to lead to dyspnœic symptoms during anæsthesia, the Trendelenburg posture is usually contra-indicated owing to its favouring the accumulation of blood within the great veins and right heart, which accumulation, as we have seen, is such a prominent feature in most asphyxial states. By neglecting these considerations, and by keeping a cyanotic and dyspnœic patient for some considerable time in the Trendelenburg posture, the face and scalp may become œdematous, and the wrist pulse feeble or imperceptible. The state thus brought about may be erroneously ascribed to surgical shock, but it is of a totally different nature. After the withdrawal of the anæsthetic and the removal of the patient to bed, there is, in a case of this kind, a grave risk of fatal cardiac failure from the prolonged asphyxial strain to which the heart has been subjected. Care must be exercised in lowering patients from the Trendelenburg to the horizontal posture. Should the circulation be feeble and anæsthesia still deep, there is undoubtedly some risk of syncope occurring; but such syncope would probably be only temporary and easily treated.[1]

The author has on one occasion employed what may be termed the **prone-Trendelenburg posture** and with very good results. The operation was that known as Kraske's. When the patient had been fully anæsthetised, the operating table was arranged as shown in Fig. 12 H; the patient was carefully turned face downwards and adjusted so that the gluteal regions formed the highest part. The object of the posture was to limit the degree of surgical shock. The arrangement answered well, but further experience is necessary before a more definite pronouncement can be made concerning it.

The **lithotomy posture** is generally secured by the use of Clover's crutch. Anæsthesia should be induced with the patient in the dorsal posture, and full anæsthesia obtained before the crutch is applied. In adjusting the crutch it is important that the leg straps should be placed some little distance *below* the knee. The neck strap is usually passed under one shoulder and over the other in order to interfere

[1] Cases have been recorded (*Lancet*, 30th December 1905, p. 1713) in which the lowering of the patient's body from the Trendelenburg to the horizontal posture is believed to have been responsible for subsequent intestinal obstruction. It is alleged that the sudden return of the abdominal contents towards the lower part of the abdomen has brought about an incarceration of the colon within the pelvis or a volvulus of the small bowel. Such allegations, however, must be received with caution. The author is informed by a leading obstetric physician that he has known fatal obstruction to arise a month after hysterectomy performed in the Trendelenburg posture, a coil of bowel having passed through a hole in the omentum, presumably when the patient's body was lowered.

as little as possible with respiration. Very obese subjects and those who are plethoric and congested in aspect may evince such symptoms in this posture that its adoption may be impracticable. It is unadvisable, in the case of elderly patients with degenerated vessels, to maintain the lithotomy posture for any great length of time, owing to the risk of gangrene in the lower extremities.[1]

Change of Posture.—In certain cases a change of posture may prejudicially affect respiration; in others it may depress or even arrest the peripheral circulation. The subject may, therefore, be most appropriately considered from two points of view—the respiratory and the circulatory.

It is often necessary, particularly in rectal, gynæcological, renal, and abdominal surgery to place the patient in some posture other than that employed during the induction stage. Under these circumstances full anæsthesia should be secured before the change is effected, and the breathing carefully watched during the change. Respiratory embarrassment, may readily arise if the posture be altered during induction, particularly in the case of muscular and obese subjects whose upper air-passages are incapacious. The most probable explanation of this fact is that by moving the patient's body, mucus and saliva trickle or flow from one part of the upper air-tract to another, so that swallowing—the precursor of coughing, retching, and vomiting—is excited, and breathing becomes suspended. With laryngeal closure from delayed or continuous deglutition there is often jaw-spasm and general rigidity. Cyanosis, with other asphyxial phenomena, may thus quickly follow a change of posture during incipient anæsthesia. But there are certain short-necked, plethoric subjects who, even though they be deeply anæsthetised, cannot be moved from the dorsal into the lithotomy or into the Trendelenburg posture without some degree of respiratory embarrassment taking place (p. 559). Towards the conclusion of an administration, change of posture rarely causes respiratory embarrassment of any importance. An

[1] A case has been verbally reported to the author in which this unfortunate accident occurred; but whether the gangrene resulted from the prolonged acute flexion of the popliteal artery or from the pressure of the leg-strap upon the vessels, he cannot say.

illustrative case (p. 572), however, appears in a subsequent chapter, in which mucus was thrown by a sudden alteration of posture into an insensitive larynx and so caused arrested breathing.

Change of posture is not likely to affect prejudicially the circulation under ether even in profound narcosis. In the case of chloroform, however, a liability to syncope is incurred if a deeply anæsthetised patient be raised from the horizontal into the sitting posture. If it be necessary to effect such a change in posture, as in bandaging after breast operations, the patient should have shown some signs of recovery before the trunk is raised. Similarly, changes of posture should be very carefully effected when surgical shock is present. During this condition, raising the body from the horizontal into the sitting posture, or from the Trendelenburg into the horizontal posture, may be attended by syncope, unless the precaution has been taken of first allowing the patient to recover to a sufficient degree the vaso-motor control which has been in abeyance during deep anæsthesia.

Change of posture may be indicated as a remedial measure. Thus, if the circulation be greatly depressed, the substitution of the dorsal posture for the sitting or for the semi-recumbent, will produce marked improvement. Similarly, the substitution of the Trendelenburg posture for the dorsal may be followed by good results. Again, should respiratory embarrassment arise as the result of the latero-prone or prone posture, it may be necessary to place the patient, at all events temporarily, upon his side or back. Sometimes the dorsal posture should be changed to the lateral. This change is advisable as a routine practice after surgical operations in general (p. 623). It is specially indicated, however, when blood or other fluids have entered the bronchial passages (p. 566).

The Transference of Unconscious Patients.—Speaking generally, the conveyance of unconscious patients from one spot to another is open to considerable objection, particularly in the early stages of anæsthesia. Whenever practicable it is advisable to anæsthetise the patient upon the table or bed to be used during the operation. The remarks already made as to the risks of change of posture during partial anæsthesia specially apply in the present connection. It may, in fact, be particularly hazardous[1] to move a patient from one place to another during the induction stage. In determining whether any given patient should or should not be moved, the most important consideration is the type to which he belongs. It is undesirable, for example, to carry from the bed to the operating table a heavily built, thick-necked man, who is just becoming stertorous, unless indeed the bed and table be near one another, and a gag has been inserted in order to provide against arrested breathing. The same remark is applicable to the transference of other difficult or bad subjects, *e.g.* those with a distended abdomen who are about to be operated upon for intestinal obstruction, those with angina Ludovici, and those suffering from grave respiratory or circulatory affections. On the other hand, in the case of children, there is little or no objection to administering the anæsthetic whilst they lie in bed, and to transferring them when on the threshold of deep anæsthesia to the room prepared for the operation. The lateral posture is much to be preferred to any other in effecting such a transference; and the anæsthetist should himself carefully supervise every detail of the proceedings. The responsibility is his should obstructed respiration, vomiting, or any other detrimental change take place, and he should never delegate the control of the manœuvre to nurses, porters, or indeed even to the operating surgeon.

When, at the conclusion of an administration, it becomes necessary to transfer the still unconscious patient from the operating table or chair to bed, the transference may excite respiratory difficulties, similar in kind to, though less in degree than those which may arise during the induction stage. The practice of wheeling or carrying recovering patients from an operating theatre or room to some other part of the building is not without its dangers. Fatalities have, in fact, taken place on these occasions. It will be convenient, however, to

[1] See a case reported in the *Lancet* of 16th May 1903, p. 1368. The difficulties described came on immediately the patient was moved to the operating table. See also *Brit. Med. Journ.*, 22nd Oct. 1904, p. 1085, and *Lancet*, 17th Sept. 1904, p. 841, for details of a fatality apparently initiated by the transference of the patient to the operating table during partially established anæsthesia.

postpone further consideration of this point till we discuss the after-condition of the patient in Chapter XXI.

Posture-Paralyses.—It is important to bear in mind that when the extremities of anæsthetised patients have been fastened up or allowed to remain in certain positions for a considerable time, the nerve-roots or nerves themselves may be so stretched or compressed that paralytic states varying both in extent and in degree may result. Attention was first drawn to this point by Büdinger[1] in 1894; and Krumm,[2] Schwartz,[3] Weir,[4] Cotton and Allen[5] have contributed to our knowledge concerning it. One common form of posture-paralysis is that which is liable to occur after any prolonged operation during which the arm of the patient has been abducted and drawn upwards, whilst the head has been turned to the opposite side. The symptoms in such a case may exhibit great variety. An Erb's paralysis is very common, the deltoid, biceps, brachialis anticus, and supinator longus being affected. Defect in sensory power is also frequently observed. Recovery is often tardy, sensation returning before motion. As regards the immediate causation of the paralytic state brought about by the posture in question some difference of opinion exists. Some observers maintain that the brachial plexus becomes compressed between the clavicle and first rib; others that the compression takes place between the clavicle and the transverse process of the fifth, sixth, or seventh cervical vertebra; others that the plexus becomes stretched over the head of the humerus. Most observers agree that the turning of the head to the opposite side, by which the plexus is put upon the stretch, is an important factor. This point is well exemplified in the following case, which occurred in the author's own practice before he was fully aware of the danger of the *combined* effect of

[1] "Über Lähmungen nach Chloroformnarkosen aus Billroth's Klinik" (*Archiv f. klin. Chir.* Bd. 47, Heft 1); *Centralblatt f. Chirurgie*, 1894, xxi. 703-705.

[2] *Klinische Vorträge*, No. 139, 1895.

[3] "Des paralysies post-anesthésiques," *Congrès français de Chirurgie*, 1897, p. 688.

[4] *Medical News*, 1901, vol. lxxix. p. 124.

[5] *Boston Med. and Surgical Journ.*, 7th May 1903, p. 499, "Brachial paralyses—post narcotic."

fastening up the arm and turning the head to the opposite side. It is interesting to note that the paralysis took place in the arm which was *least* drawn upwards, showing that the turning of the head was, at all events in this case, quite as important a factor as the position of the arm.

Illustrative Case, No. 1.—F. 35: thin. Operation for appendicitis. Arms fastened up by means of a double wristlet connecting hands together at a distance of about 7 or 8 inches. Backs of wrists resting on pillow. *Right* arm pulled up more than left. Head turned to *right*. Administration lasted forty-eight minutes. On recovery of consciousness patient complained of inability to move *left* arm. Could not flex fingers. A few days later, tenderness was felt over cervical plexus above clavicle. This remained for a fortnight. Sixteen days after operation no noticeable improvement. Flattening below shoulder. No power of abducting arm. Grasp feeble, especially with first, second, and third fingers. Numbness over thumb and two and a half fingers. Pronation and supination slow and feeble.

Dr. Lewis Jones expressed the opinion that the injury was extensive in area, but slight in degree; that it had involved the fifth, sixth, and seventh cervical roots; that it was caused by a stretching of those roots; and that the stretching was partly due to the position of the arm during the operation, and partly to the position of the head and neck.

Another form of paralysis which is not uncommon is that which may arise from allowing the arm or arms of the patient to fall to the side of the operating table, so that the musculo-spiral nerve becomes compressed between the bone and the table edge. The prolonged application of straps and bandages, *e.g.* a Clover's crutch or an Esmarch's bandage, may also induce temporary motor or sensory paralysis. Complete recovery from these various posture-paralyses generally takes place within a few weeks or months, though it may be delayed for as long as a year and a half. As regards treatment, Schwartz recommends massage and electricity (continuous and intermittent). The symptoms generally clear up and disappear from the periphery towards the centre.

When full anæsthesia has been secured, it is important to see that the arms are safely adjusted. One of the best methods of protecting them from posture-paralyses is shown in Fig. 14. The arms are placed *underneath* the free portions of the sheet upon which the patient is lying; they are pressed closed to the side, and are then fixed in that position by strong safety-pins so that they cannot reach the edge of the table. The pins should be inserted close to the elbows. Instead of the sheet being pinned to the subjacent blankets or mackintosh it may, if preferred, be passed back under the patient's body. Another excellent plan is to employ the

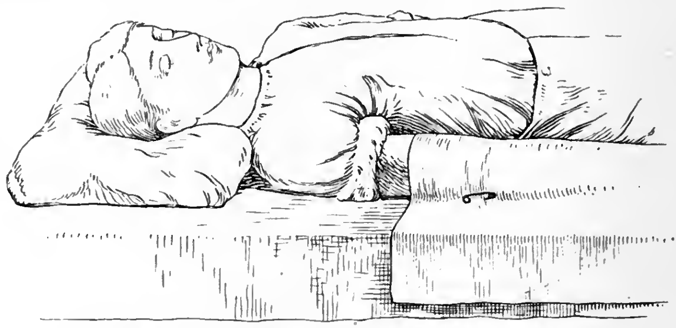

FIG. 14.—Method of fastening Arms to prevent Posture-paralysis.

ingenious and simple arm-rest recently devised by Mr. Herbert J. Paterson (Fig. 14*a*). A still simpler procedure is to extend the arms upon the table and to place the hands well under the patient's gluteal regions. In some cases it is a good plan to pin up the wrist-bands to the collar so that the hands rest over the clavicles. This arrangement has the advantage of permitting the anæsthetist to have access to the radial pulse, but care must be taken lest the upper arms gravitate towards the edge of the table. If it be necessary to abduct the arm and bring it upwards above the head, as in operations upon the breast and axilla, care must be taken not to do this too forcibly and, from what has been said above, it will be seen that the head should not be turned too much to the opposite side.

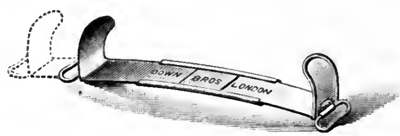

FIG. 14*a*.—Paterson's Arm-rest.

G. THE EFFECTS OF SURGICAL PROCEDURES UPON ANÆSTHETISED PATIENTS: SURGICAL SHOCK: CONSECUTIVE OPERATIONS

It has been pointed out in preceding pages that surgical procedures are capable of very materially modifying what has been termed simple surgical anæsthesia (p. 38). It has been shown that the state with which we are familiar in the operating theatre is one which is frequently the product, so to speak, of the effects of anæsthetics on the one hand and of the proceedings of the surgeon on the other. Applying the terminology of Chapter III., we may say that surgical procedures often convert simple into complex anæsthesia. It is true that in many cases this complex condition hardly deserves its title, for beyond some slight alteration in breathing, pulse-rate, or colour, which would not have been observed had no surgical stimuli been applied, there may be nothing to distinguish it from simple or normal anæsthesia. But in many cases, and particularly in many abdominal, rectal, renal, and gynæcological cases, the proceedings of the surgeon have a more distinct share in the production of the symptoms presented by the patient, and the only reason why this fact is not more generally recognised is that we have become accustomed to look upon the stertor, the stridor, the pallor, and other phenomena of the operating theatre as necessarily due to the action of the anæsthetic or its method of administration.

It will now be convenient to attempt to bring to a clinical focus all that has been said in preceding pages as to the effects of surgical procedures during anæsthesia, and to summarise the numerous ways in which these procedures may operate in practice. Surgical procedures may affect the anæsthetised patient:

(i.) By causing hæmorrhage;

(ii.) By involving the exposure of large cutaneous or cut surfaces;

(iii.) By necessitating certain postures;

(iv.) By producing interesting but unimportant reflex effects upon the respiratory or circulatory system;

(v.) By producing such grave reflex respiratory or circulatory phenomena as to constitute surgical shock; or

(vi.) By the entry of air into veins.

(i.) The effects produced by **hæmorrhage** frequently modify the phenomena of anæsthesia. Blood may be lost gradually, as in Illustrative Case, No. 75; or suddenly, as in Illustrative Case No. 74. Tachycardia, pallor, coldness of extremities, and pulselessness are the prominent symptoms of hæmorrhage. Infants, very old persons, and anæmic and cachectic subjects are naturally more seriously affected by loss of blood than more vigorous persons. During the removal of large and vascular tumours, the excision of the upper jaw, and similar cases, the anæsthetist should narrowly watch the colour and pulse of the patient. The greater the quantity of blood lost, the smaller should be the quantity of anæsthetic given. The effects produced by hæmorrhage may coexist with those of true surgical shock. In the above-mentioned Illustrative Cases the latter condition was absent. Restlessness during the recovery stage is a common after-effect of severe hæmorrhage.

(ii.) The importance of maintaining the **bodily heat** during surgical operations has already been mentioned (p. 236). The exposure of large cutaneous surfaces to cold air or to towels wrung out in lotions is certainly favourable to shock. The author has known general pallor and pulse feebleness to occur in a baby who was being anæsthetised by ether for circumcision, and who was lying without clothes close to an open window on a cold day. The prolonged exposure of large wounds, and particularly of the intestines or other abdominal contents, is also greatly to be deprecated as favouring, if not actually producing, circulatory shock.

(iii.) The influences of **posture** have already been considered, and the reader who is interested in the effects of surgical procedures during anæsthesia will do well to study carefully the remarks already made on this subject (p. 238). It has been pointed out that certain postures are capable of interfering with respiration ; whilst others may affect the circulation. The most important point, perhaps, in this connection is that if the respiratory embarrassment which may thus be brought about be allowed to persist for a considerable time, circulatory depression will become a conspicuous feature of the case. In this way a condition may arise capable of completely misleading the inexperienced anæsthetist, the pallor and feeble or imperceptible pulse being erroneously attributed either to the anæsthetic or to surgical shock. The diagnosis is at once settled by remedying the posture.

(iv.) It is unnecessary again to refer to the interesting but unimportant **reflex respiratory and circulatory phenomena** which may arise during anæsthesia. These have already been fully considered when dealing with the physiology of anæsthesia (pp. 67 to 71).

(v.) **Surgical shock** has already been defined (Chapter III. p. 42); and its three forms (*a*) respiratory shock, (*b*) circulatory shock, and (*c*) composite shock have been described.

Respiratory shock has been physiologically and clinically considered (p. 67). It has been shown to be the state which results when respiratory embarrassment of a threatening character is reflexly initiated by some surgical procedure. It occurs under all anæsthetics. A good example of this condition is furnished by Illustrative Case, No. 42 (p. 562), which is worthy of careful study. It has been seen that this form of shock is most common during light anæsthesia, and that the stertor, stridor, and muscular spasm which may individually or collectively initiate it are most frequently met with during certain operations. It is also clear, from what has already been said, that patients who, from natural or pathological causes, are most liable to respiratory embarrassment will be most liable to this form of shock. The commencement of operations, and particularly the commencement of rectal, gynæcological, and urethral operations before full anæsthesia has been secured is liable to induce respiratory shock. The rapidity with which the circulation will fail in the course of this variety of shock will depend upon the special circumstances present.

By far the commonest form of surgical shock met with in practice is that to which the term **circulatory** is applied in these pages (p. 69). Reflex circulatory disturbances are often altogether overlooked, or if observed are erroneously ascribed to other causes than the surgical procedure. The most interesting and important fact in connection with this form of shock is that, unlike respiratory shock, it is rarely if ever met with during light anæsthesia. It is essentially a phenomenon of full narcosis, and is, as we have seen, far more common under chloroform and its mixtures than under ether. There is still a widespread belief that a circulatory form of surgical shock may accompany the commencement of an operation during light or moderate anæsthesia, but this view should be discarded. The risk of operating during partially established anæsthesia **is that of the reflex respiratory derangement** above described. The author has no hesitation in asserting that in a very large number of the cases in which chloroform anæsthesia is believed to have been carried to the point of syncope, the surgical procedure has itself been the immediate and exciting cause of that syncope. In one sense and in one sense only is the anæsthetic blameworthy in the class of cases now under consideration—it predisposes to circulatory shock by reducing the blood pressure. When chloroform administration is carried to the point at which the corneal reflexes vanish and the fall of blood pressure is considerable, reflex cardio-inhibitory and vaso-motor effects which would be hardly noticeable with a less depressant anæsthetic, or with a less deep chloroform anæsthesia, now produce marked effects. In the absence of stimuli capable of reflexly affecting the centres in question, deep chloroform anæsthesia may usually be maintained without any sudden or alarming pulse depression. Conversely, in the absence of deep narcosis under chloroform, surgical stimuli will not produce any noticeable circulatory effects. The two conditions, the narcotic or predisposing and the operative or exciting, must be present; and the result will be circulatory shock. This condition may often be studied during appendicectomy and other abdominal operations. The reader is therefore referred to Illustrative Cases, Nos. 55 to 72, pp. 603 to 615, in which will be found some striking examples of reflex circulatory shock. The diagnosis and treatment of the condition will be considered in connection with these Illustrative Cases (Chapter XX. p. 616).

When respiratory shock is rapidly followed by circulatory depression, or when circulatory shock is rapidly followed by respiratory depression, the state to which the term **composite shock** has been applied will arise. For remarks upon this form of shock the reader is referred to Chapter III. (p. 72) and Chapters XIX. and XX. (pp. 562 and 602).

(vi.) The effects produced upon the anæsthetised subject by the **entry of air into veins** are considered on page 615.

Consecutive Operations.—Reference has already been made (p. 66) to the effects which may be produced upon the anæsthetised subject by the commencement of a second operation at the conclusion of the first. The degree of anæsthesia appropriate towards the close of one surgical procedure may be inappropriate for the commencement of another. If the second operation be begun by a skin incision, it may be necessary to increase the degree of anæsthesia before the incision is made, otherwise inconvenient reflex results may occur. On the other hand, if at the conclusion of a lengthy operation the surgeon wish to remove tonsils or post-nasal adenoid growths, it is important that the patient should have regained his coughing and swallowing reflexes before the second operation is begun. If this point be not attended to, the larynx may readily become invaded by blood.

H. ANÆSTHESIA WITH "REDUCED CIRCULATION"

Acting on the principle that the less anæsthetic introduced into the circulation the better for the patient, Klapp[1] suggested that the blood stream should be entirely cut off from the lower limbs by elastic bandages. These he applied close up to the groin, and he tightened them gradually so as to interrupt the venous return before obstructing the arterial inflow. When the arteries also have been occluded by tightening the tourniquets, a large amount of blood is locked up in the veins of the legs, and no anæsthetic thereafter administered can gain access to it. It is claimed that less anæsthetic is then needed to produce given effects; that excitement, cyanosis, salivation, and post-anæsthetic complications are greatly lessened; and that the blood thus locked up in the limbs acts as a reservoir which can be drawn on in an emergency to dilute and counteract the toxic blood of a patient who has received an overdose. Recovery after suspension of the administration is also said to be unusually rapid; and the danger of thrombosis to be very slight. One author claims that the anæsthetic required is reduced one

[1] *Therapie der Gegenwart*, August 1909.

half.[1] Zur Verth[2] and Franke[3] also report enthusiastically on it, as does Dawbarn in America.

Our own experience of the method is not nearly so favourable. It is true that slightly smaller quantities of anæsthetic, whether it be ether, chloroform, or a mixture, are required; but the difference is not great, and recovery is little if at all hastened. Vomiting and other similar after-effects are also met with on much the same scale as when the circulation has not been "reduced." Further, the risk of thrombosis has turned out to be not quite so negligible as some of the experimenters believe; and tingling, numbness, and other unpleasant sensations in the legs are sometimes very persistent and annoying to the patient after the administration.

I. ARRANGEMENT OF APPARATUS: APPLIANCES AND REMEDIES WHICH SHOULD BE AT HAND DURING THE ADMINISTRATION

Whenever practicable, the apparatus to be used for the administration should be arranged before the patient enters the room in which the operation is to be performed. Everything should be in perfect working order. If the nitrous oxide-ether sequence is to be employed, the nitrous oxide bag should be filled to the requisite degree (p. 288), and in cold weather the ether chamber well warmed. Special attention must be paid to the valves of the nitrous oxide stop-cock. There should be no smell of anæsthetic vapour. Any gags, mouth-props, nasal tubes, etc., that will be required for a throat or jaw operation, should be sterilised and placed on a convenient table. The apparatus when ready may be covered with a clean towel. In ordinary surgical practice these arrangements may with advantage be made immediately before inspecting the patient.

The administrator should always have at hand:

1. Instruments for opening the mouth and maintaining it in that position;

[1] H. Délagenière, *Bulletin de l'Académie de Médec.*, 25th July 1911.
[2] *Münch. medizin. Wochenschrift*, 17th November 1908.
[3] *Deutsche med. Woch.*, 26th May 1911.

2. Appliances for securing a free oral air-way;
3. A pair of tongue-forceps;
4. A small basin, a towel, and a piece of sponge; and
5. Instruments for performing tracheotomy.

He ought always to be prepared to open the mouth of the patient without delay. There are some forms of respiratory

FIG. 15.—Mason's Gag.

embarrassment which can only thus be relieved. When the teeth are more or less deficient, all that is necessary is to introduce a **Mason's gag**. The gag shown in Fig. 15 is, in the author's judgment, the best. The spring should be strong, so that the blades come closely together, and the notches for the movable catch must not be too deeply cut. The parts of the gag which come in contact with the teeth or gums should be

FIG. 16.—Wooden Wedge for separating clenched teeth, and Mouth-Prop for keeping teeth apart.

covered with rubber tubing. If there be any difficulty in introducing this gag, which is not unfrequently the case in muscular subjects with good teeth, some form of **mouth-opener** must be used. The wooden wedge of Fig. 16 answers well. A small strong **mouth-prop**, so shaped that it cannot easily slip when placed between the teeth (Fig. 16), is often of use either for inserting before commencing the administration or for introducing subsequently. The combined wedge and prop shown in Fig. 17 is often useful. It is capable of separating the teeth to the extent of a $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ inch according to the particular way in which it is adjusted.

FIG. 17.—The Author's Wedge-Prop.

The **tongue-forceps** shown in Fig. 18 is as efficient as any. It has, however, the disadvantage of bruising the tongue unless very carefully applied. A tongue-forceps which actually pierces the lingual tissue causes as a rule much less discomfort to the patient subsequently. Bellamy Gardner's tongue-clip (Fig. 19) is a satisfactory instrument of this type.

The author has found the little appliance shown in Fig. 20

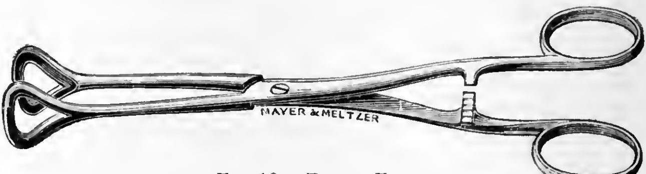

FIG. 18.—Tongue Forceps.

exceedingly useful in practice. Its object is to convert nasal breathing, which is very often inadequate, into oral breathing. It consists of a grooved metal ring from which passes a curved

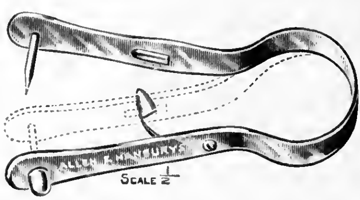

FIG. 19.—Bellamy Gardner's Tongue Clip, as modified by St. Clair Thomson.

FIG. 20.—The Author's Artificial Oral Air-way.

rubber tube sufficiently thick in its walls to prevent that approximation between the tongue and palate which is so common in certain subjects during anæsthetisation. It must not be introduced until anæsthesia is fairly established, when the mouth should be opened with a Mason's gag, and the air-way placed in such a position that the metal ring separates the teeth. A small size is necessary for children.

Another useful appliance is the tongue retractor (Fig. 21) which we owe to the ingenuity of F. W. Longhurst. When placed in position it keeps the base of the tongue and epiglottis away from the pharyngeal wall. It is especially useful for preserving a free air-way in short-necked muscular men whose upper air-passages are abnormally small. It is

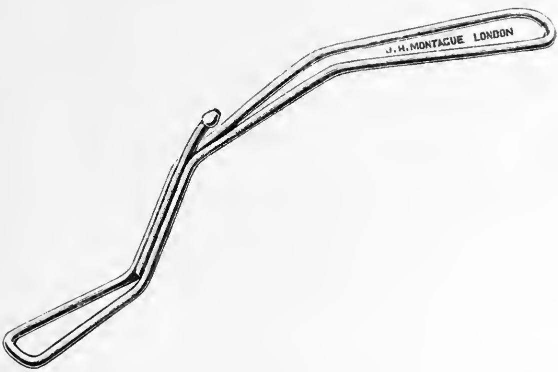

FIG. 21.—Longhurst's Tongue Lever fitted with Chloroform Tube.

furnished with a delivery tube to which a Junker's chloroform inhaler may be attached.

A new, coarse, moistened **sponge**, about the size of a hen's egg, together with a bowl of water, ought always to be at hand when anæsthetising patients with intestinal obstruction or other affections attended by vomiting. A sponge is also useful when much mucus is secreted.

Instruments for the performance of tracheotomy should always be available.[1] Fig. 22 shows a convenient **emergency case**,[2] which contains all the appliances referred to above

[1] A case occurred in the author's own practice some years ago which showed the necessity of being prepared with tracheotomy instruments on *all occasions*. Had he not had a tracheotomy tube with him, it is highly probable that he would not have been able to rescue the patient from imminent death. The case is fully described on p. 564.

[2] This little case is manufactured by Messrs. G. Barth & Co., 54 Poland Street, Oxford Street, W., and is specially adapted for use in operating theatres and elsewhere when anæsthetics are being employed.

together with a hypodermic syringe and a compartment for

Fig. 22.—Emergency Case.

such preliminary narcotics and remedial agents as may be necessary. (See p. 261 and Chap. IX.)

In **dental practice** the anæsthetist should have with him

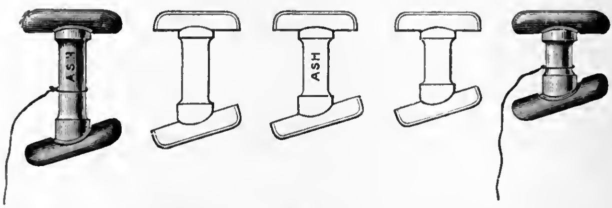

Fig. 23.—Set of five of the author's Mouth-Props for use in dental practice (half-size).

several mouth-props for keeping the teeth apart during the administration. Having tried numerous kinds, the author devised the props shown in Fig. 23. It is made of aluminium and is so shaped that it adjusts itself to the angle made by the lower jaw receding from the upper. It is furnished with detachable rubber pads, which can be renewed from time to time. When in position it engages several teeth, so that there is little or no chance of a faulty or loose tooth being injured. Five sizes are necessary. All props containing springs or screws are liable to break, to get out of order, or to be contaminated with blood, pus, etc. The props shown can be easily sterilised by boiling. All wooden or vulcanite props, although apparently less cumbrous than those recommended, will be found to slip more frequently than the props shown in the figure.

Hypodermic solutions of **morphine, atropine, and scopolamine,** may be required for use either before or during anæsthesia (Chapter IX.).

Various **medicinal remedies** have been advocated for the

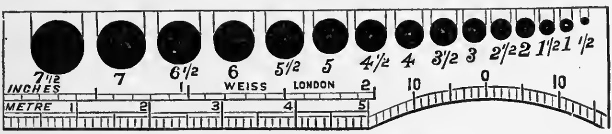

Fig. 24.—Pupillometer. (By kind permission of Mr. Edgar A. Browne.)

treatment of alarming symptoms during or after anæsthesia, and opinions are still divided as to their relative efficacy. The author regards all such drugs as useless in combating conditions directly attributable to the action of the anæsthetic. As will subsequently be pointed out (Chap. XIX.), the establishment of a free air-way, artificial respiration, and partial inversion are of far greater value than any other restorative measures with which we are acquainted. At the same time we must not lose sight of the fact that anæsthesia is frequently complicated by surgical shock of a circulatory type, so that an **apparatus for the intravenous or subcutaneous injection of saline fluid**, and drugs such as **strychnine, suprarenal extract, ergotin, pituitary extract**, and **digitalin** which, according to many authorities are useful in the treatment of surgical shock, should be in readiness when this condition is likely to arise. **Alcohol, ammonia, amyl nitrite,** and **ether** (for subcutaneous injection), have one and all their advocates; but it is questionable whether they are of any real value in the treatment of conditions brought about by anæsthetics. A cylinder of compressed **oxygen** should invariably be kept in readiness in public institutions in which anæsthetics are given on a large scale.

A **pupillometer** (Fig. 24) is of use in studying and recording the phenomena of anæsthesia.

J. ASEPTIC PRECAUTIONS: CLEANSING AND DISINFECTING APPARATUS AND APPLIANCES

Although it may be going too far to say that there is as great a need for the observance of aseptic and antiseptic principles in the administration of anæsthetics as in surgery proper, it is highly important that such principles should, as far as possible, be adhered to. Whilst in ordinary surgical cases it is unnecessary for the anæsthetist to do more than thoroughly cleanse his hands, and see that the inhalers and appliances he employs are scrupulously clean before use and carefully washed afterwards, there are certain cases in which special care and precautions must be adopted. These will be presently referred to.

All inhalers and other apparatus should be capable of being thoroughly washed, and any whose mechanism may be injuriously affected by hot water should be discarded as unsuitable. It should be a matter of routine, immediately the administration is at an end, to twice wash in hot water everything that has been used; and should any of the apparatus employed have been contaminated by pus, blood, vomited matters, etc., hot weak carbolic lotion (about 1 : 60) may be advantageously substituted for the plain water. It is a mistake to suppose that Clover's inhaler is likely to be damaged by this simple cleansing process. Apparatus which will stand boiling, such as Skinner's mask, mouth-props, gags, etc., should be thus sterilised after use. Rubber bags may be advantageously washed out with either soap and warm water, or lysol (ʒj ad Oj). In dental practice this applies with especial force; otherwise pyorrhœa or even syphilis might thus be transferred from one patient to another.

Special precautions are necessary when anæsthetising patients for operations upon the head, face, mouth, nose, throat, neck, and shoulders. In such operations the surgeon and the anæsthetist are brought into close relations with one another, and it is the duty of the latter, by preparing his hands, and carefully disinfecting, and if possible sterilising, his appliances, to adapt himself to the requirements of the former. Thus, prior to an operation within the mouth, nose, or throat, gags, props, and mouth-tubes should be boiled, and perfectly new sponges, which have previously been placed in 1 : 20 carbolic lotion and have subsequently been washed out in water, should be in readiness. In operations about the face and neck, the Skinner's mask should either be sterilised before use, or its edges protected by sterilised lint or gauze wound round the circumference of the mask, and pinned. Some surgeons and anæsthetists now work on either side of a shield which cuts them off from any mutual contact. This is really only necessary in operations on the head and neck, just those, in fact, where its presence interferes too much with the work in hand to be tolerated by either party.

K. THE ADMINISTRATION FROM THE PATIENT'S POINT OF VIEW

Patients about to be anæsthetised are usually in a state of nervous tension or apprehension, and should be treated with the utmost kindness and consideration. They should not be hurried; the necessary preparations for the operation should not be made in their presence; and everything should be done to lessen the anxiety and discomfort which must necessarily be associated with the contemplated surgical procedure. Reference has already been made to the importance of punctuality on the part of those engaged in the operation, and to certain points in connection with the posture of the patient during the induction of anæsthesia. The room should be kept quite quiet and all talking avoided during anæsthetisation. It must be remembered that sounds may seem to the half-anæsthetised patient to be much louder than they really are, and that the power of hearing disappears at a late point in the induction stage. The author has on several occasions known patients complain of the talking of bystanders. The noise made by tipping instruments from the steriliser into trays or dishes is specially likely to distress semi-anæsthetised patients.

Preliminary narcotisation has many advantages from the patient's point of view, and is strongly indicated in certain subjects (see Chapter IX.). When appropriate drugs and doses are employed it is generally possible to bring about an indifferent or lethargic state both before and after the operation, and thus to reduce anxiety and post-operative discomfort in no small degree. Some anæsthetists go so far indeed as to produce such deep preliminary sleep by means of scopolamine that the administration of the anæsthetic is not remembered. In the opinion of the author this practice cannot be recommended, save perhaps in highly exceptional cases.

CHAPTER IX

THE USE OF MORPHINE AND OTHER ALKALOIDS IN CONJUNCTION WITH ANÆSTHETICS

In pre-anæsthetic times it was customary to dull the patient's sensibility to the pain of an operation by means of large doses of alcohol, opium, and other narcotic drugs. It is not surprising, therefore, that when respirable anæsthetics were introduced about the middle of the nineteenth century, the new method should have been engrafted on the old, and the combination of narcotics with anæsthetics utilised. Owing, probably, to the facts that too large doses of opium or morphia were used, that the respirable anæsthetic was often also given unskilfully, and that the principles of anæsthesia as now evolved were but partially understood, the method was slow in gaining favour.

In 1861 a case was reported by Pitha in which he succeeded in deeply anæsthetising a patient by the combined action of **belladonna and chloroform,** after chloroform itself had proved ineffectual. In 1863 Nussbaum [1] of Munich employed **morphine in conjunction with chloroform,** by injecting it *during* chloroform anæsthesia. He used from ·03 to ·06 grm. of the acetate of morphine, and found that patients thus treated remained in a deep sleep for a considerable time after the withdrawal of the chloroform, and then woke without nausea or vomiting. At about the same time Claude Bernard observed similar effects in dogs; and in 1869 [2] published his researches.

[1] The *Bavarian Med. Intelligencer* for October 1863 is stated to contain Nussbaum's paper. See also Kappeler, *op. cit.*; *Med. Times and Gaz.* vol. i., 1864, pp. 259 and 596; *ibid.* vol. i., 1872, p. 350.
[2] *Lancet*, vol. ii., 1869, p. 789.

MM. Labbé and Guyon[1] seem to have been the first to administer morphine *before* chloroform in surgical practice. They adopted this plan, not with Nussbaum's original object, viz. that of lessening the after-pain of operations, but with Claude Bernard's idea, viz. that of facilitating the action of chloroform, and rendering smaller quantities of the anæsthetic necessary. They injected morphine about 20 minutes before chloroform was given, and found that by this practice the excitement stage of chloroformisation was very considerably lessened, and that when once anæsthesia had been produced, extremely small doses of the anæsthetic were needed to maintain insensibility to pain. In the same year Demarquay[2] drew attention to the special dangers which might arise from the combined action of the two drugs, and considered morphine contra-indicated, more especially in weak subjects. In 1877 Thiersch[3] employed the method in several operations about the mouth, and found it possible to maintain an analgesic state in which the patient, although unable to feel pain, could aid the operator by coughing out blood, etc., when requested to do so. Within more recent times other surgeons have advocated this preliminary injection of morphine. Thus, Dr. Alexander Crombie of the Bengal Army, writing in 1880,[4] stated that he had then employed it in 600 cases with excellent results. He advocated the injection of one-sixth of a grain immediately after the beginning of the administration of chloroform, and found that there was less vomiting than after chloroform alone, and that there was a striking absence of all asphyxial symptoms during the chloroformisation. Kappeler devoted much attention to the subject, and by comparing the effects of chloroform without morphine and chloroform with morphine, in the same patient, on different occasions, concluded that the mixed anæsthesia was quieter, that the excitement stage was much shortened, that the patient was brought with less muscular action into the stage of "tolerance," that irregularities in breathing, leading to asphyxial symptoms, are conspicuously

[1] *Med. Times and Gaz.*, 23rd March 1872, p. 359.
[2] *Ibid.*, 21st September 1872, p. 334.
[3] *Lancet*, 8th December 1877, p. 861.
[4] *Practitioner*, December 1880, p. 401.

absent, and that much less chloroform was required. He found, however, that vomiting was more frequent than after chloroform alone. Kappeler preferred to inject morphine 20 to 30 minutes before the chloroform was given, and used in adults ·015 grm., and in children ·01 grm.

In cerebral surgery morphine was at one time extensively used with chloroform; but most surgeons now object strongly to it.[1] In any case great circumspection is required of the anæsthetist in such cases, and the addition of morphia to the other factors tending towards respiratory depression is calculated to increase his anxieties rather than to diminish them.

Dr. Julliard of Geneva[2] advised the injection of one-sixth of a grain of morphine 20 minutes before ether is given. He very properly insisted that a preliminary trial of morphine some days before the operation should be made, in order to ascertain the patient's susceptibility to the drug. Dr. Julliard found that patients are more quietly etherised after morphine than under ordinary circumstances. He also used far less ether to keep up anæsthesia, and indeed in many cases was able to secure an analgesic effect. Curiously enough, Kappeler states that he met with many failures in giving ether after morphine, and with more excitement than usual.

Dastre, Morat,[3] and Schäfer[4] long ago advocated **the addition of atropine to morphine** with the object of avoiding cardiac inhibition during anæsthesia, the atropine being given in doses of from $\frac{1}{100}$th to $\frac{1}{120}$th of a grain.

Whilst there can be no doubt that the use of morphine in conjunction with general anæsthetics is of distinct advantage in many cases, we must not lose sight of the fact that objections to the routine employment of this mixed narcosis undoubtedly exist. In addition to Demarquay, others have raised a warning voice as to the danger of employing opiates in conjunction with anæsthetics in certain cases. Dr. E. H. Jacob[5] of Leeds pointed out that there might be some risk in administering ether to patients already under the influence of

[1] *Brit. Med. Journ.* vol. ii., 1886, p. 670. See also p. 217 of present work.
[2] *Op cit.* See also *Brit. Med. Journ.* vol. i., 1891, p. 920.
[3] See Dastre, *op. cit.*
[4] *Brit. Med. Journ.*, 16th October 1880, p. 620. Also *ibid.* vol. ii., 1880, p. 240.
[5] *Brit. Med. Journ.* vol. i., 1881, p. 30.

an opiate, and cautioned surgeons to be on the alert for this contingency when operating for hernia, as patients with that affection were often under opium at the time the anæsthetic was given. Mr. Clement Lucas[1] states that he has seen two cases of collapse and death after operations for hernia, and believes that the morphine was to a great extent answerable. These views are quite in accordance with those which the author ventured to express in 1886. When writing in that year he was unaware that any attention had previously been directed to the dangers of the mixed narcosis in certain cases. He then published[2] details of a case in which, during the operation for the removal of a cerebral tumour, the patient being at the time under the combined influence of morphine and chloroform, respiratory paralysis took place. The case possessed so many points of interest that it may be again related.

Illustrative Case, No. 2.—M. K., a female patient, æt. 26, was admitted into hospital suffering from symptoms undoubtedly due to the presence of a cerebral tumour. The day before the operation she could not be roused; her pupils were large, active to light, and equal; her pulse was 84 ; her respiration 18, and shallow ; and she had right hemiplegia involving the face. On the day of operation she was quite unconscious ; her respiration was 24, and somewhat noisy ; and her pulse 100. One-third of a grain of morphine was injected subcutaneously, and the administration of chloroform (diluted with one-fifth of ethylic alcohol) was commenced by means of Junker's inhaler. Slight coughing and feeble struggling were noted. Corneæ insensitive in about four minutes. Once only after this was it necessary to reapply the chloroform for a few seconds. One drachm of the anæsthetic was used. When operation commenced pulse regular but weak, and respiration shallow. Forty minutes after the administration was begun, breathing gradually ceased. Artificial respiration twice restored breathing for a short time. One hour after administration commenced, breathing ceased for third time, and could not be re-established. *Artificial respiration by Silvester's method was kept up continuously for four hours.* When artificial respiration was suspended, cyanosis ensued, and the pulse became feebler. About 2½ hours after administration commenced it was decided to attempt to complete the operation. This was successfully accomplished, artificial respiration being carried on the whole time. At the end of four hours automatic breathing returned, and the patient was taken back to bed.

It is difficult to say what was the actual cause of the cessation of breathing in this case. Whilst the anæsthetic

[1] *Brit. Med. Journ.* vol. i., 1882, p. 500.
[2] *Practitioner*, vol. xxxix., 1887, p. 93.

may have been the exciting cause, it is obvious from the fact that artificial respiration had to be kept up for four hours before automatic breathing returned, that other more potent influences were at work, and amongst these the morphine probably held a prominent position.[1] With twenty-five years' experience since the occurrence of the case the author's criticisms of the part he himself played in it may not be without value to the reader. In the first place it is questionable whether any anæsthetic at all should have been given seeing that the patient was more or less unconscious. Secondly, supposing an anæsthetic to have been necessary, it should certainly not have been pushed to the point at which the corneal reflex vanished, but only administered in analgesic quantities during the skin incision. Thirdly, the Junker's inhaler with a vulcanite face-piece such as was then used was one of the worst forms of apparatus in the circumstances. But notwithstanding these criticisms there can be no doubt that the full dose of morphine was a more potent factor than the anæsthetic in bringing about the respiratory paralysis.

In 1900 Schneiderlin[2] published a paper in which he dealt with the narcosis which can be obtained by the use of alkaloids, and he directed attention especially to one which does not seem to have been much used for its anæsthetic properties before his time, namely, **scopolamine, or hyoscine.**[3]

[1] See also an interesting case in the *Dental Cosmos*, November 1895, p. 937. Nitrous oxide was given after $\frac{3}{4}$ grain of morphine, and respiratory paralysis ensued. Artificial respiration was successful.

[2] *Aerzliche Mittelungen aus und für Baden*, Mai 1900.

[3] Messrs. Allen and Hanbury have supplied the author with the following information upon the relations between the substances known by the two names, **scopolamine** and **hyoscine**:—

"The British Pharmacopœia gives scopolamine hydrobromide as the synonym of hyoscine hydrobromide. Scopolamine and hyoscine are chemically identical; the substance exists, however, in three modifications distinguished—from the behaviour of their solutions towards polarised light—as dextro-rotatory, lævo-rotatory, and optically inactive. The lævo-rotatory variety has the most powerful physiological action, its effect upon peripheral nerve endings being twice as great as that of the optically inactive variety, though its hypnotic power is about the same.

"Hyoscine hydrobromide B.P. is a somewhat indefinite mixture of optically inactive and lævo-rotatory hyoscine; no test as to its lævo-rotatory power is given. The substance official in the German Pharmacopœia must have a certain lævo-rotatory power; it is called scopolamine hydrobromide and is the substance we are using.

"There is a tendency amongst writers to distinguish between hyoscine and scopolamine because of this difference, giving the name scopolamine to the definitely lævo-rotatory substance."

Since then the literature on this subject has become enormous; Lawrence[1] gives a list of about sixty papers—most of them American and Continental—and probably even this list is by no means complete; in England, too, the literature is accumulating rapidly. In Europe the pioneers of this form of narcosis have been Blos, Krönig, Gauss, and Korff. They and other observers have experimented with many drugs and combinations of drugs, such as **morphine, scopolamine, atropine, heroin, veronal, strychnine**; and some of them have employed most complicated mixtures of alkaloids, such as "**omnopon**,"[2] which is claimed to contain the chlorides of twenty alkaloids in a known and definite proportion.

At the present time these alkaloids, and mixtures of alkaloids, are employed in two somewhat distinct ways. They are given as **analgesics** for various kinds of operations, and especially for labour pains; the combination which has come most into favour for this purpose is that of **scopolamine with morphine.** This combination has been adopted in midwifery practice very extensively abroad and in Scotland, but seems to make headway slowly in England. Narcotics are also given as **a preliminary to the induction of general, spinal, or local anæsthesia**, with the design of reducing the quantity of the anæsthetic used, or of eliminating fear and nervous disturbances.

1. The Use of Alkaloids as Analgesics during Labour or during Operations

No alkaloid or combination of alkaloids has yet been discovered which will produce *with certainty and safety* a genuine narcosis deep enough for the performance of a major operation, though many experimenters have tried to find one, and are still trying. But for the limited requirements of the obstetric practitioner who is dealing with an ordinary case and does not require true surgical anæsthesia, the **scopolamine-morphine** combination has many advantages. It dulls consciousness between the pains almost or quite completely; and it reduces the sensorial response to the

[1] *Edinburgh Medical Journal*, November 1910.

[2] Leipoldt, *Lancet*, 11th February 1911; also Gray, *ibid.*, 2nd September 1911; and Robertson, *ibid.*, 7th October 1911, p. 1010.

stimulus of uterine contractions so effectively that in five cases out of six there is no recollection of pain afterwards.[1] Further, it is available for exactly that period of labour for which chloroform is inadmissible: that is, for the first stage, when the patient has mental anxiety to add to her purely physical ills. In fact, scopolamine-morphine should not be administered if the end of the first stage has been reached, or passed, when the obstetrician reaches his patient. Then, too, should a general anæsthetic become desirable in the second or third stage of labour, much less of it is required if the patient is still under the influence of scopolamine-morphine.

There are, however, certain disadvantages, though these can nearly always be avoided by due care in dosage. Scopolamine is a potent alkaloid, and doubtless it affects some patients more than others; and the same is of course true of morphine. The largest permissible initial dose is $\frac{1}{4}$ gr. of morphine with $\frac{1}{100}$ gr. of scopolamine; and it is preferable to give even less than this. A good plan is to start with $\frac{1}{6}$ gr. of morphine and $\frac{1}{200}$ or $\frac{1}{150}$ gr. of scopolamine; and to repeat in an hour's time if the requisite dulling of sensibility has not been attained. Krönig regards the condition of the memory as the best test as to the necessity of the second dose; if the patient can remember what has been taking place about her during the hour succeeding the first dose, a second one is given. The patient must be kept perfectly quiet, and it is advised that the room should be darkened. Excitement or delirium follows occasionally; this is treated by a few whiffs of chloroform. Thirst and flushing are sometimes complained of, but are, after all, small items to put in the scale against the pains of labour. Torpidity of the infant has also been alleged, but it is at least doubtful whether this occurs when small doses have been given and the effect of each carefully watched. Lastly, labour is said to be prolonged; but even this is doubtful, and certainly the effect in this way is quite a slight one, even if it does actually exist.

Minor operations, such, for instance, as the exposure of a vein for infusion anæsthesia, can also be done during scopolamine-morphine narcosis, especially if local anæsthesia be used as well.

[1] Lawrence, *op. cit.*

2. The Use of Alkaloids as a Preliminary to General, Spinal, or Local Anæsthesia

The advantages claimed for this use of narcotic alkaloids before general anæsthetics are: (1) elimination of the element of fear, to which unquestionably a certain number of anæsthetic fatalities have been due; (2) the production, in many cases, of a somnolent or apathetic state favourable to anæsthetisation; (3) the absence of excitement during anæsthetisation; (4) diminution of the quantity of anæsthetic required to produce the necessary relaxation and depth of anæsthesia; (5) diminution of secretion (especially of the secretion of mucus under ether); (6) lessened tendency to vomiting[1] and to pulmonary complications; (7) lessened shock; and (8) a longer period of insensibility after the end of the operation, whereby discomfort and pain are avoided.

The combinations which have lately been recommended for this form of alkaloidal narcosis are numerous, and we must proceed with great caution in attempting any generalisations concerning them. We must bear in mind that the subject is, so to speak, in its infancy, that it is an exceedingly complex one, and that methods of procedure which we are using and perhaps eulogising to-day we may be discarding to-morrow. Of one thing we may be certain that we have in **morphine, scopolamine,** and **atropine** three valuable and powerful adjuvants to general anæsthesia. But when we come to attempt to lay down any rules for the systematic employment of these agents, either individually or collectively in conjunction with the different anæsthetics, anæsthetic mixtures and anæsthetic sequences, now at the command of the modern anæsthetist, we are confronted by such a large number of considerations as to make the task very difficult. That there are typical cases in which these drugs, when followed by appropriate general anæsthetics, produce an almost ideal result, so far as the patient, the surgeon, and the anæsthetist are concerned, there can be no doubt. But it is by no means easy, in the present state of our knowledge, to pass from the particular to the general and to attempt to systematise this new and

[1] See p. 279.

important development in practical anæsthetics. At the same time it is obvious that having referred, in preceding portions of this work, to cases in which preliminary narcotisation is specially indicated an attempt must here be made to discuss this branch of our subject from a more general standpoint.

One of the chief difficulties in the way of any general application of this so-called "mixed narcosis" is that patients are occasionally met with who display very definite **idiosyncrasy** towards certain alkaloids and particularly towards morphine. The author's experience with this drug is, in fact, quite in harmony with that of Kappeler (*vide supra*), and before proceeding further it may be well to refer in some detail to a typical case in which **morphine-idiosyncrasy** was well marked. The case is interesting because it occurred when it was the author's practice to administer morphine and atropine to practically every adult subject requiring an abdominal section, provided no obvious contra-indications existed. In this particular case the patient was in the country, and it therefore became necessary to administer the preliminary narcotic before the arrival of the surgeon and anæsthetist.

Illustrative Case, No. 3.—F., æt. about 37. Intelligent, well-educated; operated on twice previously, for appendicitis and uterine fixation respectively. Liable to fainting attacks. Always very sick after anæsthetics; and on one occasion nearly died under chloroform, respiration having ceased for $2\frac{1}{2}$ minutes.

Morphine gr. $\frac{1}{4}$ with atropine at 10.45 A.M. At 11.20 much pallor, faintness, pulse feeble, hands cold, breathing very shallow, nauseated. Foot of bed raised, and patient asked to make herself vomit by fingering fauces; this she did, but faintness persisted. After half an hour there was no improvement; but it was decided to proceed with a general anæsthetic for abdominal exploration. C.E. was given for three minutes, followed by ether on an open mask for one hour. Induction stage very long, probably due to low blood pressure and extremely shallow breathing. Partial Trendelenburg posture. Abdominal incision made when corneal reflex still present. *No reflex movement, and no reflex effect upon breathing.* On manipulation of intestines, and especially when adhesions pulled upon, the breathing increased in amplitude, and both pulse and colour then improved. Only once was the corneal reflex allowed to disappear. Good recovery followed, though nausea was troublesome.

The patient subsequently reported that similar symptoms of poisoning had always been manifested whenever morphine had been administered.

She had no doubt in her own mind that this was the explanation of the faintness, nausea, etc. It transpired that she had warned the nurse of her idiosyncrasy to morphia.

There are several points of interest in the above case: (1) More attention should certainly have been paid to the history the patient gave of her preceding behaviour with morphine; (2) considering the patient's faint condition at the hour fixed for the operation, it was by no means an easy matter to decide whether or not to proceed; (3) the failure of artificially induced retching to improve the circulation was very unusual; (4) the difficulty of obtaining anæsthesia owing to the remarkably shallow breathing was also a conspicuous feature of the case; (5) the absence of improvement in the circulation when a partial Trendelenburg posture was adopted was equally remarkable; (6) the absence of free respiration till a strong respiratory stimulus was applied was instructive. In addition to the above case the author has met with two others (making in all three in some two hundred morphine and atropine administrations) in which morphine produced minor degrees of faintness characterised by pulse depression, pallor, cold and moist forehead, and a tendency to nausea. In neither of these cases, however, was the patient's condition sufficiently unsatisfactory to suggest a postponement of the operation. In all of these cases the dose of morphine was gr. $\frac{1}{4}$. It is of course possible that a smaller dose might not have produced such effects. Be this as it may, the fact that distinct morphine idiosyncrasy is likely to be encountered in some 2 per cent of adult subjects must not be overlooked unless the anæsthetist is prepared to consider "the greatest good of the greatest number" rather than the comfort and well-being of the particular case before him. That morphine is useful in a large number of cases there is every evidence to prove; but with the preceding facts before us it is a matter for discussion whether it is wise to use it as an adjuvant to general anæsthesia unless we can obtain some information as to the effect it produces upon the particular patient. In the absence of any definite history of previous administrations it is a good plan, if circumstances permit, to arrange for a "**test-injection**" of the proposed narcotic or combination of narcotics some few days before the contemplated operation. Should this be impracticable the anæsthetist who is desirous of securing the benefits of preliminary narcotisation must choose between employing morphine, atropine, and scopolamine—in which event he will very occasionally meet with cases such as have been referred to—and employing scopolamine and atropine without morphine. At the moment of writing the author is engaged in working out, clinically, in a series of cases, the relative advantages of these three as compared with these two alkaloids. To what extent the scopolamine can be made to take the place of morphine it is difficult to say. Seeing that morphine undoubtedly produces gastric disturbances and intestinal stasis in certain subjects, and thus adds to the after-effects of general anæsthetics, it is quite possible that subsequent experience may point to the desirability of using morphine on a smaller and scopolamine on a larger scale than has been our practice in the past. Should there be a history of morphine having produced favourable results this should constitute a special indication for its use. Moreover, should the patient be accustomed to the drug the dose should, of course, be regulated by the special circumstances present.

Some anæsthetists believe that the main virtue of these alkaloidal adjuncts resides in the **atropine** constituent, which inhibits secretions and is a respiratory stimulant. Acting on this idea they have abandoned the narcotic drugs, and give atropine simply. Undoubtedly atropine is valuable when ether is given by any method, as mucorrhœa is thus greatly diminished; the dose for this purpose should be $\frac{1}{120}$ gr., given three-quarters of an hour before the operation. It is clear, however, that there can be no narcotic effect when atropine is given alone, and that there is consequently none of that elimination of the element of fear which is claimed on behalf of combinations of the narcotic alkaloids. In the author's experience atropine tends to reduce the after-vomiting of general anæsthetics by reason of the fact that it prevents the secretion of mucus and hence the entry of this fluid into the stomach to be subsequently ejected. The great advantage of atropine, however, lies in its power of preventing shock

(p. 69). As there are apparently few if any contra-indications to its use it should certainly be given before all operations likely to be attended by this condition. Its chief, if not its only, disadvantage is that it causes considerable dryness of the mouth and thirst between the time of its injection and the administration of the anæsthetic.

Preliminary narcotisation is specially useful in highly nervous, apprehensive, and sensitive subjects who are terrorised by the idea of unconsciousness or by the prospect of the operation for which that unconsciousness is about to be induced. Such subjects generally respond very favourably to morphine (gr. $\frac{1}{6}$), scopolamine (gr. $\frac{1}{100}$), and atropine (gr. $\frac{1}{120}$) hypodermically administered an hour before the projected anæsthetic. Rood,[1] to whom we are indebted for much valuable information on this subject, recommends these agents in the doses named. If the patient's reaction to morphine is known—and this can often be elicited by inquiry or perhaps ascertained by a test-injection—the combination of the three alkaloids, in Rood's proportions, is certainly remarkably satisfactory. Whether, in view of the uncomfortable dryness of the mouth, and thirst which atropine occasions, it may not be found possible to reduce the dose of this drug future experience must decide. Some authorities, instead of administering a single injection of these three agents an hour beforehand, administer two or even three successive injections, using smaller doses, at intervals of an hour before the projected operation in order to observe the effects produced. Such a course, however, is obviously impracticable save in exceptional cases. Another object which some administrators have in giving these successive injections seems to be to obtain with safety the maximum scopolamine effect and thus to render patients so utterly oblivious to their surroundings that all memory of events immediately prior to the administration of the anæsthetic is completely destroyed. Whilst such a course may be permissible in certain highly exceptional cases it can

[1] See *Brit. Med. Journ.*, 23rd September 1911—"A Record of 400 Cases of General Anæsthesia preceded by Scopolamine." Amongst these cases there were 30 thyroidectomies (16 exophthalmic goitres). Of the 400 cases 255 had no after-effects, 120 vomited once or twice, and the remaining 25 vomited several times. "Open ether" was used in practically all the cases.

hardly be regarded with favour as a routine procedure. After a somewhat extensive experience with the three alkaloids in question, and whilst fully admitting their advantage in a large proportion of surgical cases, the author is inclined to think that the anæsthetist who pushes this preliminary narcotisation to the degree indicated and then administers a general anæsthetic is playing with fire. He would submit that in the present state of our knowledge we should endeavour by the judicious use of these alkaloidal adjuvants to avail ourselves of the advantages they offer without incurring risks from their employment. Preliminary narcotisation is perhaps seen to its best advantage when patients of the above-mentioned type have to pass through such operations as appendicectomy, gastro-enterostomy, intestinal anastomosis, etc. It is also specially indicated for operations upon vigorous muscular men who are addicted to alcohol or the excessive use of tobacco. There is for example no better plan of anæsthetising a plethoric and obese man for a rectal operation than to subject him to the three alkaloids above mentioned, and to follow on with slowly induced "open ether" anæsthesia as described on p. 337. So great, indeed, are the advantages of this system of preceding ether by atropine and scopolamine, atropine and morphine, or atropine, scopolamine and morphine, according to the special circumstances present, that the author has no hesitation in recommending the system for ordinary abdominal operations upon adult subjects. The contented, somnolent state which may often be induced by scopolamine or morphine, or both combined, is particularly appropriate when a slow induction by chloroform or the C.E. mixture prior to ether has been decided upon.

To obtain the full tranquillising effect of this preliminary dosage with narcotics it is advisable, after the injection has been given, to disturb the patient as little as possible and to keep the room quiet and dark. Some authorities even advise plugging the ears with cotton wool. Whilst some patients display no noticeable effects from morphine and scopolamine in the doses above named, others are so profoundly affected as to be deeply asleep when the time for the anæsthetic arrives. Provision must therefore always be made for the possibility of having to administer the anæsthetic to the patient in bed and for transferring him to the operating room subsequently. When the circumstances are such that the patient has to walk up or downstairs to the operating room or theatre preliminary narcotisation is generally contra-indicated.

In hospital wards it is practically impossible to secure ideal conditions, and in any case the final preparations of the nurse are necessarily accompanied by a certain amount of disturbance. As a matter of actual experience in hospital practice by no means all patients achieve the state of *dammerschlaf*, or "twilight sleep," which foreign authors advocate. One reason of this is that on a busy operating day it is impossible for the anæsthetist to supervise the dosage. Instead of carefully regulated doses, given at precise intervals of time before the induction of anæsthesia, all that is practicable is a routine dose given by the ward sister or staff nurse at a time roughly estimated according to the nature of the operation in progress in the theatre. The transference of the patient from the ward to the anæsthetising ante-room, and the presence of students, surgeons, porters, and strangers of all kinds, often clad in white overalls, all tend to minimise the chances of a successful *dammerschlaf* (*demisommeil*). Nevertheless, with large enough doses this effect is often produced; though in our own view it is far better to aim rather at a calm tranquillity of mind than at an entire obliviousness of environment.

The type of the anæsthesia which results when this system is properly applied is generally very satisfactory. Excitement and struggling are rare even in patients liable to display such phenomena, whilst intercurrent asphyxial conditions and cyanosis due to spasm of muscles in or about the upper air tract are conspicuously absent in most cases. Moreover, the reflex respiratory disturbances which, as we have seen, may culminate in respiratory shock are very uncommon in mixed narcosis, particularly when ether is used. When we add to these advantages those which, as we have just seen, more particularly belong to atropine (*vide supra*) we can readily understand the increasing favour with which this new system of anæsthetisation is being received. As regards the recovery period patients generally pass into a deep sleep after operations performed under mixed narcosis. The plan is specially indicated, indeed, for operations likely to be followed by considerable after-discomfort or pain. The author has, for example, observed very satisfactory effects, so far as the avoidance of after-pain is concerned, in abdominal cases generally, in rectal operations, in wrenchings of stiff joints, and in cases in which plugging has been deeply inserted. On the other hand the claim that vomiting is diminished is one which our experience does not bear out.

But although the type of anæsthesia from the chosen anæsthetic is generally improved by preliminary narcotisation, cases occasionally occur in which little or no advantage is derived from the injection, whilst there are others in which it would almost seem that the narcotisation itself introduces difficulties. As a good example of the widely different effects which mixtures of morphine and scopolamine may produce upon different individuals, the following case may be cited.

Illustrative Case, No. 4.—The patient was a gentleman, 72 years of age, who had lived freely. He was short of stature and well nourished. His heart sounds were satisfactory. He was judged to be a suitable case for the morphine-scopolamine-atropine mixture, and this was administered an hour before the time fixed for the operation—prostatectomy. On arrival at the house the patient was lying in bed loudly snoring. The chloroform-C.E. sequence was used and anæsthesia was easily obtained without waking the patient. When sufficiently anæsthetised he was transferred to the adjacent operating room. Although the narcotics had produced deep sleep they seemed to have no influence whatever as adjuvants to anæsthesia, for laryngeal stridor, considerable straining during bladder distension, abdominal rigidity, and occasional movement manifested themselves. Eventually moderately good results were obtained by pushing the anæsthetic. Instead of the usual gradual recovery, however, the patient became violently excited and required restraint. He subsequently made an excellent recovery.

Children may be safely subjected to mixed narcosis; $\frac{1}{12}$ gr. of morphine with $\frac{1}{200}$ gr. of atropine is an excellent preliminary to anæsthesia, especially before laparotomy and in the case of those who may be expected to secrete mucus freely.

Illustrative Case, No. 5.—A boy, aged 8, was operated on for a sarcomatous growth in the head of the humerus, complicated by enlarged axillary glands. The operation performed was removal of the entire forequarter, and $\frac{1}{6}$ gr. of morphine with $\frac{1}{150}$ gr. of atropine was given half an hour beforehand in one dose. Anæsthesia was induced in four minutes with open ether, and maintained in the same way throughout the operation, which lasted fifty minutes. There was no shock either during operation or subsequently, and two days later the patient was sitting up in bed playing with his toys.

The use of morphine or of scopolamine is contra-indicated in all patients who, from any cause whatever, are already drowsy or torpid, and also in those who, from some respiratory affection, display even a minor degree of lividity or cyanosis. Moreover, should the operation be one in which it is important that immediately after its performance, protective swallowing and coughing should be established in order to clear the tracheal or bronchial passages of blood or other fluids, preliminary narcotisation by these drugs is best avoided. Furthermore, brain lesions, of a kind likely to be associated with intra-cranial pressure, should also be taken to contra-indicate mixed narcosis. The remarks here made do not, however, apply to atropine which, indeed, may often advantageously be given when respiratory or cardiac complications are present. It is questionable whether the time-honoured custom of withholding morphine, even in very small doses, when renal disease is present is one which need be followed on all occasions. If, however, any tendency towards uræmic coma should exist it would not, of course, be wise to use this drug.

If the production of a state of semi-narcosis before general anæsthesia is useful and valuable as a preventive of psychical disturbance, it is clear enough that it will be doubly valuable as a preliminary to **spinal anæsthesia.** For the state of perfect and acute consciousness during an operation under spinal anæsthesia is one of the drawbacks of this method. In cases where spinal anæsthesia is indicated (see p. 523), and when there is no contra-indication of morphine, the combination of these two methods is quite legitimate.[1] Similarly, the alkaloids already discussed may, if desired, be used as a preliminary to any other form of local anæsthesia.

[1] A. E. Johnson, *British Medical Journal*, 3rd December 1910, p. 1768.

CHAPTER X

THE ADMINISTRATION OF NITROUS OXIDE

THE reader is referred to Chapter I. p. 7 for a short account of the discovery and early use of this anæsthetic; to Chapter II. p. 20 for information upon its chemical and physical properties; to Chapter IV. p. 87 for a *résumé* of the principal experimental work that has been done concerning its physiological action; and to Chapter V. p. 136 for remarks as to its safety and suitability in general surgical practice.

In the early days of its administration nitrous oxide was rarely inhaled in a state of purity. Not only was there difficulty in obtaining the gas in this state, but when obtained it was inhaled in such a way that considerable quantities of air also gained admission to the lungs. It thus happened that the effects produced were usually those of intoxication rather than anæsthesia, although, as on the memorable occasion when Horace Wells himself inhaled "laughing gas," complete unconsciousness was sometimes induced. By the time that this anæsthetic found its way to England, Colton's[1] experience had become so great that he was able to formulate rules for its successful administration in dental practice. He urged the necessity of excluding all atmospheric air, and of administering the gas by means of an apparatus with inspiratory and expiratory valves. But whilst air-exclusion was thus rigidly practised when employing nitrous oxide for such short operations as those of dentistry, cases were from time to time recorded in which, by the alternate inhalation of nitrous oxide and air, it was found possible to maintain more or less com-

[1] *Brit. Journ. Dental Science*, 1868, p. 257.

plete anæsthesia for protracted surgical operations.[1] Clover pointed out the advantage, in such cases, of allowing air to be breathed concurrently with the nitrous oxide; and we are indebted to him for many improvements in inhaling apparatus.[2] By the use of a nose-piece, Clover and Coleman introduced the system of maintaining anæsthesia during prolonged dental operations—a system which has, in more recent times, been successfully revived and extended (p. 309). In 1868 Dr. E. Andrews[3] of Chicago published several cases in which, by mixing oxygen with nitrous oxide, he had obtained a more satisfactory form of anæsthesia than with nitrous oxide alone; but, curiously enough, his interesting observations failed to attract the attention they deserved; and it was not till ten years later that Paul Bert again drew attention, by a series of interesting experiments, to be subsequently described, to this system of anæsthetisation. Bert's researches led him to believe that in order to obtain nitrous oxide anæsthesia in the presence of oxygen or air, it was necessary that the patient should be subjected to an increased atmospheric pressure; but experience has proved that this increased pressure is not essential. It is now established beyond all doubt that by employing certain percentages of atmospheric air with nitrous oxide a better form of anæsthesia can be obtained than with the undiluted gas; and that by using oxygen instead of atmospheric air, a still better form of anæsthesia is obtainable. There is, in fact, no doubt whatever that the complete exclusion of oxygen, which was at one time considered imperatively necessary, is opposed to those general principles which should guide us in administering anæsthetics.

It will be convenient to consider nitrous oxide under the following sections:—

Section I. The administration of pure nitrous oxide;

Section II. The administration of definite mixtures of nitrous oxide and air;

Section III. The administration of nitrous oxide with indefinite quantities of air;

[1] See *Brit. Journ. Dental Science*, 1868, pp. 393 and 485; and 1869, p. 46. Also *Brit. Med. Journ.*, 2nd May 1868. Also Turnbull's *Artificial Anæsthesia.*

[2] *Brit. Journ. Dental Science*, Sept. 1868, p. 485.

[3] *Ibid.*, 1869, p. 22.

Section IV. The administration, at ordinary atmospheric pressures, of definite mixtures of nitrous oxide and oxygen;

Section V. The administration, under increased atmospheric pressures, of definite mixtures of nitrous oxide and oxygen (Paul Bert's system); and

Section VI. The administration, at ordinary atmospheric pressures, of nitrous oxide with varying proportions of oxygen.

Section I.—The Administration of Pure Nitrous Oxide

A. APPARATUS AND METHODS OF ADMINISTRATION

Nitrous oxide is supplied by the manufacturers in iron and steel **cylinders** which contain the agent in a liquid state under considerable pressure.[1] Those yielding 50 gallons of gas are commonly used in hospitals; but 25-gallon cylinders are preferable when, as in private practice, portability is a matter of consideration. 100-gallon cylinders are even better adapted for hospitals. Every cylinder is furnished with a label stating its weight when empty and when fully charged; so that, when weighed, the quantity of nitrous oxide present may always be ascertained. $7\frac{1}{2}$ ounces of liquid nitrous oxide will furnish about 25 gallons of gas. Full, or nearly full, cylinders may at once be known by the dull sound which they emit when sharply tapped with the foot-key or some similar article. It is always advisable to have two cylinders coupled together, in case one should work badly or fall short during the administration. It is also a good plan to make it a rule on all occasions to work first from the cylinder of one side, and only to go on with the second or reserve cylinder in the event of the other becoming exhausted. If the administrator work indiscriminately from both cylinders he may easily allow the supply of the anæsthetic to fall too low. Care should be taken to turn off the gas completely after each administration, otherwise leakage will gradually occur and the cylinder become empty. Each cylinder is furnished with a screw-valve or tap, by turning which with a foot or hand-key, gaseous nitrous oxide escapes.

Fig. 25 shows two cylinders coupled together. The author has had a lengthened experience with these side-valve cylinders, and believes them to be better than any others. They have the great advantage that they require but a very simple form of stand to render them perfectly stable whilst being worked; and when fitted with the easily acting valves invented by Messrs. Barth and Co. they answer every requirement. It is only a few years since these side-valve cylinders have been brought

[1] The author has been informed by one of the manufacturers of this gas that the pressure within the cylinders which they supply often registers nearly 1000 lbs. to the square inch.

into a state of perfection. When they were first used they were not satisfactory; and to the late Dr. C. E. Sheppard belongs the credit of removing the objections which were formerly attached to their use.[1]

Some years ago[2] the author made a special study of the various methods then in use for administering nitrous oxide. He came to the conclusions—(1) That accurately fitting valves are essential at the commencement of the inhalation, in order to make sure of the rapid exit of air from the lungs; (2) that, so far as the available resulting anæsthesia is concerned, there is a decided advantage in allowing a certain amount of re-breathing of nitrous oxide towards the *end* of the inhalation; (3) that although there are certain hygenic objections to this re-breathing, it is nevertheless very convenient to be able to resort to it as a measure for securing a longer anæsthesia, or for successfully terminating an administration when the supply of nitrous oxide has unexpectedly fallen

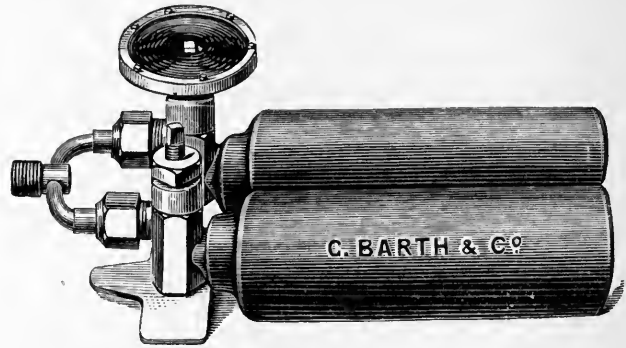

FIG. 25.—Two Side-valve Cylinders, with Stand, Double Union, and Foot-key.

short. There was no apparatus which would allow of two valves being in action for the earlier or middle stages of the administration and would subsequently permit re-breathing. The author therefore devised[3]

[1] See an interesting paper by Dr. C. E. Sheppard, *Lancet*, 21st Feb. 1891, p. 424—"Difficulties connected with the Use of Nitrous Oxide Bottles in the Horizontal Position." Dr. Sheppard found that the 50-gallon cylinders supplied by Messrs. Barth and Co. had a capacity of 50·5 cubic inches, and taking the sp. gr. of the liquid to be ·908 at 45° F. and the weight of the 50 gallons of nitrous oxide gas thus liquefied to be 15 ounces, the space occupied in the bottle by the liquid was 28·6 cubic inches, roughly three-fifths of the total capacity. He argued that as the cold produced by the nitrous oxide passing from the liquid to the gaseous form is very intense, superficial solidification of the nitrous oxide may take place, and the snow-like body thus formed may temporarily choke the tube. By bringing the inner orifice of the exit tube above the level of the liquid in the cylinder, all choking with liquid or solid nitrous oxide is obviated.

[2] See "An Inquiry into Several Methods of administering Nitrous Oxide" (*Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 86).

[3] *Lancet*, 9th May 1885.

and used a face-piece with thin rubber valves which could, at the will of the administrator, be thrown out of action, and allow of the gas-bag being used very much as Clover's "supplemental bag" was used, *i.e.* for to-and-fro breathing. Subsequently he placed these rubber valves in a little box between the stopcock and the face-piece,[1] so that plain valveless face-pieces could be attached. The valves were thrown into and out of action at will by turning a small handle surmounting the valve-box. A short trial of this apparatus led to his placing the valves

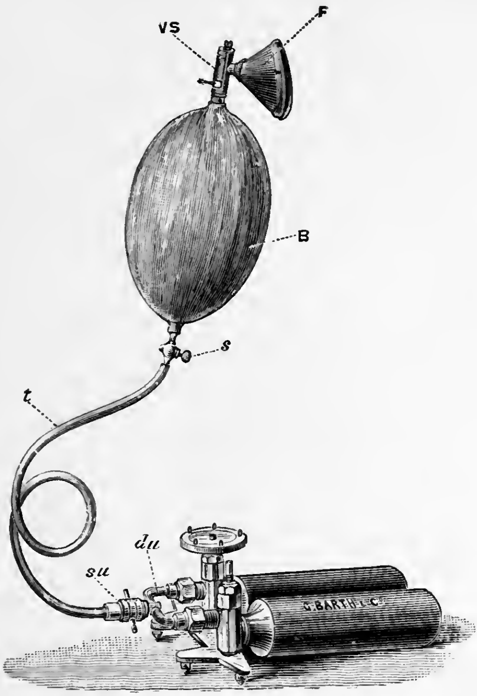

Fig. 26.—Complete Apparatus for the Administration of Nitrous Oxide Gas.

and the two-way stopcock *in one chamber*, in other words, to the apparatus which he now employs (Figs. 26 and 27).

The apparatus which the author has found to give the best results in the administration of nitrous oxide is shown in the accompanying figure (Fig. 26). It is made by Messrs. Barth and Company. From the single union (*su*) the tube (*t*) passes to join the bag (B).[2] A little stopcock (*s*) is

[1] See *Brit. Med. Journ.*, 27th August 1887, p. 452.

[2] Some administrators interpose what is known as a "quieter" between the gas cylinder and this tube, but when properly managed the noise of issuing gas is so slight as to render such a complication unnecessary.

useful in case it should be wished to disconnect a full bag from the rest of the apparatus. The bag (B) has a capacity of about two gallons. There is certainly an advantage in having the bag as near as possible to the face-piece; for not only may its movements be readily watched, but the patient can take the most forcible inspirations without any of that impediment which is likely to be experienced when a tube exists between the bag and face-piece. The valved stopcock (VS), which is the most important part of the apparatus, connects the gas-bag (B) to the face-piece (F). This stopcock, shown more in detail in Figs. 27 and 28, contains two thin valves of sheet india-rubber, which may be thrown into or out of action by turning the tap (T) (Fig. 27). The handle (H) determines whether air or gas is admitted to the face-piece. When T and H are arranged as in Fig. 27, air enters the stopcock and is breathed out through valves in the direction shown by the arrows. Fig. 28 shows in diagrammatic section the mechanism of the valved stopcock. It has two slots cut out of its circumference, an upper slot (US) and a lower slot (LS). There are two inner cylinders which revolve immediately inside the outer casing of the stopcock. The upper inner cylinder (UIC) is worked by T, the lower (LIC) by H. The upper cylinder carries the inspiratory and expiratory valves (IV and EV). The lower has a slot in its walls (shown in dotted lines) which can be made to correspond with LS by turning H. When T is turned as in the diagram, the upper slot is open, both valves act, and expirations escape as shown by the arrow. When T is turned completely round, the upper inner cylinder rotates, the valves are thrown out of action, the upper slot is closed (as shown by dotted line), and to-and-fro breathing results. Whether air or nitrous oxide be admitted to the face-piece will depend upon the position of H.

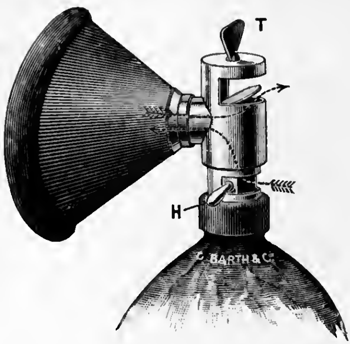

FIG. 27.—The author's Valved Stopcock, with Face-piece, etc., for administering Nitrous oxide.

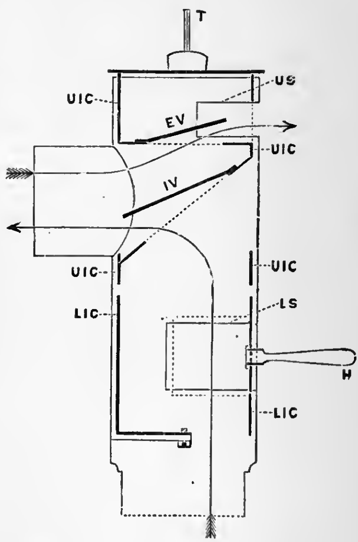

FIG. 28.—Diagrammatic Section of Valved Stopcock.

When H is placed as in the diagram, the inner cylinder which it controls allows of a free passage of gas from the bag to the face-piece (as shown by the long arrow). Should H be moved round, the inner cylinder would cut off the way to the bag and would open the air slot (LS), so that air and not gas would be respired (Fig. 27). The valved stopcock therefore permits—

(1) *Air* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

(2) *Nitrous oxide* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

In actual practice the stopcock is arranged so that the patient may first of all breathe air through valves, and then nitrous oxide through valves; and to-and-fro breathing of nitrous oxide is only called into play under special circumstances, to which future reference will be made. The arrows in Fig. 27 indicate the direction taken by the air current when the face-piece is applied to the face, *i.e.* before nitrous oxide is turned on by the handle (H). The valves should work easily. They should be examined before use to see that they do not stick, and that they have in no way become caught in the orifices which they guard. The whole stopcock has wide channels through it in order that respiration may take place freely. This is specially necessary with regard to the air-hole, so that when the apparatus is applied to the face the patient may feel no impediment in filling his chest with air. Most of the older forms of apparatus have channels far too small for successfully administering nitrous oxide gas. The face-piece should be furnished with a broad, soft air-cushion, which should be partly distended with air by means of the little tap for the purpose. Two or three sizes are necessary. The angle of the face-piece cushion, into which the bridge of the nose fits, should be acute, in order that the face-piece may accurately fit the patient. No apparatus can be considered satisfactory unless it allows the patient to *breath air through valves* before nitrous oxide is turned on. The reason for this statement will be presently discussed.

In **administering nitrous oxide** the following directions must be observed:—

1. **Make sure that there is a sufficient supply of gas before commencing.** Patients vary as to the quantity of nitrous oxide required to produce anæsthesia. The average may be roughly placed at six gallons per patient. Tall, plethoric, or alcoholic subjects may require considerably more than this. When there is much hair around the mouth it is often difficult to exclude atmospheric air wholly, and hence more nitrous oxide than usual may be needed. In such cases it is a good plan to adjust the face-piece first, and then cover its cushion with a napkin which has been wrung out in water

and folded two or three times longitudinally. Anæmic and feeble subjects, as well as children, may usually be anæsthetised by two or three gallons of the anæsthetic. Make sure that all collars, ties, belts, corsets, and any other apparel that can possibly hinder free respiration are loosened. The author once met with considerable difficulties in anæsthetising a stout lady who had assured him that her corsets were unfastened. It was found that her statement was not true.

2. **Run a small quantity of nitrous oxide through the apparatus to free it from air; half fill the bag with gas; and then turn off the screw-valve of the cylinder.** The apparatus is now charged and ready for use.

3. **Make sure that the valves are in good order.**

4. **Adjust the mouth-prop, should one be necessary** (see p. 257), and request the patient to commence breathing through the mouth. It is curious that even educated people will often breathe through the nose under the impression that they are breathing through the mouth. As oral breathing is essential for success in administering nitrous oxide, it is well to make certain, before applying the face-piece, that the patient understands what is required of him.

5. **Gently adjust the face-piece.** Success in giving nitrous oxide largely depends upon the accuracy with which the face-piece fits. If the face-piece fit accurately and the patient breathe through the mouth, a particular sound will be produced by the acting valves by which the anæsthetist will know that everything is satisfactory. Some patients hold their breath and pretend to be breathing deeply when in reality they are not doing so. Unless the patient can be made to fill his chest freely with air he certainly will not inhale nitrous oxide satisfactorily when the latter is substituted.

6. **When the patient is observed to be freely filling his chest with air through the apparatus, nitrous oxide may be substituted.**

7. **The bag should be kept nearly full throughout the administration.** At the same moment that nitrous oxide is admitted, the administrator should allow a gentle stream of gas to enter the bag from the bottle. Fig. 29 shows the administration of nitrous oxide for a dental operation by

means of the apparatus which the author finds to answer best. An attempt should be made to administer the nitrous oxide slightly above atmospheric pressure. Any evidence of excitement must be met by a slight increase in the fulness of the bag, as such symptoms are generally due to the ingress of air by the side of the face-piece.

Fig. 29.—The Administration of Nitrous Oxide for a Dental Operation (from a photograph).

8. To-and-fro breathing of nitrous oxide should not be permitted except under certain circumstances, and then only towards the end of the administration.

A great deal of discussion has taken place as to the propriety of allowing the patient to re-breathe nitrous oxide. The matter admits of consideration from two points of view, which may be called (*a*) the hygienic, and (*b*) the practical. From the hygienic point of view, it is clear that the re-breathing of nitrous oxide should not be practised unless the bag and stopcock are thoroughly washed (p. 262) after every administration. From the practical point of view, however, the question assumes a different aspect. The author is not referring to to-and-fro breathing *early* in the administration; this is inadmissible by reason of the dilution of nitrous oxide which would result from its admixture with the considerable proportion of atmospheric air previously contained in the air-passages of the patient. He refers to to-and-fro breathing towards the *end* of the administration, *i.e.* when most of the air has been washed out of the air-passages by the free inhalation and exhalation of nitrous oxide through valves. For the sake of clearness let us suppose that we have six gallons of nitrous oxide ready for an administration. We allow the patient to breathe four gallons of this through valves, so that his lungs rapidly lose nearly all the air which they contained, and all expirations escape into the surrounding atmosphere. The valve-action is now stopped, and the patient is made to breathe the remaining two gallons of nitrous oxide backwards and forwards into the bag. Anæsthesia will take a little longer than usual to become established, because of a small percentage of oxygen (from the residual air of the lungs) being still in the to-and-fro current. Had no to-and-fro breathing been permitted, the phenomena of nitrous oxide anæsthesia would have come on earlier, because of the quicker expulsion of all oxygen. The longer inhalation leads to a longer available anæsthesia, so that from some points of view this plan of administering nitrous oxide has distinct advantages. That the re-breathing *towards the end of the administration* has no bad effect upon the patient the author has proved by a very large number of administrations. He has found, it is true, that the recovery is not quite so rapid as when nitrous oxide is continuously inhaled in the usual manner; but this slight difference is connected with the longer periods of inhalation and anæsthesia. The longer we allow a patient to inhale an anæsthetic, the longer, as a rule, will he be in regaining complete control and consciousness. Some have objected that this method of re-breathing towards the end is more "asphyxiating" than the ordinary method. But the reverse is more correct if by "asphyxiating" is meant the occurrence of symptoms dependent upon the deprivation of oxygen. Were it not, therefore, for the hygienic objections above alluded to, the plan of administering nitrous oxide just described would certainly have advantages over others. The author has analysed the contents of the gas-bag, at the end of an administration, after to-and-fro respiration, and has found from 1·2 to 2·4 per cent of oxygen in a two-gallon gas-bag which, from the moment when to-and-fro breathing commenced to the termination of the administration, remained full or nearly full.[1] He once administered nitrous oxide to a patient on six different occasions. On three of these he adopted the ordinary method, allowing the valves to act throughout, and all expirations to escape. On the three other occasions the patient was anæsthetised by allowing her expirations for the first and major part of the inhalation to escape, and then, when the lungs had been well washed out with the gas, to-and-fro breathing was permitted. The times (*a*) of inhalation and (*b*) of resulting anæsthesia were taken on each occasion, and are of much interest as showing the slight but distinct gain in avail-

[1] Full details of the experiments are given in the *Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 86.

able anæsthesia when to-and-fro breathing is permitted towards the close of the administration.[1] The average available anæsthesia in the absence of to-and-fro breathing was 39 seconds; whilst when to-and-fro breathing was permitted, as described, a workable anæsthesia of 56 seconds was obtained.

B. THE EFFECTS PRODUCED BY PURE NITROUS OXIDE

Owing to the rapidity with which the phenomena of nitrous oxide anæsthesia make their appearance, it is somewhat difficult to classify them. But as this anæsthetic, more particularly when administered with oxygen, closely resembles ether and chloroform, it has been thought best to adopt the same plan that will be followed when describing the phenomena which attend the administration of the last-named agents.

First Degree or Stage.—Nitrous oxide has a peculiar sweetish taste which is by no means unpleasant. Great variation will be found to occur in the sensations which patients experience during the inhalation of this agent. When administered in the proper manner, and with due attention to details, these sensations will be more likely to be of an agreeable than of a disagreeable character. Should the apparatus possess valves which do not work easily, or should the channels through which the gas is made to pass be too small, or should the patient from want of confidence or knowledge breathe in a shallow and restricted manner, or through the nose, an unpleasant experience may result. A feeling of warmth in the lips and an indescribable though pleasant numbness over most of the body are amongst the first sensations noticed. The patient has an irresistible desire to breathe more deeply and quickly. These sensations are rapidly followed by a peculiar and pleasurable "thrilling" which hardly admits of description. Some tinnitus may be present, and curious sensations, such as fulness and expansion of the head, are occasionally experienced. As a general rule, however, loss of consciousness comes on before the patient has time, so to speak, to define his feelings. The respiration will be observed to be deepened and quickened in response to the desire of the patient just alluded to. The pulse, as Sir George

[1] *Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 342.

Johnson pointed out, grows fuller under the finger; and, according to Dr. George Oliver,[1] its calibre is somewhat increased at this stage. The increased fulness is probably due to constriction of the systemic arterioles. The time which elapses between the commencement of the inhalation and loss of consciousness is extremely short, being probably about 20-30 seconds on the average.

Second Degree or Stage.—With the loss of normal consciousness, disturbed psychical states are liable to arise. As a general rule the patient gives little or no evidence of such disturbance, more especially if allowed to remain perfectly quiet. If roughly handled he is liable to become excited and to move his arms or legs. When nitrous oxide is properly administered, symptoms of excitement are, with the rarest possible exceptions, conspicuously absent. Any injury inflicted during this stage may produce immediate reflex effects, such as shouting, co-ordinate or inco-ordinate movement, etc., but it would not be accurately remembered by the patient. Nitrous oxide is often accused of producing imperfect anæsthesia, because operations are sometimes commenced at this stage. Dreams are common, but are rarely distinctly remembered. Sometimes they are so pleasant that, at the conclusion of the administration, the patient, who is unaware of having been deeply anæsthetised, is sorry to be disturbed. On other occasions dreams are of the most disagreeable character. It is a curious fact that unpleasant dreams are more common under nitrous oxide alone than under nitrous oxide administered with oxygen—probably because the anæsthesia in the latter case is deeper, so that operations or other interferences, which in the case of nitrous oxide itself might leave some disturbed impressions, are not capable of doing so when the anæsthesia is more profound. Erotic dreams are occasionally experienced.[2] The respiration is still quicker and deeper than normal, and, save perhaps for an occasional act of swallowing, is perfectly regular. In some cases a spurious form of stertor may occur and is to be disregarded. The pulse is still full and a trifle quicker than in the previous stage. The conjunctiva is quite sensitive to touch. The pupils usually grow larger as the

[1] *Pulse-gauging*, 1895, p. 82. [2] See *Lancet*, vol. ii., 1872, p. 721.

administration proceeds. The features gradually lose their normal colour. Duskiness or lividity is most common in patients of a florid type, anæmic and sallow persons showing very little alteration in appearance. The eyelids are usually affected by slight twitching; and as the inhalation proceeds they exhibit a tendency to separate and to display the subjacent globes. The power of hearing may persist throughout this stage.

Third Degree or Stage.—The first indication that the patient is passing or has passed into the third stage of anæsthesia is usually afforded by the **respiration**. The breathing, which has hitherto preserved its rhythm, now loses it, and a peculiar and characteristic throat sound, sometimes described as "stertor," becomes audible. This sound is most probably due to irregular and spasmodic elevations of the larynx towards the epiglottis and base of the tongue, and indicates a tendency to obstruction in the air-way at this point. Deep snoring or snorting breathing may be met with in certain cases, and may either necessitate the withdrawal of the anæsthetic before the time has come, so to speak, for the deeper throat sound, or may altogether mask the latter. As has been pointed out, the position of the head and the natural conformation of the upper air-passages have an important influence in bringing about or retarding stertor. At or about the moment at which the characteristic guttural sound occurs, the rhythm of breathing is liable to be further interfered with by clonic spasm of thoracic and abdominal muscles. Sometimes, indeed, a sudden irregularity in breathing, totally independent of laryngeal closure or "stertor," and entirely the outcome of this muscular spasm, is the first indication of deep anæsthesia. It occasionally, though rarely, happens that, instead of respiration undergoing the changes mentioned, it becomes somewhat feeble; or expiration becomes prolonged and rather strained. These phenomena should, in the presence of other signs of anæsthesia, be taken to mean that the administration has been pushed sufficiently far. The author found by timing 60 consecutive nitrous oxide administrations that the average number of respirations required to produce deep anæsthesia was 29·2. The lowest recorded number was 6; the highest 72. It need hardly be pointed out that it is very exceptional for deep anæsthesia to occur after only six inspirations. The author has, however, met with a remarkable case in which the muscular phenomena characteristic of full nitrous oxide anæsthesia appeared during the third inspiration. The patient was the subject of pernicious anæmia (p. 154).

The **circulation** is well maintained during nitrous oxide anæsthesia, provided that care be taken to prevent too great a degree of asphyxia. From the observation of a considerable number of cases the author has found that, in most instances, the heart's action becomes more and more accelerated as the administration proceeds, and that, when the usual phenomena of full anæsthesia occur, the pulse is often very rapid, especially in patients with naturally quick cardiac action. A pulse of 120 immediately before the administration may, for example, rise to 160 or more when clonic movements, etc., occur; whereas a pulse of 80-90 at the beginning of the inhalation will often not exceed 100 or 110 in the third stage. As the pulse increases in frequency it loses its previous fulness; and this change is of course most conspicuous in patients with quick cardiac action. According to the late Sir George Johnson,[1] the small pulse observed at the acme of the inhalation is due to less blood reaching the left side of the heart. Immediately air is admitted by the withdrawal of the anæsthetic, the pulse abruptly undergoes a marked change. It at once becomes slower and fuller. A pulse of 140 at the acme of anæsthesia may thus suddenly drop to about 80 per minute before the effects of the anæsthetic have passed off. As consciousness becomes restored the pulse-rate again rises, as the result of mental conditions, after-pain, etc.

Various **muscular phenomena** may appear. The extremities are sometimes, though by no means invariably, flaccid. When respiration undergoes the changes above referred to, the arm, if raised by the administrator, will generally fall. But there is a tendency for clonic muscular contractions to occur in all cases, and for tonic spasm to arise in many. The author has shown[2] that the so-called "jactitation" of nitrous oxide,

[1] *Brit. Med. Journ.*, 21st and 28th April 1894.

[2] See "On the Effects produced in the Human Subject by the Administration of Definite Mixtures of Nitrous Oxide and Air, and of Nitrous Oxide and Oxygen" (*Trans. Royal Med. Chir. Soc.* vol. lxxxii. p. 163).

which in one case may be little more than a subsultus, whilst in another it may be a widely diffused epileptiform seizure, is an intercurrent condition due to want of oxygen, and not an essential feature of true nitrous oxide anæsthesia. In some cases the facial muscles are chiefly affected by the convulsive seizure; in others the whole body mildly oscillates, the spasm apparently chiefly affecting the trunk muscles; in others, the hands, legs, and arms alone may twitch; whilst in a fourth group of cases the neck may be affected by barely perceptible clonic spasm, so that the head is felt to move with fine rhythmic jerks in one or other direction.

There is little doubt that the intermittent elevation of the larynx, the irregular contractions of the thoracic and abdominal muscles, and the clonic movements of the extremities are correlated. Tonic muscular contraction is sometimes very pronounced, not only in the extremities, but in the neck, back, and other parts; some patients, indeed, pass into an opisthotonic condition during this stage. Micturition very rarely occurs, but is sometimes met with in children when the clonic movements are at their height. Defæcation is extremely uncommon. Horsley has shown [1] that in deep nitrous oxide anæsthesia the superficial plantar reflex is abolished, but the deep patellar reflex is maintained. Eulenburg's experiments [2] also show that in the asphyxial state, whether induced mechanically or by drugs such as nitrous oxide, the superficial reflexes disappear before the deep. Buxton [3] found that one-third of the men, and nearly one-third of the women, anæsthetised by him at the Dental Hospital displayed ankle-clonus under nitrous oxide.

Trewby [4] holds that in the great majority of patients swelling of the back of the tongue from slight asphyxia suffices to block up the oropharyngeal aperture, and that the breathing tends to become gradually nasal in consequence.

The **pupils** in the majority of cases are dilated in deep nitrous oxide anæsthesia. In some cases, even though the anæsthetic has been freely administered, they remain of moderate size or even contracted.

[1] *Brain*, vol. vi. p. 369. [2] *Centralblatt für med. Wissensch.* No. 6, 1881.
[3] *Brit. Med. Journ.*, 24th September 1887.
[4] *Ibid.*, 24th July 1909, p. 202.

The **conjunctival reflex**, which will have persisted during most of the administration, now either becomes less marked or disappears. It cannot be depended upon as a guide, for it may sometimes be elicited even when wide dilatation of the pupils, and other signs indicative of the anæsthetic having been pushed as far as is advisable, are present. The corneal reflex usually persists.

The **colour of the features** is invariably altered, the change being most noticeable at the height of the muscular phenomena. Flabby and apoplectic-looking patients usually become deeply cyanosed when fully anæsthetised by nitrous oxide.

With perfectly pure nitrous oxide, with absolute coaptation of the face-piece, and with perfectly acting valves, the **time taken to produce full anæsthesia** is, on the average, about 56 seconds; but, as we have seen, the duration of inhalation will depend upon the type of subject.

C. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

The anæsthesia obtainable by nitrous oxide, particularly when that anæsthetic is administered free from oxygen, is distinctly lighter than the anæsthesia of ether or chloroform. In the vast majority of cases, however, complete insensibility of short duration may be depended upon. The author has met with two or three instances in which he has been unable to obtain that absolute and dreamless unconsciousness which is procurable with other anæsthetics. (See pp. 538 and 548.)

It is often a matter of some difficulty to decide at what particular moment anæsthesia is at its height. As a general rule it is best to wait until stertor or slight clonic muscular twitching is produced. In dental practice the administration may be conducted till two or three stertorous breaths have taken place, but when the oral or nasal cavity is not to be involved in the operation the surgeon may commence his incision or other procedure when stertor first becomes audible. For reasons already given (p. 289), to-and-fro breathing towards the close of a nitrous oxide administration is advantageous in many cases, postponing as it does the onset of stertor and jactitation, and leading, therefore, to a more lengthened available anæsthesia period. In the absence of any re-breathing, asphyxial phenomena may arise before the conjunctival reflex vanishes. When re-breathing is permitted, the administration may usually be continued till the conjunctiva loses its sensibility, and as there are less stertor and muscular movement with this method, the results will be better from the surgical point of view.

Although the extraction of a tooth during imperfect anæsthesia may not give the patient the sensation which we call pain, the operation may, under such circumstances, produce such a horrible and ill-defined feeling, or give rise to such an unpleasant dream, that it is questionable whether anything has been gained by the inhalation. In addition to these considerations, the performance of an operation during imperfect anæsthesia may be attended by much inconvenient tonic muscular spasm, which in dental surgery is objectionable from the liability of extracted teeth, etc., to fall backwards during opisthotonos.

In one or two cases the author has known prolonged and somewhat difficult expiration to replace other signs of anæsthesia. He has, moreover, met with cases in which, just at the acme of anæsthesia, the patient has made a sudden attempt at retching Under such circumstances as these the administration should be discontinued. Any marked feebleness of pulse or respiration should also be taken as an indication to remove the inhaler. Dilatation of the pupils is usually present in deep nitrous oxide anæsthesia, though it cannot be relied upon as a guide.

D. RECOVERY PERIOD: DURATION OF ANÆSTHESIA AFTER INHALATION

With the removal of the face-piece, or with the admission of air by other means, the recovery period commences. Sometimes, and especially in patients who have become markedly stertorous, the withdrawal of the anæsthetic does not necessarily involve the immediate admission of air to the lungs. In other words, a more or less occluded state of the upper air-passages may persist for a while and so retard the usual process of recovery. Other things being equal, the more rapidly and freely atmospheric air gains access to the lungs the more quickly will the patient recover. One of the first effects of the admission of air is observed in the pulse, which suddenly becomes much slower and fuller. Stertor, anoxæmic convulsion, and lividity now quickly vanish; and the dilated pupils begin to grow smaller. A secondary dilatation of the pupil may be observed during the recovery period.

The anæsthesia which persists after a single, continuous administration of pure nitrous oxide is known in dental practice as the **available anæsthesia.** The duration of this anæsthesia is, on the average, about **30 seconds.** There is considerable difficulty in deciding when true anæsthesia actually terminates, and this no doubt accounts for the discrepancies in the statements made by various authors. The period of available anæsthesia is to a certain extent dependent upon that of the inhalation—a long inhalation being followed, as a general rule, by a long anæsthesia, and *vice versa.* Moreover, in dental operations the duration of anæsthesia will not unfrequently be found to be influenced by the position of the patient's head, and more especially by the position of his tongue, during the extraction. Should the head be fully extended and the operation upon the upper jaw, nitrous oxide will have every chance of quickly escaping, and consciousness may thus be rapidly regained. If, however, the head be more or less vertical in the chair and the operation be upon the lower jaw, nitrous oxide may not escape so freely, by reason of the tongue being pressed backwards.

E. DANGERS CONNECTED WITH THE ADMINISTRATION

From the physiological and clinical facts to which reference has already been made it is clear that nitrous oxide, when administered in its pure state, and in such a manner that all expirations escape into the surrounding atmosphere, is respirable only up to a certain point. When this point has been reached, oxygen must be admitted to the lungs, otherwise respiration will not proceed. When nitrous oxide is clumsily administered so that the face-piece fails to fit accurately, when more or less re-breathing is permitted, or when the apparatus is faulty in construction, this gas may appear to be continuously respirable. But when all oxygen is rigidly excluded, and at each inspiration pure nitrous oxide enters the lungs, asphyxial phenomena rapidly supervene, and it is these phenomena, whose occurrence is incidental rather than essential, that have to be taken into account in considering the accidents and dangers to which the patient is liable.

It will be convenient to consider the dangerous phenomena which may attend the use of pure nitrous oxide under three main headings: (1) Primary respiratory failure, circulation subsequently ceasing; (2) Primary circulatory failure, respiration subsequently ceasing; and (3) Simultaneous cessation of both respiration and circulation.

(1) **Primary Respiratory Embarrassment and Failure.**— When an **overdose** of nitrous oxide is administered to a healthy subject **(Fourth Degree or Stage)**, the breathing becomes embarrassed and then ceases, the immediate cause of the embarrassment and failure usually being convulsive muscular spasm, anoxæmic in its nature. In certain cases obstructive stertor, of spasmodic origin, may arise whilst the conjunctiva is yet sensitive and the patient not fully anæsthetised, and bring breathing to a standstill. In other cases asphyxial spasm of thoracic and abdominal muscles constitutes the main element in the arrest of breathing. The more vigorous the patient the more powerful will be the spasm. In tall muscular young men, for example, an opisthotonic state may be induced. Defæcation or micturition may occur. Respiratory failure from paralysis of the nervous mechanism of respiration is rarely if ever met with, at all events in its pure form, in healthy patients subjected to an overdose of this anæsthetic. At the moment when breathing ceases the colour is usually markedly cyanotic or livid, the eyeballs generally turned upwards, the lids separated, and the pupils widely dilated. The character of the pulse at this juncture will depend upon circumstances. For example, should obstructive stertor have come on rather earlier than

usual, and be the immediate cause of arrested breathing, the pulse may show but slight evidences of depression. But should more of the anæsthetic have been introduced before breathing ceases, the pulse will probably be quick and small at the moment of the arrest. In any circumstances, however, the condition induced by an overdose, in patients with a good circulation, is one of primary respiratory failure. The length of time the heart will hold out against such asphyxial symptoms will depend upon its previous condition. Experience shows that in the case of young and vigorous subjects a comparatively long period of suspended breathing elapses before the heart's action becomes seriously depressed; whereas, in debilitated or flabby patients, with dilated, fatty, or feeble hearts, any marked interference with respiration will much more quickly lead to final cardiac arrest.

Patients with any **pre-existing narrowing or abnormality of the upper air-passages** are particularly prone to pass into a state of dangerous asphyxia when nitrous oxide is pushed to its fullest extent. This is well exemplified by Illustrative Case, No. 44, p. 564, a case in which the author was obliged to perform tracheotomy in order to resuscitate the patient. Elderly obese subjects are liable to pass into a state of completely obstructed breathing by reason of the engorged tongue being spasmodically drawn towards the pharyngeal wall. Patients with enlarged tonsils, adenoid growths, etc., are similarly liable to obstructed breathing.[1] The numerous other conditions capable of favouring primary respiratory failure are elsewhere fully considered (pp. 159 *et seq.*).

As already mentioned (p. 67), the performance of an operation during partial anæsthesia may reflexly suspend breathing, and under certain conditions this reflex arrest of respiration may assume such proportions as to constitute what has been termed **respiratory shock.**

The passage of foreign bodies into the larynx, trachea, or bronchi during nitrous oxide anæsthesia may set up asphyxial symptoms of a grave or fatal character (see p. 573).

(2) **Primary Circulatory Depression or Failure.**—There

[1] Probably in this category should come two fatal cases reported in the *Lancet*, 13th Feb. 1904, p. 439, and 14th Nov. 1903, p. 1368. In both these cases enlarged cervical glands were present.

is every reason to believe that in moderately healthy subjects nitrous oxide is incapable of producing symptoms of circulatory depression except as a sequel to respiratory embarrassment. For 25 years the author has kept careful notes of every interesting or abnormal case of anæsthesia, and, on looking through his notes, he is unable to find a single instance of primary pulse failure wholly dependent upon the action of this gas.

It has been alleged that there is a grave risk of cardiac syncope from the performance of surgical operations, and particularly dental operations, upon patients imperfectly anæsthetised by nitrous oxide. But when we consider that hundreds, and possibly thousands, of persons are daily subjected to dental operations whilst in the first or second degree of anæsthesia, it is probable that the risk of syncope from this cause has been overestimated. That reflex circulatory effects may arise when patients are emerging from nitrous oxide anæsthesia and the operation is still in progress, in other words, that patients may become "faint" from the distinct perception of pain, is probable. But if consciousness be in abeyance, there is every reason to believe that surgical stimuli are incapable of depressing the circulation, at all events to any dangerous degree. In nearly every recorded nitrous oxide death some disturbance of breathing appears to have been present; and it is in the highest degree probable that, in many of the dangerous and fatal cases in which the symptoms have been regarded as primarily cardiac or circulatory, some undetected asphyxial factor has been present.

(3) **Simultaneous Depression or Failure of Respiration and Circulation.**—This condition is fortunately very rare. It is most likely to arise in patients with grave forms of cardiac disease. Instead of the circulation being well maintained up to the point at which anoxæmic spasm or stertor arises, the pulse becomes feeble or imperceptible, a bluish pallor is observed, and the respiration, instead of being stertorous or jerky, is markedly shallow. There is apparently a direct relation between the feeble circulation and feeble breathing. Given that the general circulation is satisfactory, the anoxæmic state induced by nitrous oxide leads to excessive

rather than to diminished discharges from the respiratory centre. But when, from any particular cause, such as the presence of valvular or other cardiac disease, the cerebral circulation becomes defective, the respiratory centre appears to be more affected by the deficiency than by the quality of the blood which reaches it, and it hence happens that the breathing becomes shallow, without stertor or spasm. The author has never seen this condition become so grave as to threaten life; although it is quite obvious that it might do so. In one recorded nitrous oxide fatality, the patient was the subject of an adherent pericardium and old-standing pleurisy—two conditions which would certainly render the administration of nitrous oxide somewhat hazardous. In this particular case, the author is informed on good authority that death occurred without any indications of obstruction.

Post-mortem Appearances.—The post-mortem appearances after death under nitrous oxide will naturally depend upon the presence or absence of pathological conditions during life, and upon the precise mode of death. Generally speaking they are those of death from asphyxia; but it must be borne in mind that artificial respiration, inversion, and other movements to which the body may have been subjected immediately after death, may alter the conditions of the great vessels, heart cavities, and lungs, more particularly as regards the quantities of blood contained within these parts at the actual moment of dissolution.

F. AFTER-EFFECTS

For reasons which have already been given, the administration of pure nitrous oxide is necessarily exceedingly short, and it hence happens that disagreeable after-effects are generally completely absent. **Transient giddiness or headache** occasionally occurs; and **lassitude or sleepiness** may be experienced. Although the presence of undigested food within the stomach is not necessarily followed by vomiting, it is nevertheless important that attention should be paid to the diet (see p. 225). Some patients invariably suffer from **nausea** or even actual vomiting after nitrous oxide; but such cases are very exceptional. So-called "bad travellers" are often thus affected. A double administration of the gas with an interval of consciousness is liable to lead to after-sickness, especially in dental practice. When re-breathing has been practised, recovery will not take place quite so rapidly as usual, and headache and nausea may be thus initiated. Headache unattended by nausea sometimes follows the administration when food is present in the stomach. Should blood be swallowed during or after the operation, after-sickness will be likely to follow.

Feelings of faintness are, as a general rule, dependent upon some gastric disturbance brought about by the administration. Such feelings are, as will be gathered from what has just been said, most common when the diet has not been properly regulated. In some cases, however, faintness is probably referable to the temporary heart-strain to which the patient has been subjected. It is surprising, indeed, that the heart, whose right cavities are undoubtedly distended at the acme of pure nitrous oxide anæsthesia, does not more often show signs of this strain, either at the time or subsequently. **Hysterical outbursts**, or transient states of hallucination and struggling, are sometimes met with after the administration of nitrous oxide, but are very exceptional. **Protracted stupor, cataleptic states, hemiplegia,**[1] and even **insanity**[2] have one and all followed the administration; but such sequelæ are exceedingly rare. **Temporary glycosuria** and even true **diabetes**[3] are also said to have been produced by the inhalation of nitrous oxide; but the evidence in favour of such charges cannot be regarded as conclusive. **Retinal hæmorrhage**, from intense venous engorge-

[1] A curious case is reported by Dr. Ashford (*Amer. Journ. Med. Scien.* New Series, vol. lvii., 1869, p. 408). A girl of sixteen became insensible for two hours after the exhibition of nitrous oxide. Headache, dizziness, and left hemiplegia followed. Dr. H. C. Wood also refers to another case (*Brit. Med. Journ.*, 16th Aug. 1890, p. 385) which occurred in Philadelphia: "A gentleman arose from the dentist's chair after an inhalation of nitrous oxide, staggered, and fell in an apoplexy."

[2] See an interesting paper by Sir George Savage, "Insanity following the Use of Anæsthetics in Operations" (*Brit. Med. Journ.*, 3rd Dec. 1887, p. 1199), in which is mentioned the case of a young woman, a chronic alcoholic, liable to hysterical attacks, who, after the extraction of teeth under nitrous oxide gas, was attacked by delirious mania, which lasted for three weeks and terminated in dementia. Sir G. H. Savage regards the anæsthetic as the immediate cause of the attack.

[3] See *Brit. Med. Journ.*, 16th August 1890, p. 385.

ment, has been known to occur under the influence of pure nitrous oxide.[1]

A case of **erythematous eruption** following nitrous oxide anæsthesia has been reported.[2] The patient was a perfectly healthy young man who had six teeth extracted under nitrous oxide anæsthesia. Five hours later an erythematous eruption appeared on the face, which spread to the ears and forehead, but did not involve the neck or scalp. Ten hours after the extraction the rash had completely faded and it did not return. No other cause for the eruption could be discovered; but it must be considered to be distinctly doubtful whether the nitrous oxide was in fact responsible for the rash. Possibly the removal of so many teeth precipitated toxin-absorption from a mouth which may well have been septic. The patient vomited once, eight hours after the administration and three hours after the appearance of the rash.

Section II.—The Administration of Definite Mixtures of Nitrous Oxide and Air

A careful study of the phenomena resulting from the administration of nitrous oxide with definite proportions of atmospheric air is obviously essential before we can discuss the use of this anæsthetic with unknown proportions of air. It is therefore proposed, in this section, to give a brief summary of the results which the author obtained in the course of the investigation referred to on p. 294. As will be pointed out in the following section, it has been customary, ever since the anæsthetic properties of nitrous oxide became generally recognised, to administer this agent in conjunction with atmospheric air, more particularly with the object of maintaining insensibility for prolonged surgical operations; but, so far as the author is aware, no cases have been recorded in which definite mixtures of nitrous oxide and air have been administered.

A specially made gasometer was employed by which any desired percentages of nitrous oxide and of air could be administered. The following administrations were conducted, carefully timed, and recorded:—

[1] Sir John Tweedy informs the author that he has seen a case of this kind. The hæmorrhage was extensive and "about the posterior pole of the fundus."

[2] T. W. S. Hills, *Brit. Med. Journ.*, 10th April 1909, p. 898.

Table.]

				Cases.
Nitrous oxide	with	3	per cent air	5
,,	,,	5	,,	10
,,	,,	6	,,	6
,,	,,	7	,,	6
,,	,,	10	,,	10
,,	,,	12	,,	5
,,	,,	14	,,	4
,,	,,	15	,,	9
,,	,,	16	,,	5
,,	,,	18	,,	12
,,	,,	20	,,	7
,,	,,	22	,,	14
,,	,,	25	,,	8
,,	,,	30	,,	4
,,	,,	$33\frac{1}{3}$	,,	1
				106

Great care was exercised in conducting each administration in precisely the same manner, and records were made as to (1) *the duration of inhalation necessary for the production of anæsthesia for a short dental operation*; (2) *the average duration of anæsthesia after inhalation*; (3) *the average quantity of the mixture used*; (4) *the degree of anoxæmic convulsion (jactitation)*; (5) *alterations in the colour of the features*; (6) *stertor*; (7) *phonation*; (8) *reflex and excitement movements*; and (9) *after-effects*.

It was found that anæsthesia could be obtained with mixtures of nitrous oxide and air, provided the latter did not exceed 30 per cent. With $33\frac{1}{3}$ per cent the author failed to induce complete unconsciousness. With small percentages of air the symptoms were practically identical with those produced by the pure gas. The greater the proportion of air, the longer was the inhalation period before symptoms of anæsthesia appeared. Thus with 3 per cent and 5 per cent of air the average inhalation period was 69 secs.; with 30 per cent of air it was 148 secs. The duration of available anæsthesia for an intra-oral operation was distinctly longer than after nitrous oxide alone. The shortest anæsthesia was met with when employing 3 per cent of air (30·8 secs.) and 30 per cent of air (29·7 secs.), *i.e.* at the two extremes; the longest average anæsthesia being recorded with 14 per cent, 16 per cent, and 22 per cent of air, the respective durations with these percentages being 40·5 secs., 42 secs., and 42·6 secs. It is an interesting fact that there was more anoxæmic convulsion with 3 and 5 per cent of air than with pure nitrous oxide, the explanation being that, in the absence of all oxygen, obstructive stertor comes about so quickly as to cut short the intake of the anæsthetic gas before the blood has become sufficiently altered to induce any marked convulsive seizure. With higher percentages of air the anoxæmic muscular phenomena progressively lessened, disappearing altogether with 30 per cent of air. With moderate percentages of air the clonic movements were but feebly marked. Like anoxæmic convulsions, lividity and cyanosis were more evident with small percentages of air than with pure nitrous oxide, and for the same reason. With 30 per cent of air there was but little alteration in the normal colour. The tendency to stertor progressively lessened as the percentages of air rose. With mixtures poor in air the stertor was coarser and more irregular than with those containing moderate percentages. Very interesting changes in the type of stertor were observed as the percentages of air increased. There was somewhat less phonation during dental operations performed under nitrous oxide mixed with small percentages of air than under nitrous oxide itself; but with mixtures containing more than 10 per cent of air phonation was common. Reflex and excitement movements were, on the whole, less marked than with pure nitrous oxide; and this was especially noticeable with moderate percentages, for with such percentages the best types of anæsthesia were attainable. So far as the general results of these cases are concerned, the investigation showed that with percentages of air between 14 and 22 a very distinct improvement was manifest over the ordinary nitrous oxide cases. With percentages below 14 and above 22 the improvement in general results was less marked. The conclusion at which the author arrived in the course of this investigation was that the best definite mixture for men was one containing from 14 to 18 per cent of air, whilst the best for women and children was one containing from 18 to 22 per cent of air.

Section III.—The Administration of Nitrous Oxide with indefinite Quantities of Air

The effects produced by administering nitrous oxide with indefinite quantities of air will necessarily depend upon numerous circumstances. The most important of these is the proportions existing between the various gases inhaled. Putting on one side for the moment all plans of administration in which re-breathing is possible, and taking it for granted that the gases presented to the lungs are inspired and expired through accurately working valves and through orifices of sufficiently large calibre, it may be said that there are two systems by which nitrous oxide may be administered with indefinite quantities of air. In the first of these the anæsthetist administers the pure gas as already described, till his patient is partially or completely anæsthetised; he then admits one or more breaths of air by turning the stopcock; and he continues thus to administer nitrous oxide and air alternately till (as in general surgery) the operation is completed, or till (as in oral or nasal surgery) sufficiently deep anæsthesia has been induced. In the second system of conducting the administration the anæsthetist aims at administering nitrous oxide and air concurrently rather than alternately, and with this object he employs some simple expedient or contrivance which, from the commencement to the end of the administration, will allow of sufficient air gaining access to the lungs to obviate any marked asphyxiation from the nitrous oxide. In actual practice these systems are often combined or used indiscriminately—the patient at one moment breathing pure nitrous oxide, at another nitrous oxide mixed with air, and at another air itself.

Should to-and-fro breathing be permitted during any part of a gas-and-air administration, a more complex result than that obtainable when accurately working valves are present will necessarily ensue, for instead of the excreted carbonic acid escaping as it would in ordinary circumstances, it is intercepted, so to speak, in the inhaling bag, and its quantity will progressively increase within that bag so long as to-and-fro breathing is permitted. Moreover, the quantity of this respiratory product present in the bag at any given moment will depend upon the extent to which air has been admitted with the nitrous oxide (see p. 45).

From time to time during the last thirty years, and particularly in the United States, cases have been recorded in which general surgical operations, varying in duration from a few minutes to an hour or longer, have been performed under nitrous oxide administered in one or other of the ways just described; and in this country Clover and others have chronicled similar results. The first systematic endeavour to administer nitrous oxide and air *concurrently* appears to have been made by Dr. George Brush of Brooklyn,[1] who employed an apparatus with a sliding valve which could be so arranged as to admit atmospheric air according to the needs of the patient. Operations lasting upwards of an hour were performed under the influence of anæsthesia thus produced. But there is little to be said in favour of such a line of practice, save perhaps for very exceptional cases; for the resulting

[1] *Brooklyn Med. Journ.*, May 1890.

anæsthesia is liable to be uneven and unsatisfactory in its type, owing to the physical characters and peculiar physiological action of this anæsthetic. Had we no better means at our disposal for inducing and maintaining anæsthesia, we should have to be content with the results thus obtainable; but as compared with the anæsthesia of ether or chloroform that which results from the inhalation of pure nitrous oxide and air cannot be regarded with favour. At the same time there are undoubtedly certain special cases in which the use of this system is distinctly advantageous. For example, when an anæsthesia of from one to five or ten minutes is needed, when absolute immobility and complete muscular relaxation are not essential, and when there is some special reason for avoiding ether or chloroform, this plan of anæsthetisation may be employed. It certainly has the great merit that it is rarely followed by after-effects; but it cannot be recommended when deep anæsthesia, in our modern sense, is essential to success; nor can it be regarded as appropriate for all types of subjects. As already pointed out, there are numerous patients in whom the asphyxial condition incidental to many methods of anæsthetising must be studiously avoided, and although it is theoretically possible to obtain a non-asphyxial anæsthesia by this system, such an anæsthesia is not always obtainable.

In conducting the administration of nitrous oxide and air for an ordinary surgical operation, the anæsthetist may either adopt the *alternate* plan, or, by keeping the air-hole of the stopcock slightly open, he may *concurrently* administer the nitrous oxide and air. The longer the administration has proceeded, the larger may be the quantity of air allowed. By carefully watching the patient's symptoms, the precise junctures at which the change from nitrous oxide to air should be effected, or at which more air should be allowed, will be readily ascertained. An endeavour must be made to maintain a snoring, regular breathing, with but slight duskiness.

As nitrous oxide is unquestionably of special utility in dental surgery, it is not surprising that a great deal of attention has been directed towards improving the methods of administering this anæsthetic for the extraction of teeth. Not only have attempts been made to improve the *type* of anæsthesia, but many ingenious devices have been proposed for *prolonging* the insensibility ordinarily produced. Although, as will be presently shown, the best form of anæsthesia is attainable only when oxygen (and not atmospheric air) is mixed with the nitrous oxide, "gas-and-air" anæsthesia is distinctly preferable to that produced by nitrous oxide alone. This has been specially pointed out by Mr. George Rowell.[1] When from ten to twenty breaths of the pure gas had been taken, Mr. Rowell admitted one breath of air, and subsequently repeated this procedure about every fifth breath. A longer and better form of anæsthesia results than when pure nitrous oxide is continuously inhaled. In the majority of cases a commencing irregularity in breathing without either stertor or muscular twitching is the sign that proper anæsthesia has been induced.

With regard to the prolongation of anæsthesia for protracted dental operations, the first attempt appears to have been made by Clover and Coleman, who devised and used a nose-piece through which the administration of the gas was kept up. The next step in this direction was taken by Mr. S. Coxon,[2] who, after inducing anæsthesia in the ordinary way, placed a metal tube in the mouth and kept up a supply of "gas" during the operation. It is advisable, according to Dr. McCardie,[3] to close the anterior nares when employing a mouth-tube, and if this be done, anæsthesia of several minutes' duration may be obtained. Mr. Harvey Hilliard[4] induced anæsthesia in the customary manner, and then maintained it by means of a soft tube passed through the anterior nares into the naso-pharynx. The late Mr. Alfred Coleman[5] successfully revived the use of the nose-piece; and working upon Mr. Coleman's suggestions, Mr. Herbert Paterson[6] has obtained results which are certainly satisfactory from many points of view.

The results obtained by this and other methods of prolong-

[1] See *Journ. Brit. Dent. Assoc.*, 15th October 1892, p. 669.
[2] *Clinical Journal*, 1st June 1898, p. 116.
[3] *Ibid.*, 29th March 1899, p. 37.
[4] *Lancet*, 28th June 1902.
[5] *Clinical Journal*, 25th May 1898, p. 92.
[6] *West London Medical Journal*, July 1899.

ing nitrous oxide anæsthesia for dental operations are, from the patient's point of view, sometimes very satisfactory; for not only may an absolute immunity from pain be secured for three, four, or five minutes, or even longer, but disagreeable after-effects are rarely met with. The type of anæsthesia, however, can hardly be regarded as satisfactory in the modern sense; and in order that the best results may be obtained, a third person—that is to say, some one in addition to the surgeon and the anæsthetist—is often needed.

Kirkpatrick [1] has modified Paterson's apparatus by introducing an expiratory valve in connection with the nose-piece. This valve can be thrown out of action when desired. The results in 490 cases are described as highly satisfactory, the longest period of anæsthesia obtained being seventeen minutes.

Trewby [2] also has devised an apparatus for the nasal administration of nitrous oxide. This has been in use at the Royal Dental Hospital for some time, and gives good results there.

Mr. Bellamy Gardner prefers nitrous oxide and oxygen for prolonging anæsthesia. He employs the stopcock shown in Fig. 32 fitted with Levy's double bag (one inside the other) for the two gases. From the exit portion of the stopcock, tubes pass to a nose-piece. Levy's double bag has the advantage that when both bags are distended (as is essential) the two gases enter the stopcock at the same pressure. Mr. Gardner is very satisfied with the results he obtains.

There are certain serious objections to the prolongation methods. Firstly, even the most ardent advocates of such methods appear to fail occasionally in obtaining anæsthesia. Secondly, considerable practice is necessary before good results can be secured. Thirdly, highly inconvenient movement, loud phonation, obstructed breathing, and cyanosis are not unfrequent accompaniments of an administration. Fourthly, it is difficult, if not impossible, thoroughly to cleanse and disinfect the nose-piece and tubes which are used. Fifthly, an assistant is often needed to steady the patient, insert the gag, and sponge out blood.

[1] *Medical Press*, 16th July 1902.
[2] *Brit. Med. Journ.*, 25th Dec. 1909, p. 1805.

Section IV.—The Administration, at ordinary Atmospheric Pressures, of definite Mixtures of Nitrous Oxide and Oxygen

There is one formidable objection to the use of air as an oxygenating agent when administering nitrous oxide, viz. that it contains such a large percentage of nitrogen. Although this latter gas, when given alone, will produce anæsthesia by excluding oxygen,[1] it cannot in any way contribute towards nitrous oxide anæsthesia in the presence of that percentage of oxygen which is capable of preventing cyanosis and clonic muscular spasm. If we administer with nitrous oxide a percentage of air which will prevent lividity and the other symptoms referred to, we shall, in most cases, also prevent deep anæsthesia, owing to the small percentage of nitrous oxide which would be possible in such a mixture. For example, a mixture of 40 per cent of air and 60 per cent of nitrous oxide would contain about 8 per cent of oxygen and about 32 per cent of nitrogen; and although the 8 per cent of oxygen would be sufficient to preserve nearly or completely the natural colour of the patient's face, and to suppress clonic muscular spasm, the 60 per cent of nitrous oxide would be insufficient to produce tranquil anæsthesia. If, however, instead of using air for oxygenating purposes, we employ oxygen, we shall be able to replace the 32 per cent of useless nitrogen by a corresponding quantity of useful nitrous oxide, and the proportion of the latter will now rise to 92 per cent. With such a large percentage of nitrous oxide, anæsthesia is certain to become established, and the percentage of oxygen remaining the same as in the nitrous oxide-and-air mixture, cyanosis and other evidences of diminished blood oxygenation will be prevented. These few considerations will act as a link to connect the preceding with the present section.

As already mentioned (p. 282), Dr. E. Andrews of Chicago was the first to employ oxygen in conjunction with nitrous oxide, and to obtain a non-asphyxial form of anæsthesia by this means. It was not, however, till ten years later, when Paul Bert published his interesting observations, that this system of anæsthetisation began to attract attention. Bert's

[1] The reader is referred to pp. 465 *et seq.*, where he will find details of several cases in which the author administered nitrogen for tooth extraction.

researches led him to regard nitrous oxide as an agent which, as customarily given, could only produce anæsthesia when administered pure, *i.e.* free from air or oxygen. He came to the conclusion that, whilst it was desirable to avoid all asphyxial phenomena by mixing oxygen with nitrous oxide, it was impossible to produce anæsthesia by such a mixture without increasing the atmospheric pressure (see p. 314). But in spite of Bert's views it soon became clear from the observations of Klikowitsch,[1] Winckel, Döderlein, Zweifel, Hillischer, and the author, that such an increase, although it was doubtless capable of intensifying the effects, was not absolutely necessary for the production of anæsthesia.

Before proceeding to the consideration of Bert's results (Section V.), and to the description of the best means for producing non-asphyxial nitrous oxide anæsthesia at ordinary pressures (Section VI.), it is proposed to give a brief summary of the results at which the author arrived when administering various definite mixtures of nitrous oxide and oxygen.

In the course of this investigation[2] the following administrations were conducted :—

	Cases.
Nitrous oxide with 3 per cent of oxygen	5
,, ,, 4 ,, ,,	10
,, ,, 5 ,, ,,	17
,, ,, 6 ,, ,,	11
,, ,, 7 ,, ,,	11
,, ,, 8 ,, ,,	18
,, ,, 9 ,, ,,	5
,, ,, 10 ,, ,,	10
,, ,, 11 ,, ,,	7
,, ,, 13 ,, ,,	2
,, ,, 20 ,, ,,	4
	100

As in the "gas and air" cases, these mixtures were accurately prepared and accurately administered under precisely similar circumstances, by means of an apparatus with accurately working valves, great care being taken to exclude the minutest proportions of atmospheric air. Records were made with regard to the various points referred to on p. 305. The duration of inhalation necessary for the performance of a dental operation increased as the percentage of oxygen rose, that is to say, a shorter inhalation was necessary with small percentages of oxygen than with large. For example, with 3 per cent of oxygen the average inhalation period was 96·6 seconds; whereas with 20 per cent of oxygen it was 223·5 seconds. There was a very marked contrast between the short inhalation period of pure nitrous oxide (56 seconds) and that of mixtures of nitrous oxide and oxygen. It is interesting to note that deep anæsthesia was obtainable even when the proportion of oxygen was as great as that in atmospheric air. With regard to the duration of

[1] For references to the works of these observers, see the author's book on *The Administration of Nitrous Oxide and Oxygen for Dental Operations*, p. 10.

[2] See footnote, p. 294.

anæsthesia after inhalation, this was distinctly longer than when mixtures of nitrous oxide and air were employed, just as the anæsthesia with these latter mixtures was greater than when pure nitrous oxide was used. Thus, the lowest average anæsthesia (39·7 secs.) was very little below the highest (42·6 secs.) of the air cases. The best results, so far as a lengthy available anæsthesia was concerned, were met with when using 7 per cent of oxygen, the average duration of anæsthesia being 50·1 seconds. A very interesting result of the investigation was to show that anoxæmic convulsions were readily prevented, even by small percentages of oxygen. During the inhalation of nitrous oxide, either pure or with oxygen up to 4 per cent, some degree of anoxæmic convulsion was very common. But when once 5 per cent of oxygen was reached, very little convulsive movement was observed, and with 6 per cent and over there was no such movement visible. The anoxæmic convulsion of pure nitrous oxide became progressively attenuated and weakened, so to speak, as the proportion of oxygen mixed with the anæsthetic gas increased. With regard to alterations in the patient's colour, the author found that with less than 11 per cent of oxygen some degree of lividity was present; but with this percentage and over, the normal colour was retained. With 8, 9, and 10 per cent of oxygen the alteration was very slight. With smaller percentages the lividity was of course greater. The effects of even small percentages of oxygen in preventing stertor were very marked. Thus, with 3, 4, and 5 per cent of oxygen the ordinary stertor of pure nitrous oxide lost its irregular character, and became replaced by a regular, snoring sound, similar in its type to that of ether or chloroform anæsthesia. With somewhat higher percentages of oxygen, snoring became less pronounced. With 20 per cent of oxygen the snoring altogether vanished. Phonated sounds were far less common under nitrous oxide and oxygen than under nitrous oxide and air. They were most common with very small or with very large percentages. Reflex and excitement movements were uncommon with small percentages of oxygen; but were liable to arise and possibly to become inconvenient, when the percentage of oxygen rose to 10 per cent or more. Stamping, kicking, side-to-side movements, etc., were very common with from 10 to 20 per cent of oxygen. As regards the general result: the best mixtures for adult males were those containing 5, 6, or 7 per cent of oxygen; and mixtures containing, 7, 8, or 9 per cent were best for females and children.

The chief drawbacks to the use of definite mixtures of nitrous oxide and oxygen are—(1) that they are difficult to prepare with accuracy and in sufficient quantities; (2) that different subjects require different percentages; and (3) that the proportion of oxygen cannot be increased or decreased to meet special conditions arising during the administration. At the same time it is interesting to know what phenomena are associated with different percentages; for it is only upon a basis of this kind that we can successfully administer nitrous oxide and oxygen for protracted operations (see p. 326).

Section V.—The Administration, under increased Atmospheric Pressures, of definite Mixtures of Nitrous Oxide and Oxygen (Paul Bert's Method)

The following extract from the writings of Paul Bert will express the views which he held:[1]—

"My experiments have demonstrated that, in an animal breathing pure nitrous oxide, when anæsthesia is established, 100 volumes of arterial blood contain 45 volumes of nitrous oxide. If, then, we introduce into the blood 45 volumes of nitrous oxide for every 100 volumes of blood, we shall obtain anæsthesia. Now, when pure nitrous oxide is contained in a bag under ordinary pressure this gas is at the tension of 100. But if the bag of gas is placed in an air-tight chamber, the pressure in which is raised to two atmospheres, the tension of the gas in the bag will be 200. And if this bag within the air-tight chamber, instead of containing 100 per cent of nitrous oxide, viz. this gas in a state of perfect purity, contain only 50 per cent, the tension of this 50 per cent of nitrous oxide will be equal to 100, that is to say, the quantity of nitrous oxide will be exactly that which is necessary to induce anæsthesia. The other 50 per cent can therefore be occupied by another gas for sustaining life, viz. oxygen, and it will therefore be possible to carry out prolonged operations. I have chosen these figures to render the explanation of the method at which I have aimed more intelligible. But they must not be considered as indicating the proportions of the oxygen and nitrous oxide to be employed. The proportion of oxygen would be too high,—in fact, we know that air contains only 21 per cent. The problem therefore resolves itself into a very simple calculation. By mixing 85 parts of nitrous oxide with 15 parts of oxygen it is only necessary to raise the pressure to 89·5 cm. Supposing the barometric pressure to be 76 cm., an extra pressure of only 13·5 cm. of mercury is required to induce anæsthesia. Under these conditions the animal operated upon soon falls asleep and into deep anæsthesia. The circulation and respiration are in no way influenced by the nitrous oxide, though the perceptive faculties are suspended, and if the quantity of the gaseous mixture inhaled by the animal is sufficient, it is possible to maintain the most absolute anæsthesia for several hours."

After a series of satisfactory experiments upon lower animals, Bert put his theory to a practical test. He had constructed for him a metal chamber in which the atmospheric pressure could be raised to the desired extent. The chamber was large enough to contain several persons. A mixture of 85 per cent of nitrous oxide and 15 per cent of oxygen was administered to a patient, and an extra pressure of 13·5 cm. (*i.e.* a total pressure of 89·5 cm.) was employed.

The apparatus is too complicated, too costly, and too cumbrous to

[1] *Progrès Médical*, No. 9, 1880. See also *Traité d'Anesthésie Chirurgicale*, by J. B. Rottenstein, Paris, 1880, p. 303.

allow of its being widely used. The author is informed, too, on good authority, that the increased pressure within the chamber not unfrequently produced considerable discomfort to those engaged in the operation.

The question naturally arises: Is the anæsthesia thus obtained more satisfactory in its type than that which can be secured by administering these two gases together, in proper proportions, at ordinary atmospheric pressures, and by varying the percentage of oxygen to meet the special circumstances of each case? That an increase in atmospheric pressure is serviceable in preventing or treating excitement has been proved by those who have employed Bert's method—notably by Dr. C. Martin of Lyons; but, until further experiments have been made, it is difficult to say whether, at ordinary atmospheric pressures, such excitement cannot equally well be avoided or allayed by decreasing the proportion of oxygen in the mixture.

Section VI.—The Administration, at ordinary Atmospheric Pressures, of Nitrous Oxide with varying Proportions of Oxygen

The first successful attempt to administer nitrous oxide and oxygen at ordinary atmospheric pressures by means of an apparatus capable of regulating the proportions of the two gases was made by Hillischer[1] of Vienna; and it was the report of his work that first directed the author's attention to the subject. In 1886 the author commenced a series of experimental administrations at the Dental Hospital of London; he tried a large number of different methods of procedure;[2] and he carefully tested Hillischer's apparatus. He found that by Hillischer's method it was impossible to regulate accurately the oxygen supply; that the channels through the apparatus were too narrow to allow of free respiration; that the administrator required the services of an assistant in order to keep the gas-bags properly filled; and that the apparatus was not sufficiently portable to fit it for the requirements of English practice. He therefore devised an apparatus free from these objections; and as it has for many years fulfilled its requirements, the remainder of this section will be devoted to describing its action and the type of anæsthesia it is capable of producing.

The Author's Method of Administration

A. APPARATUS

Two cylinders of liquefied nitrous oxide and one of compressed oxygen are needed. The stand for these cylinders is shown in Fig. 30. It is constructed with the object of being as portable as possible, the oxygen

[1] See a pamphlet by Dr. Hillischer, *Schlafgas*.

[2] In a paper which the author read at the Odontological Society (*Trans. Odont. Soc.*, June 1892) he described in detail the various methods which he tried.

cylinder being placed above two nitrous oxide cylinders. When the nitrous oxide is released by working the foot-key, it passes into the vertical brass tube of large calibre at the extreme left of the wood-cut.

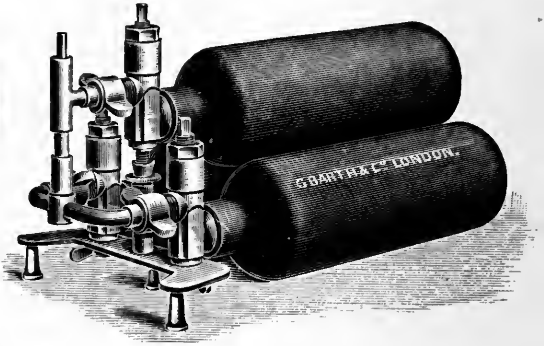

FIG. 30.—Stand and Union for the Nitrous Oxide and Oxygen Cylinders.

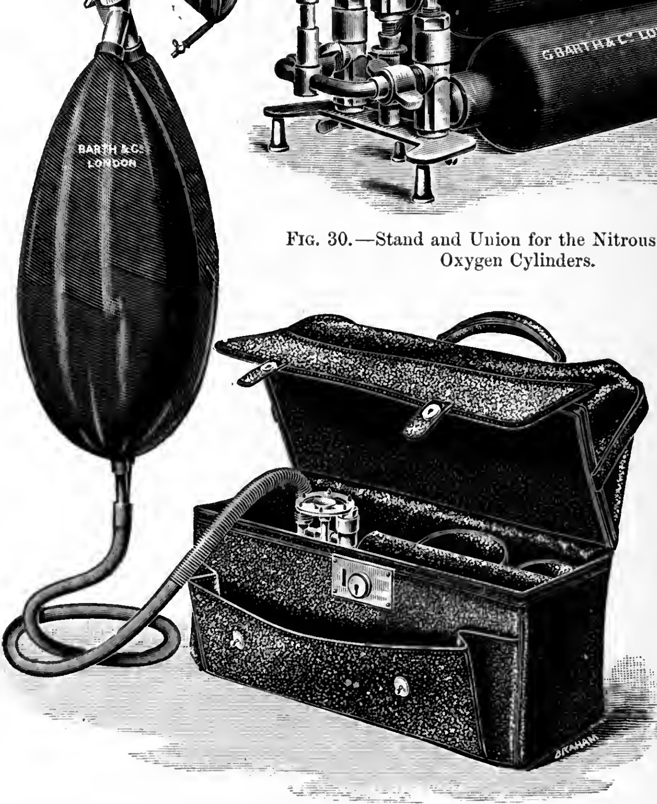

FIG. 31.—The author's Apparatus for administering Nitrous Oxide and Oxygen.

When the oxygen is released, it passes into the vertical brass tube of smaller calibre which is seen to be emerging from the centre of the nitrous oxide tube. To these two brass exit tubes, one inside the other, two corresponding rubber tubes are attached for the transmission of the respective gases to the double bag shown in Fig. 31. It will be seen that the first few inches of the nitrous oxide transmission tube are surrounded by spiral wire to prevent kinking. When the two tubes approach the double bag they are made to pass independently by means of a Y-piece to supply this double bag with the two gases. To the double bag the regulating stopcock is attached. The latter is shown in detail in Fig. 32. NOT is the nitrous oxide tube, with its removable inspiratory valve *iv'*. This is the tube to which the nitrous oxide half of the double bag is attached. OT and *iv* are the oxygen tube with its inspiratory valve. Nitrous oxide passes along NOT and through the large orifice NOO to the mixing-chamber in which revolves the inner drum ID with its large slot S. The handle has an indicator which may be turned to various points on the flange shown in the wood-cut. The oxygen which passes along OT enters the little oxygen chamber OC, from which it passes to the mixing-chamber through the 10 small orifices OO, any number of which may be opened by rotating the inner drum. All the 10 oxygen orifices are of the same size except the first, and by means of the supplementary stopcock SS, this can either be made of the same size as the other 9 (first position of SS), or it can be made equal to the 10 orifices collectively (second position of SS), or to 20 such orifices (third position of SS). From the mixing-chamber the gases are inhaled through the main inspiratory valve IV, expirations escaping at the expiratory valve EV. PD is a partial diaphragm which serves to direct the expirations upwards towards EV. When the inner drum is in position, and the indicator points to "AIR," air enters the stopcock at AH, and is breathed through IV and EV, the nitrous oxide and oxygen both being shut off. As the handle H is raised, the indicator passes from "AIR" to "N_2O," and pure nitrous oxide is breathed, because AH and OO are closed and NOO is open. If the handle H be still further raised, the indicator passes to "1," which means that whilst the nitrous

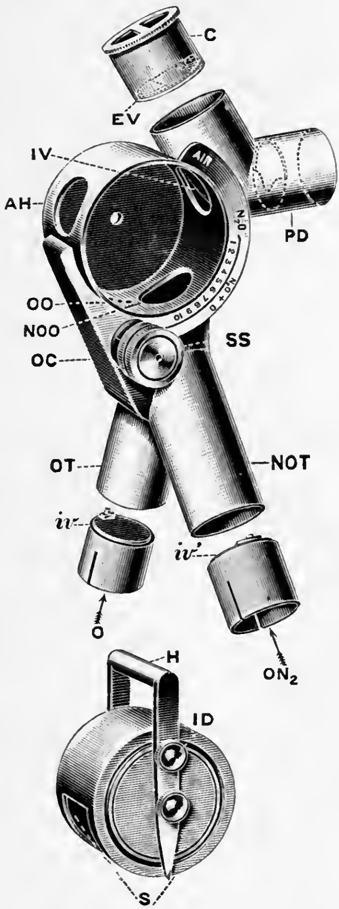

FIG. 32.—The Regulating Stopcock and Mixing-chamber shown in detail.

oxide orifice NOO is still open, and the patient is breathing nitrous oxide, the first of the 10 oxygen orifices is also open, and oxygen gains admission with the nitrous oxide to the air-passages. At the commencement of the administration, SS is so adjusted that the first oxygen orifice is the size of the rest, so that when the indicator points to "1," only a small percentage of oxygen, 1 per cent or less, is breathed. By moving the indicator to "2," "3," etc., any number of the 10 oxygen orifices may be opened, and a corresponding number of small streams of oxygen added to the nitrous oxide. If more oxygen be required than can pass through with the indicator at "10," the supplementary stopcock SS may be turned to its second position (= ten extra holes) and the indicator brought back to "2," when an amount of oxygen corresponding to that which would pass through eleven holes will be inhaled. If the indicator be made to pass to "3," whilst SS is in its second position, twelve holes will be opened; and so on. If large quantities of oxygen be needed, SS may be turned to its third position (= twenty extra holes). By this arrangement the administrator has at his disposal, so to speak, 29 oxygen orifices. The precise percentages of oxygen coming through these orifices will depend upon numerous circumstances, and the numbers given do not represent percentages. It is not necessary that the precise percentages of oxygen should be known. Each apparatus will be found to have its own particular characters, and these characters will always repeat themselves under the same circumstances. One apparatus may let through more oxygen than another; but the proportions can be easily graduated. It is very important that the rubber bags and all valves should be kept in good order. The valves require to be renewed occasionally.

B. THE ADMINISTRATION

The type of subject must be taken into consideration. Just as with ether and with chloroform it is impossible to produce the best results on all occasions, so it is impossible in the case of nitrous oxide. The best subjects for this method are middle-aged women of placid temperament. Weakly middle-aged men are also good subjects, unless possessing so much hair about the face as to make it difficult to obtain a proper fitting of the face-piece. Muscular or heavily-built men, obese and elderly patients of both sexes, and all persons who smoke or drink to excess are comparatively difficult to anæsthetise by this method. Boys and girls, especially if florid, may secrete much mucus and saliva and display a tendency to retching and vomiting. Young women are favourable subjects as a general rule. Young men often give trouble by reason of muscular spasm. Patients with adenoid growths, enlarged tonsils, and allied conditions may also give trouble, and may require a larger percentage of oxygen than usual. Alcoholic subjects display a tendency towards "jactitation," and are very susceptible to the deprivation of oxygen, so that the best results are to be obtained by the prolonged administration of a mixture comparatively rich in this gas.

In order to obtain the best results, the patient must be as carefully prepared as for any other general anæsthetic; and special attention should be paid to the posture in which the administration is conducted. If the sitting posture be adopted the remarks made on p. 182 must be borne in mind. For general surgical work the dorso-lateral or lateral posture (Fig. 12) is the best; but the dorsal position may be permitted, provided the patient's head be turned well to one side.

The anæsthetist should make sure that he has a sufficient supply of the two gases, and that his apparatus is in perfect working order. The bags should not be charged until immediately before the administration, and they should then be half filled with their respective gases. In general surgical practice it is a good plan to place a small wooden mouth-prop (Fig. 16, p. 257) between the teeth, particularly if there be the slightest nasal obstruction. In dental practice one of the mouth-props shown in Fig. 23, p. 260, should be introduced. The face-piece should be carefully chosen; for want of co-aptation will lead to partial or complete failure. When the face-piece is applied, air will be breathed freely through the apparatus, and the sound of the acting valves will prove that the face-piece fits well. If there be much hair about the face a folded wet napkin may be placed around the cushion of the face-piece. The patient should be instructed to breathe freely and moderately deeply, "in and out through the mouth."

When the administrator sees and hears that breathing is free, the indicator may be turned to "2." Nitrous oxide with a small percentage of oxygen will thus gain admission to the lungs. It is best to commence with a comparatively small percentage of oxygen, as we have to allow for that originally present in the lungs and blood. If we begin with, say, 10 per cent, excitement will be liable to arise. After two or three seconds the oxygen indicator may be turned to "3," and in a few seconds more to "4." In the case of children, anæmic subjects, and debilitated persons, the indicator may be moved to "3" and "4" more quickly than in the case of strongly-built individuals. During these manipulations the two bags must be kept as nearly as possible equal in size. It is rarely, if ever, necessary to replenish the oxygen bag during the administration for a dental operation, but the foot or hand must be constantly kept working the nitrous oxide key. In general surgery, when a more or less protracted administration is called for, fresh oxygen must be admitted to the bag from time to time. Considerable practice is necessary to keep both bags equal in size and partially distended throughout. Should phonation, laughter, excited movement, or struggling assert itself, the administrator must turn back the indicator for a few breaths. In 40 or 50 seconds from the commencement of the inhalation the indicator may usually be allowed to point to "5," and in 20 seconds more to "6," "7," or even "8." It is often unnecessary in dental administrations to give more oxygen than this, though in most cases the indicator may be pushed to "10." In general surgical cases a progressive increase in oxygen is necessary—that is to say, the longer the patient has been inhaling the mixture, the greater should be the proportion of oxygen. General surgical procedures may usually be commenced about two minutes after the face-piece has been applied. From this point onwards the anæsthetist will find that he has to pilot his patient along a narrow channel. On the one side he will have to avoid the clonic respiratory movements, etc., which prevent a free and lengthy intake of the anæsthetic; and on the other any inconvenient signs of incomplete anæsthesia. He must be sparing in his addition of oxygen when anæsthetising those patients whose appearance suggests that they will be likely to require what we may call, for want of a better term, a strong dose of the anæsthetic. Patients who are easily affected by anæsthetics —such, for example as children and debilitated persons of both sexes—may invariably be anæsthetised by nitrous oxide with considerable percentages of oxygen. The author finds, for example, in anæsthetising such patients, that after 5 or 10 minutes' inhalation he can usually keep open about 20 of the minute oxygen orifices in the apparatus. A similar tolerance of large proportions of oxygen will be met with in asthmatics and other patients who may be suffering from respiratory difficulties. In protracted administrations it may be advisable to admit an occasional breath of fresh air. Should inconvenient stertor arise, oxygen must be more freely admitted, and the jaw pressed forwards (p. 554) as in administering other anæsthetics. The longest administration the author has conducted without allowing even one breath of air was one which lasted 35 minutes.

If a protracted administration be required and the bedstead upon which the patient is lying be of inconvenient proportions, it is a good plan to reverse the patient's position, placing his head at the foot of the bed.

C. EFFECTS PRODUCED

First Degree or Stage.—This is very similar to that already described as occurring under nitrous oxide. There is, however, one noteworthy difference, viz. that the presence of even a small percentage of oxygen more or less completely removes the *besoin de respirer* so common with pure nitrous oxide.

Second Degree or Stage.—Consciousness is lost a trifle later than with pure nitrous oxide; and the period that elapses between loss of consciousness and the establishment of anæsthesia is longer. Neurotic and alcoholic subjects, as well as those whose nervous systems have become undermined by excessive work, worry, etc., may move their arms or legs, laugh, or gesticulate during this stage. Excitement occurring during the administration may usually be at once stopped by diminishing the percentage of oxygen. The respiration during this stage not unfrequently becomes very deep and rapid, and then abruptly calm or even imperceptible. There is no cause for anxiety in this rapid respiration; it always coexists with a good regular pulse and florid colour, and gradually gives place to tranquil, unembarrassed, and distantly-snoring breathing, as deep anæsthesia approaches.

Third Degree or Stage.—When the typical anæsthesia of nitrous oxide and oxygen has become established, the patient's condition will be suggestive of natural sleep.

The **respiration** is usually remarkably calm and perfectly regular during this stage. A barely audible inspiratory roughness or snoring is not uncommon. The loud "stertor" of an ordinary nitrous oxide administration is never met with. Respiration is rhythmically performed. Owing to there being less venous engorgement, and hence less swelling of all parts within the upper air-tract, than when nitrous oxide is given in the ordinary manner, patients with enlarged tonsils may be anæsthetised with comparatively little tendency to obstructed breathing.

The **colour of the face and lips** varies. In some cases the patient becomes a trifle paler than usual; whilst in others, and especially in those previously pale from apprehension, the colour becomes more florid. The duskiness and lividity so common under pure nitrous oxide are, generally speaking, entirely absent. As will subsequently be pointed out, it is sometimes necessary during the administration of the mixture, either to bring down the proportion of oxygen below 10 per cent, or to give pure nitrous oxide for a short period; and in such circumstances a variable degree of duskiness will of course ensue.

The **circulation** is well maintained during deep anæsthesia. The pulse is invariably accelerated; but it is neither so quick nor so small as the pulse under pure nitrous oxide.[1] The author has administered nitrous oxide with oxygen to patients whose circulatory functions were at the time of inhalation seriously disorganised, and can testify to the very satisfactory manner in which the mixed gases have been taken. He has given the mixture to a patient in a half-fainting condition, sitting vertically in a chair, and has found an almost imperceptible pulse become perceptible and of fair volume during

[1] Dr. Walter Broadbent (*Brit. Med. Journ.*, 8th July 1899) publishes an interesting pulse-tracing under nitrous oxide and oxygen, showing some lowering of tension, which he believes is due to peripheral dilatation.

the inhalation. Dr. Leonard Hill, working with his "sphygmometer," finds that the arterial pressure either rises slightly or remains constant.

Clonic **muscular movements** are usually conspicuous by their absence; and the so-called "jactitation" of nitrous oxide is, with the rarest exception, never witnessed. A minor degree of tonic spasm in the muscles of the neck, back, and extremities is often manifested, more especially as the immediate reflex result of the operation. Opisthotonos very rarely occurs.

The condition of the **eyelids, globes, and pupils** deserves special notice. The eyes usually remain closed throughout the administration. During the first 45 or 60 seconds any attempt to raise the upper lid will cause a reflex tightening of the orbicularis. This spasm, however, gradually passes away as the inhalation proceeds, and at the end of about 75 or 90 seconds the upper lid may usually be raised without resistance. The eyeballs will now be found to be fixed, and in many cases turned to the right or left. In some instances there may be observed slight oscillatory movements of the globes; not so rapid as those of ordinary nystagmus, but not so slow as those which would indicate conscious observation. The pupils are variable. As a general rule they are of moderate size. Wide dilatation is distinctly rare. The author has on many occasions witnessed contraction and dilatation of the pupil in almost immediate response to a greater or less percentage of oxygen. The pupils may reflexly dilate during the extraction of a tooth, even though the patient be absolutely unconscious and free from all pain. The conjunctival reflex is, in the vast majority of cases, quite absent, though the cornea is generally sensitive to touch. During a protracted administration, however, the cornea may lose its sensibility.

Reflex **phonation**, as for example during tooth extraction, is uncommon. Of 153 dental cases the author noted it, more or less, in 29.

Anæsthesia is known to be present by one or all of the following signs:—

1. The conjunctival reflex is lost;
2. The breathing is regular and tranquil, or is softly snoring

in character (like the breathing of good chloroform anæsthesia);

3. The arms are flaccid; and

4. The eyeballs are fixed or present slight oscillatory movements.

In some cases the muscular system, instead of being relaxed, is rigid at the acme of anæsthesia, but such cases are exceptional. Alcoholic patients appear to be particularly liable to this rigidity.

The **period of inhalation** requisite to secure deep anæsthesia varies considerably in different cases; some patients being, for reasons already given, far more quickly and deeply affected by nitrous oxide than others. Of sixty-seven carefully (métronome) timed dental administrations with the apparatus above described, the author found the average period of inhalation to be **110·5 seconds**, a figure which represents the average period of inhalation found necessary to provide the operator with a subsequent anæsthesia of sufficient duration for the performance of an average dental operation.

In sixty-nine carefully (métronome) timed dental administrations, the average **period of available anæsthesia** was **44 seconds.** It is right, however, to point out that great variation occurs in the duration of this period. The longest anæsthesia was 90 seconds, the shortest 21 seconds. Within certain limits, the longer the administration the longer will be the subsequent anæsthesia. The following figures are of interest in this connection:—

Anæsthetic employed.	Average Period of Inhalation for Dental Operations.	Average Period of Resulting Anæsthesia.
Pure nitrous oxide . .	about 56 secs.	about 30 secs.
Nitrous oxide mixed with a percentage of oxygen sufficient to prevent asphyxial phenomena	about 110 secs.	about 44 secs.

So far as the simple maintenance of unconsciousness is concerned, this system may be regarded as applicable in general surgery; but as the surgeon of the present day very properly requires that his patient shall not only be unconscious but tranquil and immobile, it can hardly be contended that the anæsthesia from nitrous oxide and oxygen will always meet his requirements. As already pointed out, the anæsthesia is comparatively light; and inconvenient reflex movements may hence arise. It is true that the tendency to these reflex phenomena gradually lessens as the administration proceeds; but this fact does not wholly dispose of the objection. It is also true that by the preliminary use of morphine, atropine, scopolamine, and other drugs (p. 272) major operations become possible, as Crile and other trans-Atlantic surgeons bear witness. But hitherto British operators and anæsthetists have not taken the method into favour. Skin incisions, particularly about the lower extremities, and procedures within and about the rectum or genito-urinary organs, are specially liable to lead to inconvenient reflexes. Alcoholic subjects, those who smoke to excess, highly neurotic persons, and vigorous young men and women are especially likely to evince such phenomena. Even with the best subjects the repeated administration of these gases has a tendency to induce a comparative insusceptibility to their influence, so that it may become increasingly difficult to secure the desired degree of relaxation and freedom from movement. In addition to these objections to the system, it must be remembered that the administration of the two gases for a lengthy operation is by no means an easy matter; for not only is it difficult to be certain of having a sufficient supply of the two agents, but it is somewhat irksome to carry out the numerous manipulations for a protracted period. Moreover, although it was at one time thought that this system of anæsthetisation would prove to be invariably free from after-affects, this is unfortunately not the case. Other things being equal, there is certainly less risk of nausea and vomiting than after ether or chloroform; but the author has notes of several cases in which gastric after-affects assumed considerable proportions. In one case in which he administered the gases for the removal of the breast, the vascularity of the parts was as great as it usually is under ether; and the patient, who was particularly anxious to avoid this latter anæsthetic, because of previous experiences, was sick for many hours after the administration. It is true that such cases are very exceptional, but they must not be ignored.

The author has administered nitrous oxide and oxygen for Syme's amputation, lithotrity, removal of the breast, excision of varicose veins, varicocele, removal of ossicles of internal ear, resection of the patella, removal of necrosed bone from a tubercular hip, several intra-uterine operations, the removal of epitheliomatous glands from the groin, and for a large number of minor surgical operations. In one minor surgical case (dressing wound and readjusting splints) the administration lasted 52 minutes,[1] in which time 200 gallons of nitrous oxide and about 25 gallons of oxygen were used. As already indicated, good and tranquil anæsthesia can only be secured *in certain types of subjects*; and even when dealing with such types there are only certain operations that should be undertaken. For example, to attempt to anæsthetise by this system a vigorous, thick-set, alcoholic man for a rectal operation would be but to court failure. On the other hand, to employ this form of anæsthesia for some comparatively trifling operation upon a middle-aged and non-excitable lady who had on a previous occasion been greatly distressed by the taste and after-effects of ether or chloroform would be the best line of practice. A careful selection of cases is, in fact, essential, and if such a precaution be adopted, the anæsthesia of nitrous oxide and oxygen will be found to be of the greatest possible value. When a patient who is a good type of subject for an anæsthetic (p. 142) requires an operation of from 5 to 10 minutes' duration; when slight reflex movement, should it occur, would not embarrass the operator; when other anæsthetics have produced very unpleasant after-effects; and when the patient can be so placed that the administration can be properly conducted, the results will, as a rule, be most gratifying. It is a matter of no small importance to a highly nervous and fastidious patient to know that he can be anæsthetised with perfect safety; to pass into anæsthesia without discomfort or suffocative sensation in about seven or eight breaths; to be kept in a state of complete oblivion during

[1] A case is recorded in which the administration lasted 135 minutes. *Lancet*, March 1902. Soc. of Anæsthetists.

some surgical operation; to regain consciousness without nausea or unpleasant taste; and to be able to take nourishment of some sort after a short interval.

During the last few years this combination of nitrous oxide and oxygen has become a favourite one with American anæsthetists. Some of the more enthusiastic aver that even for abdominal sections sufficient relaxation may be obtained, though others deny this.[1] Thirteen thousand administrations are recorded by Teter,[2] with one death. Ten per cent of his cases had to have ether in addition. He recommends a preliminary injection of morphia; and lays great stress on the necessity of both gases being warmed, as he finds rigidity of much more frequent occurrence when they are given cold. The apparatus used is not described in detail.

D. DANGERS CONNECTED WITH THE ADMINISTRATION

There is no form of anæsthesia at present known which is so devoid of danger as that which results from nitrous oxide when administered with a sufficient percentage of oxygen to prevent all asphyxial complications. The author has employed this system up to the present time (March 1912) in over 20,000 cases, as near as he is able to estimate, and with the exception of two or three cases, in which transient respiratory embarrassment arose, and of one case in which transient syncope, probably of reflex origin, took place (*vide infra*), he has had no cause for anxiety. Owing to the fact that little or no strain is thrown upon the circulation, persons with feeble and dilated hearts are anæsthetised by nitrous oxide and oxygen without that slight risk which obtains when the former gas is administered alone. Moreover, those patients who, by reason of senile or other changes in the thoracic parietes, pleuræ, or lungs, may evince symptoms of embarrassed breathing at the acme of ordinary nitrous oxide anæsthesia, are certainly less likely to do so in the presence of oxygen. Two fatalities have been recorded since the last edition of this work: one by Teter,[2] and one by Lydston.[3] In the latter

[1] *Medical Record*, p. 926, 19th Nov. 1909.
[2] *Journal of the American Medical Association*, 7th Aug. 1909, p. 448.
[3] *Medical Record*, 12th Nov. 1910, p. 866.

case a very small quantity of ether was also given, but is held to have had no share in producing the untoward result.

E. RECOVERY: AFTER-EFFECTS

The recovery from the effects of this mixture, when administered for a dental or other minor operation, is usually very satisfactory, though not quite so speedy as from nitrous oxide alone. We cannot be surprised at this difference, seeing that the inhalation is invariably longer when nitrous oxide is given with oxygen. The difference, however, is slight; and when the inhalation has been short, there is practically none to be detected. It is only when an inhalation of two to three minutes, or longer, has been conducted, that the more tardy recovery manifests itself. The longer the inhalation, the greater will be the tendency to after-effects. **Nausea** or actual **vomiting,** although rare, is more common than after nitrous oxide alone—a fact which must not be lost sight of.

In a few instances the author has met with slight **pallor, feebleness of pulse, and faintness**; but he has never seen such symptoms assume grave proportions.

In one case in which temporary syncope occurred, the patient was in the habit of fainting in hot rooms and in church. She was twenty years of age and 6 feet in height. She was placed deeply under nitrous oxide and oxygen for the extraction of a tooth. There was no reflex movement during the operation. After the tooth had been removed she remained unconscious for about a minute with considerable pallor and feebleness of pulse. The author bent her forwards in the chair with her head low. Recovery was gradual, with a feeling of "pins and needles."

It is quite possible, and indeed probable, that this condition was of reflex origin, in other words, that the state was one of slight circulatory shock (p. 253). The case is interesting when read in association with the cases of surgical shock in Chap. XIX., in several of which there was a similar history of previous syncopal attacks.

The author has notes of three cases of **transient maniacal excitement** immediately after the administration. In all three cases the patients were men of powerful build.

Mr. Edgar Willett[1] has recorded a case in which, after a few minutes' inhalation of nitrous oxide and oxygen, the patient remained practically asleep for four days.

After the more protracted administrations in general surgery, gastric after-effects are not uncommon. This point has been referred to above. As with other anæsthetics, much will depend upon the duration of the administration and the type of subject.

F. ILLUSTRATIVE CASES

In the following table are given four illustrative dental cases. The times were taken by a métronome, and an assistant recorded the symptoms of the patients. The table shows the effects of more and less oxygen, the intervals at which this gas was admitted, and many other points.

[1] *Lancet*, March 1902. Soc. of Anæsthetists.

[Table.

Illustrative Case, No. 6.

A typical case.

Sex and Age.—M. 18.

Description.—Fairly nourished; good colour. A postman.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
18	3	Six breaths taken.
33	4	
39	4	Deep respiration.
51	5	
72	5	Quieter breathing.
78	6	
90	6	No conjunctival reflex.
99	6	Pupils $3\frac{1}{2}$ mm. in diameter.
108	6	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Good colour.
9	No movement or phonation.
21	Opposite side of mouth being operated upon.
30	Operation over.
42	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Typical.
Remarks.—No pain. No phonation or movement; no stertor or muscular twitching; good recovery; dreamt he was at his work.

Illustrative Case, No. 7.

A typical case except for slight duskiness. See remarks.

Sex and Age.—F. 33.

Description.—Spare; sallow.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
12	3	
24	4	
39	5	
51	6	
57	6	Twitching of eyelids.
66	6	Conjunctival reflex not abolished.
72	7	
78	7	Restless movement in chair.
81	5	
84	3	
87	2	
93	3	Movement ceased.
96	5	
108	5	Slight conjunctival reflex.
120	5	No conjunctival reflex.
123	5	Breathing quicker and more audible.
126	5	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Distinctly dusky.
9	Very slight phonation.
12	Normal colour returned.
24	Some movement of legs.
30	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Good but not typical.
Remarks.—Restless movements probably due to too much oxygen at 72 secs. Movements quite controlled by less oxygen (more N_2O); but some duskiness at end due to this diminished quantity. Otherwise typical. No "stertor" or "jactitation."

Illustrative Case, No. 8.

Long inhalation and long anæsthesia after.

Sex and Age.—F. 33.

Description.—Fairly well nourished ; fair complexion.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
18	3	
30	4	
36	5	Quicker breathing.
54	6	
60	6	Quieter breathing.
72	6	Soft snoring.
84	6	Ditto.
96	7	Distinct conjunctival reflex.
108	7	Snoring passing off. Slight rigidity of neck.
132	7	Tendency to turn head to left. Conjunctival reflex still present.
150	8	Very slight snoring.
171	8	Conjunctival reflex slight.
177	8	Some phonation.
180	8	Breathing quicker and more audible.
186	8	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
9	Some phonation.
18	Phonation ceased, operation proceeding.
27	Slight rigidity, good colour.
48	Movement of hand towards head.
66	Extraction finished.

Teeth or stumps extracted.—4.
General result.—Very good, barely typical.
Remarks.—She slightly felt the last stump. Probably deduct 6 secs. from 66 above mentioned. Instance of long administration and long anæsthesia. A good deal of oxygen given.

Illustrative Case, No 9.

Too much oxygen given intentionally for purposes of demonstration. Excitement thus produced easily controlled.

Sex and Age.—F. 37.

Description.—Healthy appearance. (Pulse 120 before prop inserted.)

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	3	
6	3	Pulse 132.
18	4	
21	4	Pulse 144.
33	4	Average breathing.
36	4	Tranquil breathing.
42	5	
51	5	Very calm breathing.
54	6	
66	5	Slight evidences of approaching excitement.
69	4	
72	4	Some phonation.
78	3	Restless movement in chair, with tendency to slip forward.
81	3	Pulse 120.
84	4	
93	5	Quite quiet.
102	5	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Colour a trifle dusky.
15	No phonation.
21	Conjunctiva insensitive.
36	Anæsthesia at an end.

Teeth or stumps extracted.—1.
General result.—Very good, barely typical.
Remarks.—Started with oxygen indicator at "3" instead of "2," and turned it to "4" in 18 seconds.

Cases of real or apparent insusceptibility to nitrous oxide, with or without oxygen, are occasionally met with. Possibly some of these cases are due to alcoholism, but in others there seems no explanation, and one is forced back upon idiosyncrasy. The following are brief notes of two such cases from the author's experience.

Illustrative Case, No. 10.—F., æt. 30. Thin; muddy complexion. Nervous, but quite amenable and intelligent, even helpful. Heart sounds normal; very slight mucous cough. Suffering from toxæmia of obscure causation: pemphigus and purpura. Operation—extraction of two difficult stumps. A prop was put in, correct position assured, and all other usual precautions taken. "Gas and oxygen" was then given in the ordinary way. After 4 or 5 inhalations the patient put her hands up to the face-piece; she was, however, easily controlled by the nurse and the operator. When the corneal reflex had disappeared, permission was given to commence the extraction. The moment the forceps was applied there was a (reflex) shriek, throwing back of the head, and stiffening of the body. The patient then slipped down into the chair, and had to be raised into position. With some difficulty the face-piece was reapplied; anæsthesia, or, rather, abolition of reflexes with some duskiness and slight stertor, was again procured. Still the patient screamed and moved as soon as the operator began, but one root was secured. The patient by this time was fully conscious, with tremor, sobbing, rapid pulse, and general distress.

On a subsequent occasion "gas and ether" was given. The Clover's inhaler was warmed beforehand. Induction of anæsthesia required thirteen minutes, and even then there were rigidity, phonation, and muttering. The corneal reflex was absent, but when the forceps was plunged into the alveolus a phonated sound was emitted, and breathing at once deepened. Within two minutes the patient became sufficiently conscious to rinse out the mouth. No vomiting followed. In this case there was apparently insusceptibility both to nitrous oxide and to ether, notwithstanding that the patient was distinctly anæmic.

Illustrative Case, No. 11.—F., æt. about 35. Says that nitrous oxide is always useless, and that she always feels pain when extraction is performed under this anæsthetic. One tooth was to be extracted. She was accordingly given "gas and ether" in the usual way. She did not struggle, and when apparently well etherised, chloroform on an open mask was substituted. Some struggling then took place, so the ether inhaler was reapplied for one or two minutes; then chloroform was given again. At the end of nine or ten minutes from the commencement of induction a Mason's gag was put in, and the operation performed. Reflex phonation and slight muttering were excited by this proceeding. The patient made a rapid recovery, and no vomiting occurred.

She afterwards described accurately the whole process of induction, including the changes right up to the second (final) application of the chloroform mask. This was a marked case of insusceptibility to all anæsthetics, nitrous oxide included.

It would appear that an acquired insusceptibility may be manifested in those who are infected with the parasites of **malaria.** This observation was made long ago, but lately three very marked instances have occurred in the practice of W. Munro Anderson, to whom the author is indebted for particulars of the cases. In one case nitrous oxide and oxygen entirely failed to produce anæsthesia, and 25 gallons of pure N_2O only created a moderate analgesia. In the second, induction was very prolonged, and even then the anæsthesia produced was only long enough for the extraction of one tooth. In the third there was entire failure to anæsthetise, and finally chloroform was resorted to.

CHAPTER XI

THE ADMINISTRATION OF ETHER

THE reader is referred to Chap. I. pp. 6 and 9 for a short account of the discovery and early use of this anæsthetic; to Chap. II. p. 21 for information upon its chemical and physical properties; to Chap. IV. p. 93 for a *résumé* of the chief experimental work that has been done concerning its physiological action; and to Chaps. V., VI., and VII. for remarks as to its safety and suitability in general surgical practice.

A. APPARATUS AND METHODS OF ADMINISTRATION

Ether may be administered—

I. By the strictly open system.
II. By the perhalation[1] system (so-called "open ether").
III. By other methods unattended by rebreathing.
IV. By the "close" or rebreathing system.
V. In conjunction with oxygen.
VI. By means of nasal tubes.
VII. By intra-venous infusion.
VIII. By the introduction of its vapour into the rectum; or
IX. By intra-tracheal insufflation.

It will be convenient to consider etherisation under these different headings.

I. The Strictly Open System of Etherisation

In strictness the term "open etherisation" should be limited to the dropping or sprinkling of ether upon a lint,

[1] The author regrets the necessity of introducing this new word. There seems to be no other by which to designate the passage of the respiratory current *through* a fabric moistened with anæsthetic.

gauze, or flannel fabric spread over a frame which is so loosely applied to the face that fresh air may enter and expired air escape without necessarily passing through the ether-soaked fabric. In recent years, however, the term has been applied universally to what is here called the perhalation system (*vide infra* II.).

Strictly open etherisation, as defined above, is only applicable throughout an administration when anæsthetising infants, young children, and those subjects whose general condition is such that abnormally small quantities of anæsthetic are needed. It may often, however, be employed with advantage during the final stages of a prolonged or severe operation which has been conducted under some other system.

A mask of the Skinner (Fig. 33), Esmarch, or Schimmelbusch type, covered with flannel, lint, or several layers of surgical gauze, and a bottle with stopper such as that shown in Fig. 34, are required for the application of this system.

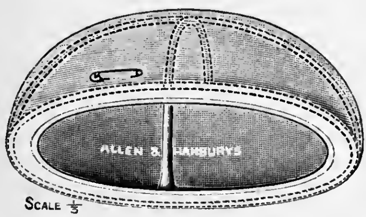

FIG. 33.—Skinner's mask (Allen and Hanbury's model).

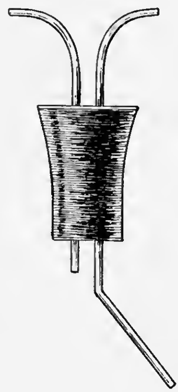

FIG. 34.—Irwin's stopper with Sprinkler for Ether.

The process of dropping or sprinkling ether, more or less continuously, upon an open mask is so simple as to need no special description. In the case of infants and small children, whose air-passages are highly sensitive, the vapour is likely to cause some reflex suspension of breathing; but brisk lip friction, with a handkerchief or soft towel, will rapidly correct the condition and restore respiratory rhythm. With older subjects an attempt should be made to administer such a mild and equable vapour during the initial stages of anæsthetisation that no discomfort is occasioned. The more the attention of the patient can be diverted from the actual process of inhalation the better. Thus, amenable children should be encouraged to count aloud; whilst adults may, with advantage, be engaged in conversation. The frequency with which ether should be added to the mask must be regulated by the effects which the vapour produces. Some patients have a strong dislike to the odour, although they can readily control themselves and inhale the vapour when freely diluted. Others seem to possess a peculiar susceptibility to ether, even though it be most carefully administered, and display choking sensations directly they detect the characteristic smell. In this connection it is important to remember that oral breathing is, as a general rule, to be preferred to nasal. By instructing his patient to inhale and exhale wholly through the mouth the anæsthetist will often succeed in allaying disagreeable sensations. There should be no undue haste. From five to ten minutes will generally be needed in the case of infants and young children before the breathing becomes regular and other signs of deep anæsthesia present themselves.

Whilst infants and small children can rarely be anæsthetised by this system without temporary resistance, the other class of patients for whom it is appropriate, namely, those who are ill or almost moribund from some serious constitutional ailment, will generally pass into anæsthesia without any excitement or struggling worthy of the name (see Illustrative Case, No. 12). If an attempt be made to anæsthetise fully strong adult subjects by the strictly open system failure will almost certainly result. This remark does not, of course, apply to cases in which some preliminary narcotic has been freely used.

Although it is theoretically possible to administer ether by the strictly open system from a folded towel or from one of the numerous varieties of cone inhalers still in use, such a plan is not to be recommended; for it is impossible with appliances of this kind to avoid those wide fluctuations in vapour percentage which cause such discomfort to the patient at the outset of anæsthetisation, and which, as we now know, are generally the cause of struggling and excitement. With open masks, however, such as those mentioned above, it is comparatively easy, in most cases, to prevent disagreeable sensations: for the anæsthetic may be dropped upon the mask so gradually that the patient is hardly conscious of the process.

Illustrative Case, No. 12.—Middle-aged, ill-nourished woman, *in extremis* from a sudden abdominal crisis. She had been treated for obstinate constipation with a strong purge, and a few hours afterwards had experienced sudden violent pain and collapse whilst sitting at her tea. Six hours later she was anæsthetised for abdominal exploration. The pulse was very rapid and only just perceptible; temperature subnormal, extremities cold, respiration feeble and sighing. Ether was given by the strictly open method; a very small quantity sufficed to produce anæsthesia. The descending colon was found ruptured across at the site of an old stercoral ulcer; the peritoneal cavity was full of hard fæces, pus, and blood. The pulse was now imperceptible, and oxygen was given continuously. The abdomen was rapidly closed, and the patient died in the ward ten minutes after leaving the operating theatre. It can hardly be doubted that any other system of (general) anæsthetisation would have killed this patient outright.

II. The Perhalation System of Etherisation (so-called "open ether")

If, during strictly open etherisation, the mask should be permitted to fit the face so accurately that the whole of the to-and-fro respiratory current passes *through* its etherised fabric, the strictly open system will become replaced by the perhalation system—in other words the process of etherisation to which the term "open ether" is now generally applied will result.

According to a private communication from Dr. Fergusson of Boston, whose courtesy we desire especially to acknowledge, the invention of so-called "open ether" is due to Dr. Lawrence H. Prince, now of Berlin, Wis., U.S.A. This frank admission of priority is greatly to the credit of Dr. Fergusson, who has, until recently, regarded himself as the originator of the method; and in any case he discovered it independently soon after Dr. Prince. The latter's first paper on the subject was published in 1895,[1] and his second a year later.[2] In the latter contribution the administration of ether

[1] *Chicago Medical Recorder*, 1895, pp. 365-378.
[2] *The Railway Surgeon*, vol. ii. No. 23, p. 529.

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by dropping it on to layers of gauze spread on an Esmarch mask is carefully described.

Whilst the perhalation system cannot always be applied *ab initio* it may be regarded as the best system for maintaining ether anæsthesia. It hence follows that if it be decided to employ "open ether," anæsthesia should be induced to a partial degree either by ether administered upon strictly open lines, as above described; or, better still, by the C.E. mixture (p. 483) or by chloroform (p. 487).

The two objects to be achieved in applying the perhalation system are: (1) to present to the patient, more or less continuously, an equable atmosphere containing approximately eight to ten per cent of ether vapour; and (2) to secure, by the employment of some appropriate, simple, and easily sterilisable mask, or inhaler, and by special attention to the patency of the upper air-passages, an unobstructed respiratory current to and from the surrounding air. Recent researches of the Anæsthetics Committee of the British Association for the Advancement of Science[1] have shown that in one of the most satisfactory perhalation methods, the ether percentage actually inhaled ranged between 9·3 and 10·8; and that even when the anæsthetic was added in excessive quantities to the flannel mask employed it was impossible to raise the percentage above 12.

This system may be applied by numerous methods. No useful purpose would be served, however, by enumerating these or by describing the many appliances which have been devised. Were our knowledge as to the effects of different ether percentages greater than it is, we might perhaps be able to classify these methods with some approach to scientific precision. Whether the fabric be of flannel, lint, or gauze, the effects are practically identical, provided the mask be not so thickly covered as to restrict respiration. In order to secure the best type of etherisation it is advisable, except in infants and children, to administer subcutaneously about three-quarters of an hour beforehand $\frac{1}{120}$ or $\frac{1}{150}$ gr. of atropine, with the object of preventing excessive mucous secretion. In patients whose reaction to morphine is known, the atropine

[1] *Proceedings*, 1911.

may be supplemented by this drug with or without scopolamine as already indicated (Chap. IX.).

If it be decided to employ ether throughout, the administration should be commenced by the purely open system, the anæsthetic being added to the mask in consecutive drops. If, however, chloroform or the C.E. mixture be selected for the induction stage one or other of these anæsthetics, or possibly both, may be administered immediately prior to ether as described on pp. 484 and 488. In the former case the dropping of ether is continued until a fairly saturated mask is tolerated by the patient, at which point it will become necessary to close in the periphery of the mask so as to insure the passage of the respiratory current through its fabric. This may be effected by encircling the mask with gauze or by other means, but the simple device shown in Figs. 35 and 36 has, in the author's hands, proved to be the most satisfactory. When the moment for the change to the perhalation system has arrived the gauze face-pad (A) is inserted between the mask and the face, and the sprinkling of ether is continued. In women and weakly adults, and particularly in prenarcotised patients, this simple plan generally secures a sufficient degree of perhalation. In stronger and more resistent subjects, however, it is necessary to use the additional encircling gauze collar (C) in order to insure the passage of the whole of the respiratory current through the meshes of the mask. The

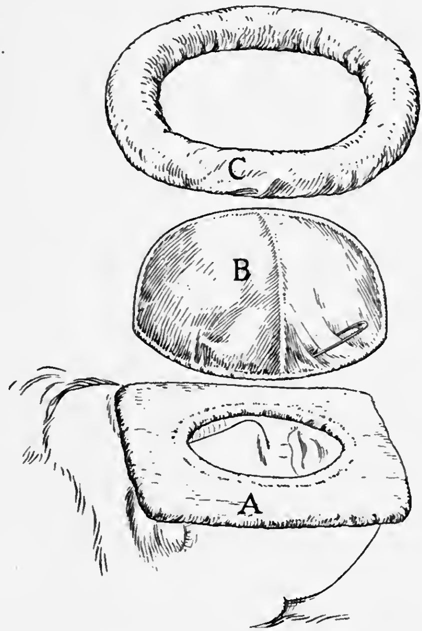

FIG. 35.—Face-pad (A), Skinner's Mask (B), and Gauze Collar (C).

arrangement of the pad, mask, and collar when thus adjusted is shown in Fig. 36. It should be the object of the anæsthetist to conduct the administration gradually, but continuously, from the moment at which a few drops of ether are first placed upon the open mask to the moment at which that mask has become more or less saturated with ether and encircled by the gauze collar. From this point onwards ether is freely sprinkled upon the mask. The effect of each addition of ether should be noted. Breath-holding, or any other indication of too rapid an administration should be taken to indicate a more gradual process. From seven to twelve minutes are generally needed before full anæsthesia becomes

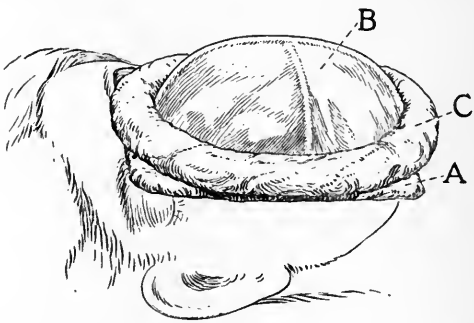

FIG. 36.—Face-pad, Mask, and Gauze Collar *in situ*.

established. Any unusual delay will almost certainly be due to some inadequacy in the upper respiratory channels preventing that free intake of ether vapour which is essential. Should such delay occur, or should any sniffing sound indicate that an inadequate nasal air-way exists, means should be adopted to obtain oral in lieu of nasal breathing. In children and in some other subjects the simple insertion of a mouth prop between the teeth, coupled with pushing the lower jaw forwards, will generally suffice to effect this change. Should it not do so, and should the patient still fail to respond to full doses of ether, a Mason's gag must be inserted, the fauces rapidly sponged out, and the oral air-way, shown in Fig. 20, introduced. The latter procedure can only be effected, of course, if the patient be sufficiently anæsthetised to tolerate the presence of the rubber tube. Far less mucus will be secreted during oral than during nasal breathing. Mr. Bellamy Gardner advises the use of the tongue clip, Fig. 19, p. 258. No definite rule, however, can be laid down for the establishment of a perfectly free and unobstructed air-way owing to the fact that cases differ as to the particular manœuvre required. Suffice it to say that unless such an air-way be maintained the ether anæsthesia will not be of the best type. The amount of ether needed to keep up a proper degree of anæsthesia will depend, of course, upon the adoption or non-adoption of preliminary narcotisation, the type of subject, the freedom of respiration, and the nature of the operation.

Whilst in the case of strong men ether can hardly be added too freely to the mask, a less heroic administration is necessary with women and feeble subjects, particularly towards the conclusion of an operation. In a large number of cases, in fact, it will be found possible, after once deep anæsthesia has become established, to remove the gauze ring around the mask and thus to lessen ether percentage. In very severe operations, indeed, it may even be found possible to remove the face-pad and thus to revert to strictly open etherisation. Any expiratory mucous râle should carefully be noted and treated by frequent sponging, or better still, by encouraging a cough or act of retching, the latter course being practicable only when no inconvenience to the surgeon would result.

In a recent contribution to the *Lancet*[1] Mr. W. Legge Symes and the author have given results of certain experiments which they undertook with the object of ascertaining the percentages of ether actually inhaled from a Skinner's mask. They found (1) that the ether percentage ranged between 5 and 15 according to the extent of douching and the nature of the fabric employed; (2) that gauze yielded a higher percentage than lint or flannel, the percentage rising roughly according to the number of layers; (3) that with flannel or lint masks, adjusted as described above (Fig. 36), a more or less equable atmosphere containing approximately 8 or 9 per cent of ether vapour might be depended upon.

[1] "On the percentages of ether vapour administered in so-called 'open ether' methods" (*Lancet*, 27th Jan. 1912, p. 215).

The type of anæsthesia produced depends upon: (*a*) the freedom of the air-way itself—that is, upon whether respiration be oral or nasal, and whether it be free through the particular channel used; (*b*) upon the extent to which the open mask is closed in by pads or gauze. If the air-way be not free, or if the mask be so closed in by pads or gauze that only a square inch or two of the moistened fabric is visible, sub-oxygenation may occur; respiration will be deeper than in other circumstances, and less ether will be required. A free air-way and a large exposed surface of mask will result in quiet respiration; but the quantity of ether used will be considerable, up to ten or even fifteen ounces per hour. On the other hand, with a more restricted respiration or a closed-in mask, deep anæsthesia may be maintained with four to ten ounces per hour for adult patients. These figures refer to patients who have received moderate doses of morphine-atropine, or kindred narcotic drugs. When large doses have been given, and when the profound anæsthesia necessary for, say, abdominal section is not required, smaller quantities of ether will suffice. As with chloroform, a patient requires, as time goes on, progressively less and less anæsthetic to maintain a given degree of anæsthesia, so that, towards the close of a prolonged operation, it is possible to maintain complete muscular relaxation with smaller quantities of ether than those mentioned above. Dr. R. H. Fergusson of Boston, one of the very early advocates of the "open ether" system, states that he can induce anæsthesia with his special mask in from two to five minutes with four to six drachms of ether; and that he used only three and a half ounces of ether for anæsthetising a patient for a hysterectomy which lasted one hour and forty minutes. This he describes as an average result:[1] apparently no narcotic was given as a preliminary. The author's experience with the method above described has not included any case where such small quantities have sufficed.

[1] *Journal of the American Medical Association*, 30th December 1905.

III. Other Methods of Etherisation unattended by Rebreathing

A large number of appliances have been devised for administering ether vapour with unknown quantities of atmospheric air. Many of these belong to what may be termed the cone type of inhaler. Others possess some kind of reservoir for the ether, and the air which is generally drawn through the reservoir by the inspiratory action of the patient takes up the vapour. Cone inhalers are generally made of some more or less impervious material, and are furnished with a sponge upon which the ether is poured from time to time. All ether cones of this type possess the great disadvantage of supplying ether vapour in such variable percentages as to excite all varieties of respiratory discomfort and difficulty. It is true that ether is a very safe anæsthetic even in concentrated percentages, and that there is not the necessity that exists in the case of chloroform to regulate the strength of its vapour to a nicety. But, at the same time, it is undoubtedly important, if we wish to obtain the best results, to keep the vapour percentage at or about the level already indicated. The time has come, indeed, when all ether cones, with impervious walls, should be proscribed in practice, for it is clear from what has been said above that it is impossible with such appliances to administer that equable ether atmosphere which is essential to success. Inhalers of the reservoir type are liable to much the same objection, although in their case the channels through which the patient breathes are, as a rule, considerably wider than those available in ether cones. Although Clover's Portable Regulating Ether Inhaler, when used without its bag, may be made to deliver ether vapour in gradually increasing proportions, it is difficult or impossible with such an appliance to maintain any regular percentage of vapour. Rendle's celluloid mask is, perhaps, one of the least objectionable of the cone inhalers, but the anæsthesia it produces is less satisfactory in type than that obtainable by perhalation methods.

IV. The Close System of Etherisation (by means of Bag-Inhalers)

It is doubtful who first practised limitation of fresh air during the inhalation of ether vapour. The late Professor J. Morgan of Dublin appears to have been the first writer on the subject in Great Britain,[1] but he refers to Professor Porta of Pavia[2] and to Dr. Smith of New York, both of whom had, prior to his (Dr. Morgan's) lectures, administered ether from a bladder or bag. Dr. Morgan's ether inhaler (described by him in 1872) consisted of a box or reservoir for the ether, and a flexible tube and mouth-piece through which the patient breathed the vapour. The box was furnished with an india-rubber diaphragm capable of expanding and contracting as the patient breathed.[3] In July 1876, Clover described[4] "An apparatus for administering nitrous oxide gas and ether singly or combined"; and at the time he wrote he had used this apparatus successfully in 2300 cases. The ether vapour, supplied from a reservoir, was breathed backwards and forwards from a bag attached to the face-piece, fresh air being admitted from time to time. In January 1877, Clover described[5] his "Portable Regulating Ether Inhaler" (Fig. 37). In February of the same year Dr. (now Sir Lambert) Ormsby of Dublin introduced[6] his apparatus (Fig. 43, p. 352) to the notice of the profession. Whilst Clover's ether inhaler has certain advantages over Ormsby's, the latter apparatus very favourably compares with the former in many respects. It is therefore proposed to describe fully these two inhalers, the method of using each, and the advantages of the one over the other.

[1] See an interesting article by Professor J. Morgan, entitled, "Ether *versus* Chloroform . . . With a description of an inhaler, and the mode of administration" (*Med. Press and Circular*, 31st July 1872).

[2] Asshurst, *Principles and Practice of Surgery*, p. 77.

[3] *Med. Press and Circular*, 28th August 1872, p. 165.

[4] *Brit. Med. Journ.*, 15th July 1876, p. 74. This apparatus will be referred to when discussing the administration of nitrous oxide with ether in Chapter XVI.

[5] *Brit. Med. Journ.*, 20th January 1877, p. 69.

[6] *Lancet*, 10th February 1877, p. 218; also 9th June 1877, p. 86. In a private communication to the author, Sir Lambert claims also the credit of inventing the principle of Clover's inhaler.

Clover's Portable Regulating Ether Inhaler

This most ingenious and useful apparatus is represented in Fig. 37. F is the face-piece ; E is the ether reservoir through which the air-current passes ; and B is an india-rubber bag. When the face-piece fits the face accurately, the patient breathes backwards and forwards into the bag. Mr. Pridgin Teale has very properly drawn attention to the importance of the face-piece in ether administration ; and in an excellent article[1] gives diagrams of good and bad face-pieces. Clover's apparatus possesses no valves, nor does it contain any contrivance for the admission of fresh air. The face-piece tightly plugs on to a tube (T), which fits into one end of a shaft passing through the ether reservoir. The mount of the bag B fits into the other end of this shaft. By revolving the ether reservoir on the tube T the current is made to pass to any desired extent over ether. The apparatus is charged with ether at the funnel-shaped tube FT, the stopper of which is removed for the purpose. The best kind of ether-bottle is one fitted with what is known as Irwin's stopper,[2] already shown in Fig. 34. A little measure (Fig. 38), capable of holding about $1\frac{1}{2}$ oz. of ether, is usually supplied with the inhaler, and

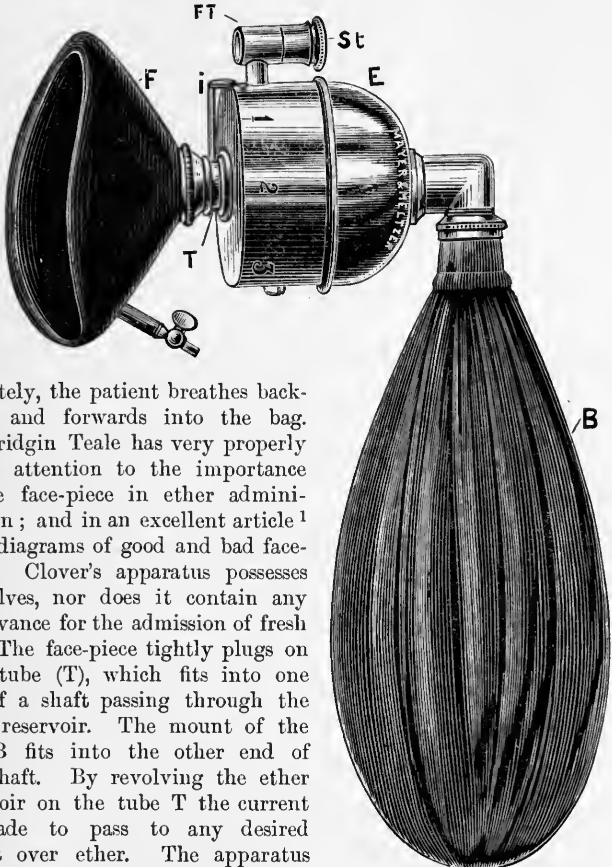

Fig. 37.—Clover's Portable Regulating Ether Inhaler. (Original pattern.)

[1] *Encyclopædia Medica*, vol. i.

[2] *Lancet*, 24th Sept. 1898.

is used for filling it with ether. The face-piece and bag hardly need further description; but the ether reservoir must be carefully considered, in order that the working of the inhaler may be understood.

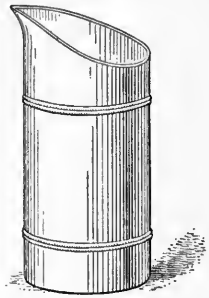

Fig. 38.—Measure for filling Clover's Ether Inhaler. (Half-size.)

In Figs. 39 and 40 the ether reservoir E and the tube T are shown in section. E consists essentially of a metal sphere tunnelled by the shaft S, into which T fits. The sphere is the reservoir for the ether. The filling tube (FT), closed with a stopper (St), is provided for charging the sphere with ether. Only one-half of the sphere is apparent in the finished apparatus, the other being covered in by a cylindrical cap or cover (C). The space which results is nearly filled with water by the makers of the instrument. This water-chamber prevents the apparatus from becoming too cold. When the temperature of the room is low, it is a good plan to immerse the inhaler in warm water for a few moments before use, by which plan the water in the water-chamber

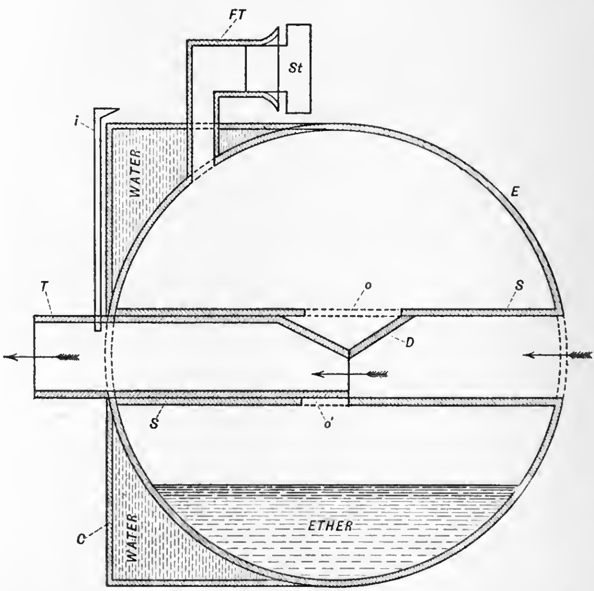

Fig. 39.—Section of Clover's Portable Regulating Ether Inhaler. (Original pattern.) Indicator at "O." (Two-thirds actual size.)

takes up and retains heat for a sufficient time to ensure a proper evaporation of ether in the adjacent sphere. About half-way along the shaft there are four large openings, two (O) on the upper wall of the shaft, and two (O′) on the lower. These allow of communication between the interior of the shaft on the one hand and the ether reservoir on the other. These openings are so large that the shaft S almost loses its continuity where they occur. Projecting from the wall of the shaft there is a half diaphragm D, which closes up one-half of the calibre of the shaft, leaving the other half free. This half diaphragm is not fixed at right angles to the long axis of the shaft, but is sloped as shown. The tube T, upon which the face-piece plugs, passes into the shaft S. It has a whistle-shaped end which fits up against the half diaphragm D. It also carries a

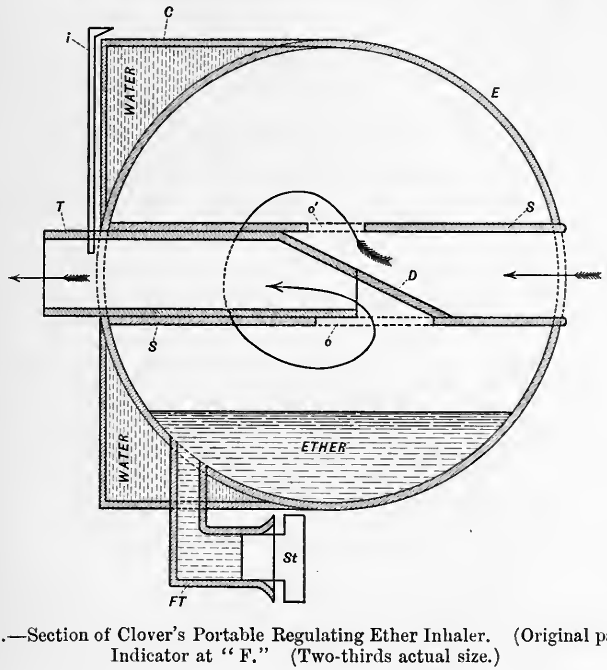

Fig. 40.—Section of Clover's Portable Regulating Ether Inhaler. (Original pattern.) Indicator at "F." (Two-thirds actual size.)

long rod or indicator (*i*), which points to figures on the circumference of the ether reservoir (Fig. 37). When the tube T is tightly plugged into the face-piece, as is the case when the apparatus is being used, the ether reservoir will rotate easily upon T, and the figures on the circumference will travel one after the other past the indicator (*i*). If the indicator point to "0," an inspiration will take the course shown in Fig. 39. It will pass straight through the shaft without entering the reservoir containing the ether. The openings (O and O′) in the shaft are unavailable, the upper ones (O) by reason of the half diaphragm D, and the lower ones (O′) by reason of the whistle-shaped end of the tube T. When the ether reservoir is rotated till the indicator points to "F," the course of an inspiration will be very different. It will now enter the opening O′, and having passed over the ether (see long arrow), will escape at the opening O into the tube T, and so pass to the patient. The whole of the current will thus become deflected and pass over the ether. An expiration would, of course, travel backwards to the bag by exactly the same route as that by which the inspiration came. The two sectional drawings show the course of an inspiration with the indicator at "0" and "F" respectively. The degree to which the current is made to pass over the ether will depend upon the extent to which the ether reservoir is made to rotate upon the whistle-shaped tube, and this extent is registered by the indicator (*i*). With the indicator at "0" the

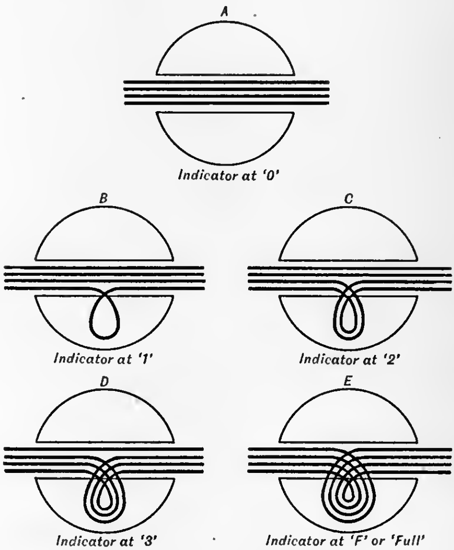

FIG. 41.—Diagram showing the extent to which the air-current passes over ether in Clover's Portable Inhaler when the indicator points to "0," "1," "2," "3," and "F." The whole current is diagrammatically represented by four lines.

current is a wholly direct one, passing backwards and forwards to the bag without entering the ether chamber (Fig. 41). With the indicator at "1," one quarter is indirect, *i.e.* passes over the ether, and three quarters are direct, *i.e.* pass to and from the bag without being deflected. With the indicator at "2," two quarters are indirect, and two quarters direct. With the indicator at "3," three quarters are indirect, and one quarter direct. With the indicator at "F" or "FULL," four quarters (*i.e.* the whole of the current) are indirect, and pass over the ether in the chamber.

Numerous modifications of Clover's original inhaler have been introduced. Fig. 42 represents a modification which has been constructed for the author by Messrs. Barth and Co. It differs from Clover's original pattern in the following particulars: (1) Its internal calibre or air-way is much larger; (2) instead of the ether reservoir rotating upon the central tube, the central tube rotates within the fixed reservoir; (3) the face-piece is screwed into the ether reservoir, so that these two parts never unexpectedly become separated; (4) the ether reservoir can be adjusted, whatever the position of the patient may be, so that ether may be poured into it through its wide-mouthed filling-tube without removing the face-piece from the face. In order to secure these improvements, it was found necessary to modify the internal mechanism of Clover's original apparatus, and to have two separate inner tubes,

FIG. 42.—The author's Modification of Clover's Portable Regulating Ether Inhaler.

these revolving as one tube by means of the indicating handle which fits into each. The large bore of the apparatus is distinctly of advantage, not only in lessening the initial unpleasant sensations of re-breathing, but in reducing the asphyxial phenomena (stertor, cyanosis, and laboured breathing) of well-established ether anæsthesia. The apparatus, moreover, is specially useful, and indeed was more particularly designed for administering nitrous oxide and ether in succession (p. 492). The author is glad to take this opportunity of thanking Messrs. Barth and Co., of Poland Street, Oxford Street, W., the makers of this apparatus, for the patience and care with which they have made numerous experimental inhalers for him whilst engaged in perfecting this appliance.

Directions for using Clover's Portable Regulating Ether Inhaler (or any of its modifications)

1. In cold weather, and particularly when about to anæsthetise powerfully-built or alcoholic subjects, partly immerse the ether reservoir in warm water for a few moments.

2. Fit on a face-piece of appropriate size; turn the indicator to "1" or "2" for the escape of air; pour in $1\frac{1}{2}$ oz. of ether; replace the plug; turn back the indicator to "0"; blow once through the apparatus to free its air-way from any trace of ether vapour; and attach the bag.

3. Request the patient to turn his head to one side; instruct him to commence breathing through the *mouth*; and whilst he is doing so, gently apply the face-piece, pressing it rather more tightly during expiration than during inspiration, in order that the bag may become nearly filled with expired air.

4. Allow to-and-fro breathing for about half a minute with the indicator at "0," and see that the bag expands and contracts freely.

5. Very gradually rotate the reservoir or move the indicator so that at the end of the first minute the indicator points to "1," at the end of the second minute to "2," and at the end of the third minute to "3." During the first minute or so the reservoir should be rotated or the indicator moved continuously yet almost imperceptibly. When consciousness has been destroyed, *i.e.* at the end of about $1\frac{1}{2}$ minute, ether may be admitted rather more freely.

6. Any swallowing, "holding the breath," or coughing will indicate that the vapour is too strong, and the indicator must be moved back somewhat till respiration has again become unrestricted. Muscular excitement is very uncommon; should it occur, the administration must be pushed and it will soon subside. In cold weather it may be necessary to expedite vaporisation during the induction stage by applying the hand to the ether chamber.

7. When stertor commences, a single inspiration of fresh air should be admitted by raising the face-piece; and the administration may then be resumed. The admission of fresh

air from this point onwards must be regulated by the susceptibility of the particular patient to this particular process of anæsthetising. As the administration proceeds, more and more fresh air may be given without disturbing the anæsthesia. After the first four or five minutes it is usually advisible to allow one inspiration of fresh air every ten or twelve breaths; after half an hour one inspiration every four or five breaths may be permitted. Stertor, deep cyanosis, rapid and laboured respiration, and especially a strained form of expiration, are the indications for more air. In the case of patients with beards more air gains admission between the face and the face-piece than in other subjects, so that the inhaler must be kept tightly applied during the initial stages, and removed less frequently than usual during the later stages. The anoxæmic factor is almost as powerful as the ether factor in this system of anæsthetising. The less air given the less ether will be needed, and *vice versa*.

8. Some degree of cyanosis is to be expected, especially during the first five minutes. Later on it may be prevented by removing the inhaler for fresh air from time to time.

9. Regular and snoring breathing, insensitive corneæ, and muscular flaccidity are the usual signs that deep ether anæsthesia has been induced.

10. The point at which the indicator should be kept after these signs have appeared must depend, as must the regulation of the air-supply, upon the susceptibility of the patient. As a general rule "F" need only be reached when anæsthetising powerfully-built or alcoholic subjects. Less and less ether will be needed as the administration proceeds, so that at the end of fifteen minutes the indicator may usually be allowed to point to "2" or "$2\frac{1}{2}$," at the end of half an hour to $1\frac{1}{2}$ or "2," and so on.

The above directions apply to the administration of ether to normal adult subjects, and it must be remembered that certain modifications will be needed when dealing with other cases. Strong, plethoric, or alcoholic patients usually require large quantities of ether, and a free use of the anoxæmic factor, in order to obtain good results. On the other hand, children, feeble, anæmic, and cachectic subjects, and those whose vascular systems are affected by morbid or senile changes will demand careful treatment and the avoidance of any asphyxial strain.

Ormsby's Ether Inhaler

The Ormsby's inhaler usually supplied by the instrument-makers is constructed as represented in the accompanying diagram (Fig. 43). F is a metal (zinc) face-piece which can be bent to any desired shape. Its edge is guarded by an india-rubber pad (P), which can be inflated with air. To the other edge of the face-piece there is fixed a wire cage (C) contain-

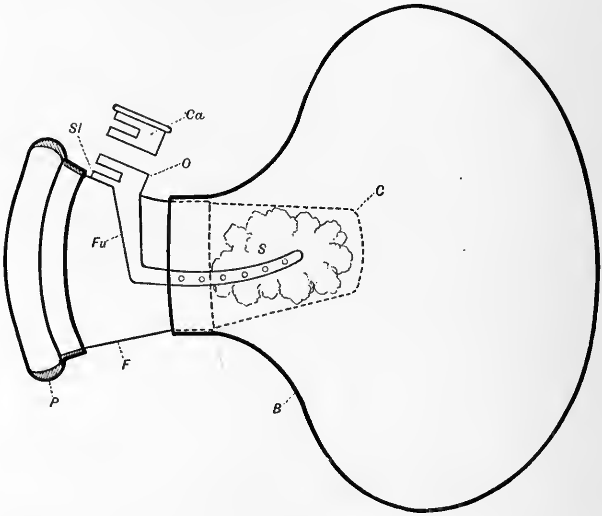

Fig. 43.—Diagram of Ormsby's Ether Inhaler. (Original pattern.)

ing a sponge (S). The bag (B) fits on to the face-piece, and its neck grasps the cage. The bag is covered with a loose netting by some makers of the apparatus. On the upper surface of the face-piece there is a circular opening (O) with a slot (Sl) cut in its circumference. Fixed into the mouth of this opening there is a funnel-shaped tube (Fu), which passes downwards and then divides, the two arms, which have perforated holes in them, coming into contact with the sponge. A cap (Ca) fits over O, and like O is furnished with a slot, which may be made to correspond to the slot (Sl) in O. When the slots correspond, air will gain admission to the apparatus; when they do not correspond, this communication with the air is cut off. When the cap is taken off, as in the figure, the funnel-shaped tube (Fu) may be used for supplying ether to the sponge.

Experience with this useful inhaler has led to one or two slight modifications in its construction. In actual practice the funnel-shaped filling-tube is rarely used, for it is found to be more convenient to pour ether directly upon the sponge. Then, again, the bag usually supplied with the inhaler has proved to be far too small, especially for anæsthetising patients with full chest capacity. And lastly, any netting over the bag is unnecessary. The late Mr. Woodhouse Braine, who preferred Ormsby's apparatus to all others for ether-giving, therefore used for many years an inhaler possessing no filling-tube and having a capacious bag of red rubber without a network covering. The red india-rubber is little if at all affected by ether.

Fig. 44 represents a modification of Ormsby's inhaler, which has the

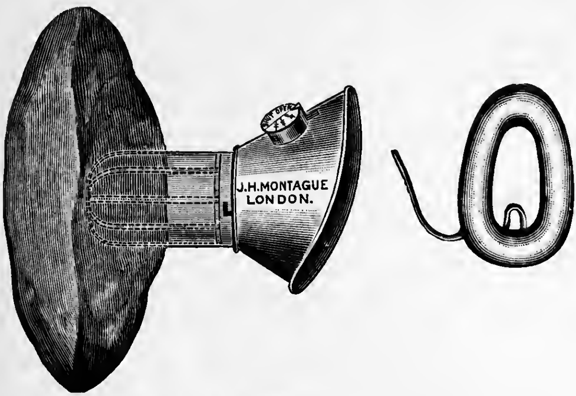

Fig. 44.—Carter Braine's Modification of Ormsby's Ether Inhaler.

great advantage that it can be readily cleansed. The cage is made of fenestrated metal, not of wire, and the face-piece pad is detachable.[1]

Directions for using Ormsby's Inhaler

The method which is generally adopted is one of extreme simplicity.

1. Wring out, in hot water, an open-meshed unbleached sponge of sufficient size and insert it in the cage. It should fit well but not tightly.

2. Pour a small quantity of ether upon the sponge.

3. The air-slot being open, very gradually apply the face-piece to the face. At first hold it some little distance off; then bring it nearer and nearer, encouraging the patient to breathe freely.

[1] See *Lancet*, 3rd December 1898.

4. Gradually close the air-slot.

5. Be prepared for the patient attempting to push away the inhaler, rising from the bed, etc. When once the administration has been fairly started, the inhaler should not be removed till signs of anæsthesia are approaching, or till more ether is required.

6. When more ether is needed, about half an ounce at a time may be added to the sponge.

7. From this point onwards the administration must be conducted upon the same principles as those above laid down for etherisation by means of Clover's inhaler.

The following alternative and ingenious method, introduced by Mr. Horace Pechell,[1] has the advantage of more gradually increasing the strength of vapour :—

1. A small quantity of ether is first poured into the bag of the inhaler.

2. A dry sponge is then introduced into the cage.

3. The face-piece is applied with the air-slot open.

4. The air-slot is gradually closed.

5. The ether is then made to moisten a large area of the bag in order to increase the strength of vapour breathed.

6. As the induction proceeds, the bag is gently tilted in order to allow the ether to reach the sponge.

7. Lastly, when once this stage of the administration has been reached, the quantity of ether which should be added to the sponge, and the frequency with which the face-piece should be removed, must be regulated by the principles already laid down.

Whilst Ormsby's inhaler is not so satisfactory as Clover's for *inducing* ether anæsthesia, owing to the fact that ether vapour cannot be so gradually admitted, it is certainly a very excellent apparatus for *maintaining* this state. It is hence a good plan, if Ormsby's inhaler is to be used for ether, to precede the administration of this anæsthetic by ethyl chloride (p. 496) or by a small quantity of the C.E. mixture (p. 483). If, however, such methods be impracticable, the anæsthetist must do his best to reduce, as far as possible, the initial discomforts which must always attend the earlier stages

[1] *Clin. Journ.*, 15th June 1898, p. 155.

of etherisation. The differences in the type of the fully established ether anæsthesia resulting from Clover's inhaler on the one hand, and from Ormsby's apparatus on the other, have yet to be thoroughly explained. On many occasions, whilst administering ether, the author has changed from a Clover's to an Ormsby's inhaler with marked improvement in the symptoms of the patient. He has often known cyanosis to vanish quickly and the breathing to become less hampered by effecting this change of inhalers during deep ether anæsthesia. It is probable that the narrow channels through which the patient has to breathe in Clover's apparatus are responsible for differences of this kind. But there is another possible explanation, viz. that during the intervals in which the inhaler is removed from the face the narrower and more circuitous channels tend to retard diffusion between the bag and the outer air. In Ormsby's inhaler there is greater chance of diffusion, and expiratory products are hence not so likely to accumulate. The large-bore apparatus referred to above (p. 349) was designed with the object of combining, if possible, the advantages of both Clover's and Ormsby's inhalers, and it certainly throws less stress upon breathing, and causes less cyanosis than the ordinary narrow-bore inhalers which have been so long in use. It appears, moreover, to produce less coughing and laryngeal irritation than Clover's original apparatus —an interesting fact considering that the bore is larger. Possibly the ether vapour is more evenly diffused through the inspired air than in the small-bore models.

V. The Administration of Oxygen with Ether Vapour

There is little if any advantage to be gained by this system of anæsthetising, except in certain special cases. We have seen that in vigorous subjects some degree of air limitation may be advantageous in conducting etherisation. When we pass, however, from the vigorous subject, at one end of the scale, to the exhausted and feeble individual at the other, we have not only to be careful to provide a sufficient supply of air with the anæsthetic, but we may even find it necessary to replace air by oxygen in our administration. Generally speaking, when respiratory embarrassment is present to such a degree that there is duskiness or actual cyanosis, all closed methods are contra-indicated. Should it be necessary to give oxygen and ether together, the arrangement of apparatus shown in Fig. 45 will be found to answer well. The oxygen, which is made to bubble through a bottle containing hot water and standing in a basin of hot water, is transmitted to a Skinner's mask upon which the ether is sprinkled. Should the ether cause laryngeal or tracheal irritation it may be alternated or replaced by the C.E. mixture. The author has employed this arrangement of apparatus with success in certain desperate cases of intra-thoracic disease, *e.g.* double empyema,

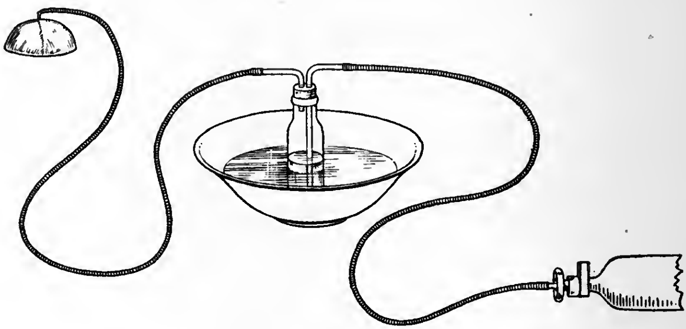

FIG. 45.—The Administration of Warmed Oxygen and Ether Vapour.

escape of contents of empyema into bronchi, etc., using the C.E. mixture instead of ether.

VI. Nasal Etherisation

For operations on the tongue and adjacent parts, Dr. G. W. Crile has devised a method which permits of the administration of ether continuously, without the necessity for laryngotomy. The apparatus is simple, and consists of two rubber tubes sufficiently large to fit the nares closely; these are coupled to a much wider rubber tube by means of a Y-shaped glass junction; and the large rubber tube is in turn connected with a glass funnel (somewhat of the pattern of a filter-funnel), the wide end of which is covered with a single layer of thin flannel. Between the filter-funnel and the Y-piece to which the nasal tubes are fitted is a glass trap to prevent any excess of ether from running down the nasal tubes.

After preliminary injection of morphine and atropine, anæsthesia is induced by the "open" ether system. The mouth is then opened, and the pharynx, epiglottis, and larynx brushed with a 2 per cent solution of cocaine. The nasal tubes are then inserted, and pushed on until their extremities are opposite to the epiglottis. The pharynx is then packed with sterilised gauze, whilst the tongue is pulled forward. Care must be taken that the tubes are not compressed, and that the lateral parts of the pharynx at the sides of the tubes are fully occluded. Ether is then dropped on

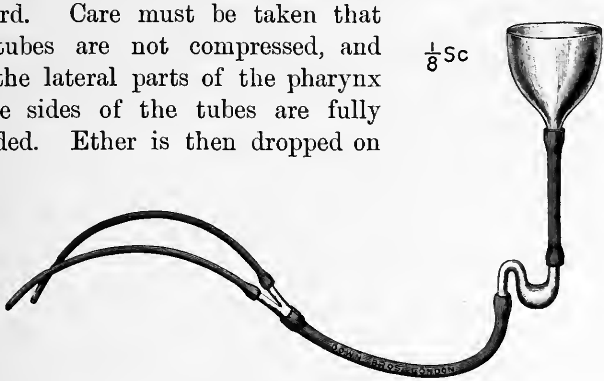

FIG. 46.—Crile's Ether Tubes.

the flannel covering of the funnel. The same apparatus can be used for giving chloroform.[1]

VII. Intra-venous Etherisation

To Burckhardt we owe the latest system of ether anæsthetisation—that by venous infusion of a solution of ether in normal saline.[2] The experimental work on animals, which preceded the clinical application of the method by Burckhardt, was the work of several observers, especially of

[1] For fuller details of this system the reader is referred to an account of it by H. M. Page, *Lancet*, 7th August 1909, p. 364. The only disadvantage seems to be that in that large class of patients in whom there is nasal obstruction on one or both sides owing to spurs, deflected septum, and so on, difficulty is often encountered in passing the tubes through the nasal passages.

[2] *Münchener med. Wochenschrift*, 15th Feb. 1910, p. 361.

Ehrmann. In England the system was introduced by F. S. Rood, who was the first to contribute to the literature in this country.[1] At the time of writing (March 1912) Rood has used ether infusion in 136 cases and has had practically no bad after-results. Only six of his patients vomited and three of these had swallowed blood. The chief advantage claimed for this system of etherisation is that it is specially applicable for operations in the neighbourhood of the air-passages, where anæsthetist and surgeon often mutually inconvenience each other. Thus in such procedures as removal of the tongue, upper jaw, thyroid gland, deep glands of the neck, laryngeal growths, and operations in the palate, nose, pharynx, etc., it is obvious that of two systems equally safe, that one is preferable in which the anæsthetist has no need to encroach in any way upon the air-passages. It is at the same time obvious that *the anæsthetist must take just as much pains to secure and maintain a sufficient air-way and an efficient respiration,* as if the anæsthetic were being administered *via* the respiratory route. Another advantage is that, since the respiratory method is indirect, and acts by charging the blood in the pulmonary circuit, a direct method is preferable since it enables dosage to be much more accurately measured. Another is that the irritation of the respiratory tract by ether vapour is avoided.

The possible disadvantages of the infusion system are sepsis, air embolism, thrombosis and pulmonary embolism, and œdema of the lungs. The former ought to be a negligible quantity; the second and third are said, in practice, not to occur in any appreciable percentage; and no instance of the third has yet been reported in England. As yet, however, it is much too early to pronounce an opinion on this point, for only a few hundred administrations have taken place in this country, and no figures are available on which to base a trustworthy estimate of the complications by which infusion anæsthesia may be attended. Schmitz Pfeiffer,[2] and Küttner independently, are against Burckhardt's method, having experienced clotting and pulmonary embolism.

[1] *Brit. Med. Journ.*, 21st Oct. 1911, p. 975.
[2] *Beit. zur klin. Chirurgie*, B xcvi. p. 3.

Kummel[1] supports Buckhardt's continuous method and considers Küttner's case explicable on grounds unconnected with the method of administration. Barteleman[2] suggests that these copious infusions have dangers of their own in certain cases: he believes that the bactericidal properties of the blood are lessened by dilution, and hence that intra-venous anæsthesia is dangerous in septic cases. Air embolism is considered by Blair and M'Guigan.[3]

Burckhardt, who first adapted the method to human beings, used an ordinary infusion apparatus. With this he employed a 5 per cent solution of ether in normal saline, ran in enough to produce surgical anæsthesia, and then interrupted the stream until the patient showed signs of coming round. The percentage of five was employed because with higher concentrations there is a risk of causing the blood to lake; 10 per cent, for instance, causes a considerable risk of this complication. On the other hand 5 per cent has proved to be somewhat inadequate. In Rood's recent cases 7·5 per cent of ether was employed. The disadvantage of Burckhardt's plan is that the interruption of the stream sets up a tendency to thrombosis around the cannula. The modification described by Rood[4] is, in principle, a device for keeping up a steady, slow, and controllable flow of ether-saline solution.

Apparatus (Fig. 47). A 7·5 per cent solution of ether in normal saline flows from a reservoir, which is fixed 8 ft. above the floor level, through the indicator, and then through a warming chamber into the cannula, and so into the vein. The indicator consists of a cylindrical bulb with a capacity of 8 oz. When the apparatus is working, the lower half is full of the solution, while the upper half contains air. The solution flows from the reservoir into the bulb through a pipette, and drips on to the surface of the fluid below. The system being a closed one, the pressure within it is transmitted through the indicator by means of the air contained therein; hence it follows that the rate at which the solution drips from the pipette furnishes a satisfactory index of the rate at which it is entering the vein. The flow is entirely controlled by one tap placed immediately below the indicator. When once anæsthesia is established, the ease with which the apparatus is controlled leaves the anæsthetist more than usually free to watch the condition of his patient.

[1] *Archiv f. klin. Chirurgie*, B v. p. 95.
[2] *Zeit. f. Chirurgie*, B xxxvii. p. 1417.
[3] *Annals of Surgery*, vol. lviii. p. 471. [4] *Loc. cit.*

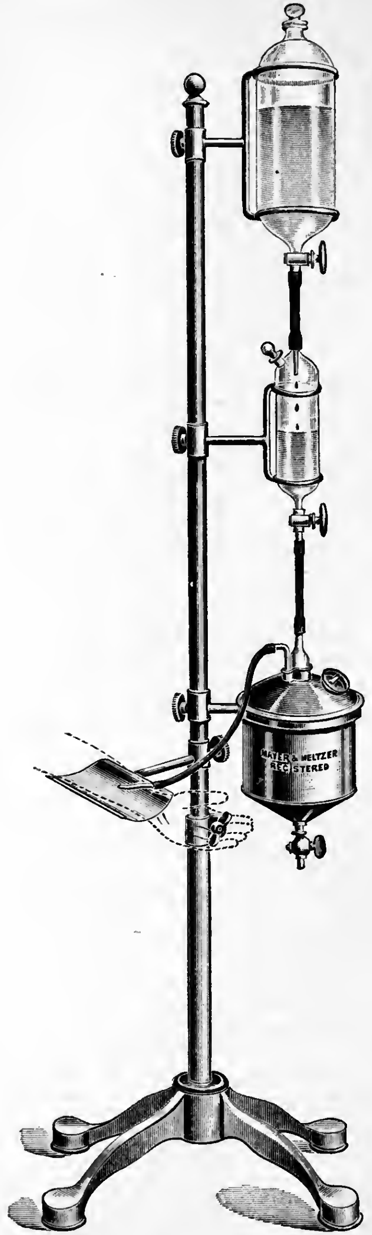

Fig. 47.—Rood's Apparatus for Infusion Anæsthesia by Means of Ether. (By kind permission of Dr. F. S. Rood.)

Method of Induction.—An hour before the induction a hypodermic injection is given, which consists of scopolamine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{6}$, atropine gr. $\frac{1}{100}$. These doses are to be regarded as typical of those required for a fairly robust adult; in other cases they may have to be modified according to the age and condition of the patient. The patient is placed on the operating table and the selected arm is lightly bandaged to a splint to prevent flexion of the elbow; a few drops of eucaine having been injected into the skin, the median cephalic or median basilic vein is exposed through an incision of a third of an inch. The strictest asepsis is, of course, preserved throughout this procedure. The solution is run in rapidly during the period of induction, which usually lasts about five minutes. The tap is then turned so that a succession of drops is allowed to enter the vein practically continuously. From this point onwards the symptoms of the patient must be watched and the anæsthetic regulated accordingly.

It would be premature to speak with any certainty as to the place which this system of etherisation is likely to take in the surgery of the future. Experience has already shown that it is valuable not only in operations such as those above mentioned, but also in cases in which the patient's general condition is such that etherisation through the respiratory passages is more or less contra-indicated. Owing to the length of time necessary to prepare the solution the system is obviously more suitable for hospital than for private practice. All one can say at present is that intra-venous etherisation promises exceedingly well, not so much for routine work as for selected cases.

Jeremisch[1] uses 1 per cent hedonal and 5 per cent urethane in normal saline solution, given intra-venously. Hedonal has also been used in London by Page[2] (pp. 132 and 467).

VIII. Rectal Etherisation

Rectal etherisation seems to have been first suggested by Roux in 1847[3]; and Pirogoff practised it upon the human subject in the same year. The chief object in view was to facilitate the performance of operations within and about the mouth, nose, and pharynx. Liquid ether, sometimes mixed with water, was at first used; but it was soon found that more satisfactory results followed the employment of ether vapour. The method was revived by Axel Yversen and Mollière. The latter gave the method a fairly extensive trial.[4] He first tried Richardson's hand-bellows for introducing the ether vapour, but afterwards, in five cases, used an india-rubber tube which was connected with a bottle of ether immersed in water at 122° F. The ether vapour was allowed to enter the rectum gradually. As a rule, not more than 2 oz. of ether was used. After 5 to 10 minutes a taste of ether was experienced by the patient, and drowsiness was felt. The rectal administration was supplemented by inhalation if necessary. Excitement was rarely met with. In the same year Dr. Weir[5] published a case in which rectal etherisation proved fatal. Dr. W. T. Bull[6] also published seventeen cases. Melæna occurred in seven of these. Numerous other trials of the system have been recorded.[7] In some of these, profound and prolonged stupor with cyanosis, contracted

[1] *Deutsche Zeit. f. Chirurgie*, B cviii. pp. 5 and 6.
[2] *Lancet*, 23rd March 1912.
[3] *Journal de l'Académie des Sciences*, 1847, p. 146.
[4] *Lyon Médical*, 28th April 1884.
[5] *New York Med. Record*, 3rd May 1884. [6] *Ibid.*, 3rd May 1884.
[7] See *Med. Times and Gaz.*, 7th June 1884 (quoted in *Practitioner*, vol. xxxiii. p. 58); also *Brit. Med. Journ.*, 3rd October 1885, p. 659.

pupils, and asphyxial symptoms occurred. Dr. Buxton has employed rectal etherisation for certain cases, and finds it "to answer admirably for operations about the mouth, nose, and post-buccal cavities, for intra- and extra-laryngeal operations, for staphylorrhaphy, and for operations for the relief of empyema."[1] A few years ago[2] F. H. Cunningham and F. H. Lakey recorded 41 successful cases of rectal etherisation. If the risk of diarrhœa, melæna, and after-stupor could in any way be greatly reduced, rectal etherisation would be strongly indicated in certain cases. But as matters stand, the process has too many objections attached to it to warrant us in employing it. A fatality has recently been recorded by Cunningham; death was due to general peritonitis.[3]

IX. Intra-tracheal Insufflation

The administration of ether by pumping warmed, moistened, and etherised air through a tracheal cannula was originated by Elsberg, and has been tested recently in America by several experimenters, and in this country by R. E. Kelly.[4] The method is especially commended as a substitute for high pressure and negative pressure cabinets in thoracic surgery, because the respiratory movements of the chest walls and diaphragm are rendered unnecessary. The apparatus employed is complicated and expensive; it is described in Kelly's paper, where also the American researches are summarised.

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF ETHER

The phenomena of ether anæsthesia will necessarily depend upon the system and method of administration adopted, the type of subject, etc. Bearing this in mind, it is convenient to describe four stages of etherisation, although in any given case little or no evidence of the first or second stage may present itself.

First Degree or Stage.—In consequence of the pungent

[1] *Op. cit.* p. 86.
[2] *Boston Med. and Surg. Journ.*, 20th April 1905.
[3] *Ibid.*, 24th March 1910. [4] *Brit. Med. Journ.*, 20th July 1912, p. 112.

and rather disagreeable odour of ether, it is impossible to avoid completely all unpleasant sensations at the commencement of the inhalation. When given by the strictly open method, or cautiously administered during the re-breathing of a limited quantity of air as by Clover's inhaler, the irritant effects of the vapour will be greatly minimised. Should the vapour be too strong for the particular patient, the glottis will close, as in the early stage of swallowing, and a feeling of suffocation may be experienced. When the anæsthetic is so administered that closure of the glottis, repeated acts of swallowing, and cough are more or less completely prevented, respiration will rhythmically proceed, and will become deeper and quicker than normal. Disturbances of the special senses (p. 63) are common. The pulse is usually considerably accelerated. The pupils are large and very mobile.

Second Degree or Stage.—Loss of consciousness takes place abruptly. The patient passes into a condition in which, although memory, volition, and intelligence are interfered with, he readily responds to stimuli. The response may have all the appearance of conscious response. Laughing, struggling, and shouting may be met with; but such phenomena are more likely to occur in vigorous and alcoholic patients who require considerable quantities of anæsthetic than in others. The pupils are still mobile, and usually more or less dilated. The muscular system is not uncommonly thrown into a state of tonic contraction. In exceptional cases a fine tremor, known as "ether-tremor," may occur.[1] This phenomenon appears to belong more to the second than to the third stage of etherisation, seeing that it may usually be controlled by a deeper anæsthesia. Mucus and saliva are freely secreted, especially in young and florid subjects, and especially if respiration be nasal. The features become flushed, the conjunctivæ

[1] The author has notes of several cases of "ether-tremor." In four of these it was considerable. The ages of three of the patients were 21, 24, and 30 respectively; no age is recorded in the other case. In one instance (the patient aged 30) the tremor came on before the operation commenced. In the patient aged 24, a healthy and well-developed man, undergoing an operation for varicose veins, the tremor was associated with a very large pupil and some lid-reflex. Julliard (*op. cit.*) states that he has never witnessed this phenomenon in women, and also that the patients in whom tremor occurs are invariably alcoholic or extremely nervous subjects. With the latter statement the author cannot agree, as he has witnessed the symptom in question in young and non-alcoholic patients.

injected, perspiration commences to break out over the face and other parts, and a harmless degree of duskiness, varying with the quantity of air admitted and with the patient's normal colour, may be observed. The pulse is quick and bounding. Any articulate language which may have been uttered becomes replaced by disjointed speech, which in its turn is followed by inarticulate muttering, and subsequently by mere syllables or expiratory noises. The breathing during this stage is inclined to be irregular and a trifle hampered, owing to the tendency to general muscular spasm. Temporarily suspended respiration may thus sometimes be met with, more especially in muscular subjects. The commonest cause for these slight irregularities in breathing at this stage is the employment of too strong a vapour. Clenching of the teeth from masseteric spasm, half-performed acts of swallowing necessarily interfering with respiration, and varying degrees of laryngeal spasm are one and all liable to arise from this cause. As the inhalation proceeds, however, the breathing grows more and more regular, and commencing stertor may be heard. Those muscles whose special office it is to carry on respiration now become incapable of being reflexly affected by the stimulus of ether, whilst others, whose spasmodic contraction would only indirectly affect the rhythm and amplitude of breathing (such as many of the muscles bounding and influencing the conformation of the upper air-passages), are now unable to interfere with free respiration, owing to their having become flaccid under the anæsthetic. In this manner the patient passes into the third stage of anæsthesia.

Third Degree or Stage.—When the respiration has become regular and stertorous, the cornea insensitive to touch, and the extremities flaccid, the patient may be said to have passed into the third degree of anæsthesia, and to be ready for any surgical operation.

The **respiration** during deep etherisation is usually somewhat forcible and distinctly audible. Owing to the almost invariable presence of a small quantity of mucus in the fauces and larynx, breathing has a moist character in addition to its usual stertor. A little tendency to spasm of the masseters and adjacent muscles may remain for a while and necessitate the lower jaw being pushed forward from behind (see Fig. 67, p. 554). Such spasm, however, gradually subsides. The anæsthetist must bear in mind that unless he keeps up a nearly continuous administration the patient will quickly pass back into the preceding stage, and irregularities in breathing will thus become developed. The rate of respiration is always markedly increased, varying considerably in different cases, and being dependent upon numerous circumstances, foremost amongst which must be mentioned the degree of air-limitation practised. Ether-stertor is most commonly due to the base of the tongue coming in contact with the pharynx, and as breathing usually takes place through the nose the stertor usually has a nasal character. Pushing the lower jaw forwards from behind at once diminishes or stops the snoring. A tendency to laryngeal closure, either from too strong an ether vapour or from operative measures upon certain parts of the body, is not uncommon, but rarely gives rise to difficulty. Sometimes the crowing breathing will persist throughout. When dependent upon the first-named cause, the spasm will subside with less of the anæsthetic; when occurring during rectal or other operations upon sensitive parts, more of the anæsthetic is usually indicated.

The **circulation** of the etherised patient gives numerous clinical indications of its remarkable fulness and force. The heart's action is excited; the pulse is full, bounding, and regular; the face is abnormally flushed; and incised parts, more especially in the neighbourhood of the neck, are very vascular. By means of Leonard Hill's "sphygmometer" it may be demonstrated that the arterial pressure remains constant at its normal level, or falls at most 5-10 mm. of mercury. The pulse, slower than during the second stage, but quicker than normal, is usually from 80 to 110 per minute. It is not uncommon, however, especially in cases in which respiration is greatly accelerated from air-limitation or embarrassed from other causes, for the pulse-rate to be 160 or even more. In one (myxœdematous) patient the author found it 190 per minute during deep anæsthesia, the only peculiarity of the case being that respiration was also very rapid. A roseolous rash sometimes makes its appearance upon the chest, neck, and other parts, when the vascular excitement is at its height.[1] Profuse perspiration is not uncommon.

The **pupils** are usually of moderate size or slightly dilated, *i.e.* from $3\frac{1}{2}$ to $4\frac{1}{2}$ mm., and are active to light. The causes which may influence their size will be dealt with below when discussing the depth of anæsthesia necessary for surgical operations (p. 372). Kappeler found by observations upon 150 cases that the pupils were contracted in 37 during deep etherisation. If there has been a preliminary narcosis with morphine or atropine or a mixture of these drugs, the fact must be remembered and its influence upon the condition of the pupils allowed for.

The **position of the eyeballs** during deep anæsthesia is similar to that observed under chloroform (see p. 414).

The degree to which the **muscular system** is relaxed will depend not only upon the depth of etherisation, but upon the nature of the operation which is in progress. In some cases a minor degree of rigidity may persist for a considerable time. In several instances the author has noticed that rigidity has passed away with an increase in the quantity of air admitted. There is, in fact, no better plan of obtaining complete abdominal relaxation than by the progressive administration of ether by what has been termed the perhalation system (p. 337), *i.e.* with over 90 per cent of air.

It is hardly necessary to point out that the **colour of the face and lips** will greatly depend upon the degree to which air is withheld.

C. DANGERS CONNECTED WITH THE ADMINISTRATION

In healthy and moderately healthy subjects the risk connected with the administration of ether is very slight. The fatalities which have been reported have almost invariably taken place in exhausted or markedly diseased individuals.

1. **The Administration of an Overdose: Fourth Degree or Stage.**—Should the administration of ether be carried too

[1] Mr. Edgar Willett states (*St. Bartholomew's Hosp. Reports*, vol. xxxii.) that the eruption appears suddenly after three or four minutes' etherisation; that it gradually disappears after two more minutes; that it is most common in women; and that it usually affects the area supplied by the superficial cervical plexus.

far, respiration will commence to show signs of failure. With this indication of danger the pupils will usually be dilated; the colour dusky rather than pale; the eyelids slightly separated; and the pulse, although still good considering the respiratory depression, somewhat less forcible, and probably slower than it was previously. In some cases the breathing assumes a modified Cheyne-Stokes character.

The manner in which respiratory failure occurs will vary in different cases. In the majority of instances the breathing loses its stertor, becomes feebler and feebler, and then altogether ceases. In some instances, prolonged, difficult, and rather wheezy expiration, with shallow inspiration, may be observed, and may indicate a dangerous depth of narcosis. In others, again, the regular and deep stertor which has been present may be succeeded by jerky, intermittent, and gasping breathing, during which the respiratory movements may abruptly come to a standstill.

An occluded state of the upper air-passages, although possibly occurring in some cases as the result of too large a quantity of the anæsthetic, is more often associated with a light or moderately deep anæsthesia. It is quite conceivable that a falling together or spasm of the arytæno-epiglottidean folds, such as that which the late Lord Lister described as arising under chloroform, may result from toxic doses of ether; but evidence on this matter is still needed. Similarly, spasmodic fixity of the chest is probably more frequently associated with incomplete than with dangerously deep narcosis (see p. 579).

The all-important point concerning respiratory failure in moderately healthy patients under ether is that *however such failure may arise, the circulation at the moment when breathing ceases is sufficiently satisfactory for remedial measures to be almost invariably successful.* The heart is not likely to fail unless restorative measures be too long delayed.

2. **Respiratory Failure occurring independently of an Overdose.**—The respiratory embarrassment which occasionally occurs in connection with the early stages of etherisation rarely gives cause for anxiety. Masseteric spasm, swelling and spasm of the tongue and other structures within the oral and naso-oral cavities, half-performed deglutition movements,

laryngeal spasm, and general muscular spasm of the neck, chest, and abdomen may one and all arise during ether administration. By the adoption of simple measures (p. 554) respiratory embarrassment thus arising may generally be quickly corrected. In certain circumstances, however, it may be difficult or impossible to overcome the spasm upon which the cessation of breathing depends, and it may then become necessary to adopt those lines of treatment (p. 557) which are suitable in such an emergency. Florid, thick-set, short-necked subjects, with accurately meeting teeth, and an inadequate nasal air-way, are particularly liable to respiratory embarrassment of this nature.

Respiratory shock, *i.e.* reflex arrest of breathing from the commencement of surgical procedures during partially established anæsthesia, may arise under ether. This condition has already been fully described (pp. 67 and 253).

Just as there is a liability to temporarily obstructed breathing immediately before deep anæsthesia is established, so there is a chance of its occurrence during recovery, *i.e.* at or about the time that the usual clenching of the teeth and swallowing which precede vomiting are liable to arise.

Respiratory embarrassment from all these causes is always unattended by symptoms of cardiac depression, unless, indeed, the embarrassment has existed for a considerable period, or the patient's general condition is highly unsatisfactory.

3. **Circulatory Failure occurring independently of an Overdose.**—In moderately healthy subjects primary circulatory failure under ether may, for all practical purposes, be regarded as an impossible event. It must be remembered, however, that in *bad* subjects, and especially in those with feeble, dilated, fatty, or otherwise diseased hearts, death may take place under ether with circulatory symptoms. It is true that in most, if not in all, of such cases, some slight impairment of or embarrassment to respiration is present, but the patient dies from cardiac syncope during the slight asphyxial strain. It is in this way that neglected cases of strangulated hernia succumb during the process of etherisation. The "last straw" is furnished by some trivial interference with free breathing,

such as that which arises during the stage of struggling or during vomiting.

Circulatory shock, *i.e.* reflex circulatory depression of surgical origin, may be met with under ether, but it rarely assumes grave proportions or threatens life (pp. 69 and 253).

4. **The Passage of Foreign Bodies (Blood, Vomited Matters, etc.) into the Larynx and Trachea.**—For remarks on this subject the reader is referred to p. 566.

5. **Other Dangers.**—Cerebral hæmorrhage has been known to occur during etherisation,[1] but it is of extreme rarity. We must not lose sight of the fact, however, that persons with very brittle arteries run a greater risk of this accident under ether than under less stimulating anæsthetics (see p. 167). There are certain other exceptional conditions which may arise during the use of ether as during the use of other agents: reference will be made to these in Chaps. XIX. and XX. The pulmonary and renal complications which occasionally follow the use of ether will be considered below (**E.** After-effects).

The treatment of the various difficulties and dangers met with under ether is identical with the treatment necessary when such difficulties and dangers occur with other anæsthetics, and it will therefore be considered in Chaps. XIX. and XX.

D. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

As a general rule the administrator should endeavour to keep the etherised patient in the third stage of anæsthesia. There is in each case a particular and proper level of narcosis; and, in order that this level may be satisfactorily maintained, the anæsthetist must repeatedly consult certain guides or land-marks which will now be considered. In deciding at what place or point we should keep our patient, we must be guided by a variety of considerations. We must bear in mind that, other things being equal, there are certain operations which demand a more profound anæsthesia than others.

[1] See a case reported in *Amer. Journ. Med. Sciences*, 1888, New Series, vol. xcv. p. 83.

In the next place, there are some patients whose reflexes are so highly developed that very deep etherisation is necessary in order that good surgical anæsthesia may result. On the other hand cases often present themselves in which, especially after the use of a preliminary narcotic, markedly small quantities of anæsthetic are needed. Moreover, after the operation has been in progress for some time, and more especially if much blood has been lost, and the patient is showing even slight signs of exhaustion, a smaller percentage of anæsthetic will maintain the necessary relaxation. By carefully observing the effects produced by more and less ether upon—

(*a*) The respiration;
(*b*) The occurrence of swallowing movements;
(*c*) The lid-reflex; and
(*d*) The pupils,

the administrator will have but little difficulty in deciding upon the precise place or level at which anæsthesia should be maintained. Having once established surgical anæsthesia, he will find that he is able to work in one case almost entirely by the respiration; in another by the occurrence of swallowing movements; in another by the lid-reflex; in another by the pupil; and that a few exceptional cases will remain in which he will have to draw his inferences from all these or possibly from other signs.

(*a*) Of all the guides as to the depth of anæsthesia, **respiration** is by far the most trustworthy. When once surgical anæsthesia has become established, the continued administration of ether will increase the rate, depth, and stertor of respiration, whilst the temporary withdrawal of the anæsthetic will be found to have an exactly opposite effect. A puffing of the lips with expiration is common in deep etherisation. In those cases in which it occurs it constitutes a good guide. In some patients there is an undoubted tendency towards slightly obstructed breathing, more especially when the anæsthesia is not so deep as it should be. This tendency, which is thoroughly discussed on p. 365, must always be borne in mind. It is not a dangerous tendency, because by simply keeping the lower jaw pressed forwards from behind it disappears. It is most pronounced in muscular and vigorous subjects. In many cases, and more especially in operations upon comparatively insensitive parts, and in protracted administrations, the respiration need not be kept so deep and stertorous as is generally desirable. Sometimes an expiratory moaning sound is made, and may constitute, by its alternate absence and presence, in response to more or less ether, a valuable guide to the administrator. A moist expiratory râle (? laryngeal or tracheal) indicates that less of the anæsthetic should be given; and the same may be said of "strained" or prolonged expiration.

(*b*) The act of **swallowing**, easily recognised by placing the finger over the larynx, is sometimes the first indication that the patient is emerging from deep anæsthesia, and when it occurs the administrator should at once briskly rub the lips and give more ether, in order to avoid straining and vomiting.

(*c*) The **lid-reflex**, *i.e.* the closure of the eyelid when the conjunctiva or cornea is touched by the finger, although regarded by many as an untrustworthy guide, is in the author's experience a most valuable indication of the depth of anæsthesia. In order that it may be properly made use of, the administrator must remember three facts. In the first place, it very commonly happens that, although no lid-reflex can be elicited by touching the margin of the lids or the conjunctiva covering the sclerotic, a brisk closure will follow the application of the finger to the *cornea*. In the next place, the conjunctiva, by being repeatedly touched, loses its sensibility. And lastly, there are degrees of this reflex, so that the patient may require to be kept at a stage of anæsthesia bounded on the one side by considerable and on the other by very slight lid-reflex. It is sometimes easier to feel than to see a minor degree of lid-closure in response to touch. Moreover, when from having frequently touched the conjunctiva of one eye its sensibility has become diminished, the other eye may be tested. It is a good plan, indeed, to keep one conjunctiva, as it were, in reserve. Whether or not the administrator should allow the lid-reflex to be present must depend upon the behaviour of the patient when he is permitted to display a slight degree of this reflex. Generally speaking, the lid-reflex should be kept in abeyance, especially during operations upon sensitive parts, and in patients whose reflexes are highly developed. In anæmic and weakly subjects, and towards the end of long operations, lid-reflex may usually be allowed, and will be found to be perfectly compatible with satisfactory anæsthesia.

(*d*) If carefully watched and studied, the **pupil** will, in most cases, afford valuable information. It will be of little service as a guide until after about a quarter of an hour from the beginning of the administration. The anæsthetist should then watch its behaviour with more and less of the anæsthetic, and he will usually have but little difficulty in deciding what size of pupil indicates proper anæsthesia in the case before him. We have already seen that the average pupil of deep etherisation is one of moderate size ($3\frac{1}{2}$ to $4\frac{1}{2}$ mm.); but in some patients a smaller, and in others a larger may be seen during satisfactory narcosis. The anæsthetist will usually observe that if he gives less ether, the pupil of the particular case will become smaller; if he increases the depth of etherisation it will grow larger. He may find, for example, that if he allows a pupil of 4 mm. to come down to 2 or $2\frac{1}{2}$ mm., the patient will commence to swallow, strain, or show indications of cough. The pupil does not, however, always diminish in size in response to less ether, and increase in size in response to more. The matter is complicated by the frequent tendency of the pupil to grow large from reflex irritation caused by surgical or other procedures. This tendency is more marked when a light anæsthesia is maintained. Should this tendency to reflex dilatation be present, we can readily understand that the pupil would grow smaller with *more* of the anæsthetic. Neurotic and anæmic subjects, as well as children, not infrequently exhibit a great susceptibility to reflex dilatation of the pupil throughout. In old people, on the contrary, and in those whose reflexes are not so highly developed, the pupil is less likely to fluctuate in size, and is usually smaller. This reflex enlargement of the pupil may be distinguished from what we may call the true toxic dilatation by observing the effects of more and less of the anæsthetic upon it. Suppose, for example, that the patient is undergoing an operation, and that his pupils are 5 mm. The question will arise: Are these pupils of reflex origin, or are they due to a deep anæsthesia? The problem may perhaps be solved by consulting the lid-reflex and other guides; but it may be more certainly settled by observing whether the pupil grows smaller or larger with less ether. If it become smaller with less ether the previous dilatation was probably due to a very profound anæsthesia; if it become larger with less ether the previous dilatation was probably of reflex origin. These considerations explain the apparent anomaly of an increased quantity of ether producing in one case a larger and in another a smaller pupil. Carrying the matter one step farther, the reader will see that, supposing the patient to possess a pupil of 5 mm., and the dilatation to be of reflex origin, more ether will first of all bring the pupil down to, say, $3\frac{1}{2}$ mm., and then, should the administration be continued, will cause the pupil to dilate again to 5 mm.; but this latter dilatation will be the toxic dilatation. The progressive diminution in the size of the pupil, which may often be observed in a long operation, is probably due to the progressively lighter anæsthesia and the more liberal supply of air which are found to be permissible. Finally, we must bear in mind the fact, when considering the pupil under ether, that any marked deprivation of oxygen will tend to effect an additional increase in size. When morphia has been given before "open" ether, the pupils may remain persistently small throughout the administration; the tendency of atropine is, of course, exactly opposite, and as these two drugs are now so frequently given together, the pupils are then less valuable as indications of the plane of anæsthesia that has been reached.

E. AFTER-EFFECTS

As a general rule, distinct signs of **recovery** from etherisation should be evinced soon after the withdrawal of the anæsthetic. As pointed out (p. 623), recovery will take place more speedily and satisfactorily when the patient is placed upon his side. Ether is often given in unnecessarily large quantities, the patient being saturated, as it were, with the drug. A prolonged stupor, unattended by cough, and characterised by slight duskiness and deterioration of pulse, may follow this injudicious and excessive use of ether. A minor degree of duskiness after this anæsthetic is not uncommon, and is usually connected with the presence of mucus in the air-passages, and with the quieter breathing following the withdrawal of ether. Directly coughing or retching has occurred, the patient's normal colour will become restored.

Ether generally leaves behind it a somewhat disagreeable **taste**, whilst its **odour** may be detected in the breath for a considerable time after the administration. Provided the patient has been properly prepared, that the administration has been skilfully conducted, that the purest ether has been used, that the patient has been placed in a proper posture after the operation, and that the inhalation has not been very protracted, there will usually be but little trouble from **nausea, retching, or vomiting.** Transient retching, with the expulsion of a small quantity of colourless or yellowish fluid, is the rule rather than the exception. This so-called "vomiting" after ether is almost characteristic of the use of the drug. It comes on soon after the anæsthetic has been discontinued; it is violent for the moment; and it rapidly subsides, leaving the patient either dazed, half conscious, and looking about him, or still unconscious and in a quiet sleep. As a general rule, ether-vomiting takes place and is passed over whilst the patient is still unconscious, although repeated attacks are not uncommon, especially after lengthy administrations, and in certain subjects, *e.g.* those with habitual naso-pharyngeal or nasal catarrh.

Many authors have compiled statistics showing the frequency of vomiting after ether administration. Most of these statistics deal with closed methods of ether administration, often preceded by "gas" or ethyl chloride. Some include the very slightest regurgitation of mucus, others exclude everything but marked and repeated vomiting. Accordingly it is not surprising to find great divergence among the percentages quoted. The most trustworthy series is probably that analysed by Blumfeld,[1] who met with absence of after-sickness in but 112 cases out of 501 administrations of "gas and ether."

[1] *Lancet*, 23rd Sept. 1899.

After the administration of ether by "open" methods there is less vomiting than when closed methods have been used: probably not more than one-third of the patients vomit after regaining consciousness. It has been claimed for the morphine-atropine and similar narcotic adjuvants to "open" ether anæsthesia that vomiting is thereby lessened. In our own experience this has not been the case; and we are even inclined to think that if anything vomiting is slightly more frequent than after "open" ether pure and simple.

On several occasions the author has met with **hæmatemesis** after ether.

The patients, have, as a rule, been in good condition, and partly by reason of their physique and partly from the nature of the operation it has been necessary to keep up a very deep anæsthesia. As a general rule, too, the patients in whom the hæmatemesis has arisen have not taken ether as smoothly as most cases, displaying jaw-spasm, cough, tendency to retch, etc. In one case—that of a florid boy of twelve—a persistent tendency to vomit occurred throughout the administration. Ether was first of all given, but after five minutes chloroform was substituted. The fluid which was then ejected contained no blood; but at the end of half an hour's deep chloroform anæsthesia hæmatemesis came on. The author has seen other cases in which this symptom has arisen after the ether-chloroform sequence. He has also met with one case in which it occurred after the A.C.E.-chloroform sequence. The patient was a bad subject of sixty-six, suffering from senile dementia, chronic bronchitis, and cardiac disease: lithotrity was performed quite successfully: hæmatemesis came on after the operation, but gradually subsided. In the majority of the author's cases the operation has been for the radical cure of hernia. The vomited material has either been porter-coloured or so similar to undigested beef-tea that its true nature has not been suspected. In one or two of the cases he has had the ejected fluid examined by competent authorities who have confirmed his opinion as to its nature. The hæmatemesis is probably capillary or congestive. The author has never known it give rise to any subsequent trouble or to recur to any serious extent. In one case the patient, who had a gastric ulcer, was seized with hæmatemesis whilst under ether. It was thought advisable to suspend the operation at the time; but as a subsequent attack took place, the patient was again anæsthetised, the stomach opened, and the ulcer successfully treated.

Hæmoptysis is rarely met with. The author has only seen one case during twenty-five years' practice, and in this the hæmorrhage was slight and soon subsided. **Pulmonary infarction** may account for some of these cases.

The **respiratory complications** of ether have attracted much attention from anæsthetists, surgeons, and physicians. There is no doubt that bronchitis, broncho-pneumonia, lobar pneumonia, and pleurisy are not very uncommon after operations under ether, especially after ether by closed methods. Other anæsthetics are so much less commonly attended by these sequelæ that the terms "**ether-pneumonia,**" "**ether-bronchitis**" have been invented, although it is by no means certain that ether plays the chief part in their production.

Several years ago Jackson, Saundby, and Lawson Tait[1] drew attention to these respiratory complications. Later, Drummond published a series of eight cases of ether-pneumonia, two of which proved fatal.[2] In all the cases the distribution of the lesion was lobular, and autopsies on the two fatal cases proved the presence of broncho-pneumonia. Six of the eight were abdominal cases. Crouch and Corner[3] corroborated the work of others in this direction. In 2400 ether anæsthesias they found six cases of bronchitis; two of broncho-pneumonia; one of bronchitis and pleurisy; and one of bronchitis, broncho-pneumonia, and pleurisy; all these complications set in within 24 hours of operation. Nine of the ten were abdominal cases, and all of them were anæsthetised with "gas and ether." During the same time 600 chloroform anæsthesias were conducted without a single case of pulmonary complication. In America a large number of cases have been published. Thus in 2500 ether administrations at the Montreal General Hospital, 55 pulmonary complications were observed, or 2·2 per cent.[4] Clover's inhaler was used, though some of the cases seem to have been unsuitable for ether at all. 35 of the cases occurred during the five winter months, as against 20 in the seven summer months. In 37 of the patients a pre-existing focus of sepsis existed before the development of lung symptoms. The 55 cases include 14 of lobar pneumonia; 16 of broncho-pneumonia; 19 of acute bronchitis; and 6 of pleurisy. Dr. Armstrong believes that the greater frequency of right-sided lobar pneumonia which was observed supports the view that these inflammatory lung complications are due to the invasion of septic matter from the mouth and pharynx rather than to infection through the blood and lymph.

Similar results have been published from the Baltimore clinic,[5] in which 9000 cases from the gynæcological wards were analysed. Here, too, the right lung seemed more prone to lobar pneumonia than the left, but the upper lobe was attacked almost as frequently as the lower, and this was considered to be the reverse of what would be expected if inhalation of septic particles were the principal causal factor. In this

[1] *Birmingham Medical Review*, May 1894.
[2] *Brit. Med. Journ.*, 1st Oct. 1898.
[3] *Lancet*, 24th May 1902, p. 1457.
[4] G. E. Armstrong, *Brit. Med. Journ.*, 19th May 1906.
[5] O. B. Wight, *Johns Hopkins Hospital Bulletin*, March 1908, p. 89.

series there were 30 cases of bronchitis and 17 of broncho-pneumonia. Another series of 2000 consecutive anæsthesias is reported from Boston.[1] Among 1089 laparotomies there were 8 cases of broncho-pneumonia, 9 of bronchitis, and 3 of pleurisy; among the remaining 911 cases, there were 1 case of bronchitis and 1 of pleurisy. Ether by open and semi-open methods was the anæsthetic used; there were no fatalities.

In an interesting oration before the Medical Society of London, Pasteur[2] goes very fully into the subject of post-operative lung complications. He thinks that ether *per se* is probably not a direct cause of pulmonary inflammation, and that respiratory troubles during anæsthesia—whether due to faulty administration, unsuitable method, surgical manipulations, or the quality of the anæsthetic itself—favour the aspiration of saliva into the lungs, and that in this way the anæsthetic may become an important contributing cause of lung troubles. He attaches much more importance to disturbance of respiration during anæsthesia than to the anæsthetic itself. Pasteur's statistics are confined to abdominal cases, because pulmonary lesions are so much more frequent therein than in others. Among 3559 laparotomies performed at the Middlesex Hospital in 1906-10, there ensued 88 cases of pneumonia, with 31 deaths; 53 of bronchitis, with 4 deaths; 26 of dry pleurisy, without mortality; 12 of massive collapse; 7 of pleural effusion; 8 of pulmonary infarct; 2 of gangrene of the lung; 1 of abscess of the lung; and 4 of empyema. These complications occur with especial frequency after operations above the umbilicus (in 12·59 per cent of such cases). They are more likely to arise in septic cases, but are frequently associated with clean wounds. They usually develop within two days after operation, and are uncommon after the fourth day. Complications arising after the first week are generally associated with septic processes; and most of the deaths occur in septic cases. Respiratory after-effects are not, in this series, shown to be more frequent after ether than after chloroform. Pasteur's figures are supported by numerous statistics from Germany, where a great deal of attention has been paid to this subject lately. Indeed, pulmonary complications would appear to be a great deal more frequent and fatal there than in great Britain. A careful analysis of the German work, with references to 24 German papers on this subject, has been published by Homans.[3]

Whether it is the actual ether vapour, or the presence of globules of mucus charged with ether and with bacteria, which irritates the bronchi and the parenchyma of the lung to the pitch of inflammatory reaction, it is quite certain that excessive secretion of mucus is significant of troublesome after-effects, of which pulmonary complication is one. Such mucus formation is especially seen during ether

[1] W. P. Graves, *Boston Medical and Surgical Journal*, 29th Sept. 1910.
[2] *Lancet*, 20th May 1911, p. 1329.
[3] *Johns Hopkins Hospital Bulletin*, April 1909, p. 125.

anæsthesia, and particularly when an asphyxial element has been allowed to develop. In certain cases ether causes the secretion of so much tracheal and bronchial mucus that a condition results to which the term "**mucus-inundation**" may be applied. Fatal asphyxia may result from the presence of this excessive mucus secretion within the bronchi, which was probably the cause of death in the two following cases, one of which is taken from the *Transactions of the Society of Anæsthetists,* and the other was reported privately.

Illustrative Case, No. 13.—F. æt. 30. Married. Has lost weight for three months. Pale. Cachectic-looking. Heart and lungs normal. Pulse 72, regular and strong. Urine contains traces of albumin. Exploratory abdominal section. Ether administered by Clover's inhaler. "During the period of induction the index never exceeded two, and throughout the operation stood at one or a little under." Went under quietly in about $3\frac{1}{2}$ minutes. No coughing or laryngeal spasm. No conjunctival reflex. Respiration free and unimpeded. Pulse full, soft, and regular. Towards end of operation some cyanosis and *a good deal of frothy mucous secretion.* Operation lasted 65 minutes. Patient transferred to trolley. Still somewhat cyanosed. Breathing rather shallow and sighing. Pulse 120, of good quality. Conjunctival reflex present. Pupils equal and contracted. Five minutes later pulse 134, regular, and of good quality; "respiration unimpeded though shallow"; cyanosis still present; conjunctival reflex still present. Ten minutes after operation over, a sudden change in colour was observed, the cyanosis being replaced by a "ghastly ashy-grey colour"; pulse suddenly became "bad," and after one or two sighing respirations, breathing ceased. Head lowered and artificial respiration commenced, the tongue being drawn out by forceps. Strychnine, brandy, and oxygen administered. Interrupted current applied to præcordium. Pulse absent at both radial and femoral arteries: no heart sounds audible. Artificial respiration kept up for 40 minutes, but without success. *During the performance of artificial respiration a large quantity, estimated to have been at least a pint, of frothy, watery secretion came away.* In all slightly over 4 oz. of ether used. The ether was analysed and found to be of sp. gr. ·720. Ether from the same bottle had been used for other patients without any ill effects. *Post-mortem.*—Liver and kidneys healthy though engorged with blood. Spleen small. Upper lobes of both lungs slightly emphysematous. Lower lobe of right side tough and contains very little air. "The rest of both lungs is saturated with frothy fluid which pours out of the bronchial tubes on pressure. The bronchi themselves are healthy. There are no signs of stomach contents in the air-passages and the fauces are clear. The heart is of normal size and proportions; the right side cavities are full of blood." Heart muscle apparently healthy. All valves competent. No signs of embolism or thrombosis in pulmonary vessels. Brain engorged with blood but healthy.

It is, perhaps, hardly right to express an opinion upon a case which one has not had the opportunity of observing, but it is probable that the ether set up free secretion of mucus, which led to air limitation and consequently cyanosis; this would excite still further secretion, and so a vicious circle was established. The heart muscle gradually became poisoned by oxygen starvation and carbonic acid retention; and asphyxial syncope followed.

Illustrative Case, No. 14.—F. æt. 32. Lungs and heart normal. No previous history of chest affection. Operation for ruptured perineum of some years' standing. Lasted nearly an hour. Weather fine and hot. Ethyl chloride-ether-chloroform sequence. 4 c.c. of Duncan and Flockhart's ethyl chloride; pure methylated ether of sp. gr. ·720 administered by Bellamy Gardner's inhaler; Burroughs Wellcome's chloroform, with definite percentage of ethyl chloride, administered by Vernon Harcourt's inhaler. Induction quiet and normal. No spasm or cyanosis. After about a quarter of an hour chloroform was substituted for ether, as the latter had produced some "bubbling of mucus." Chloroform "taken easily, and the mucus, although somewhat freer than usual, diminished." No cyanosis was observed either by administrator or operator. The depth of anæsthesia was "of the ordinary third degree." "The pupil remained fairly contracted throughout. No reflex movements. No coughing or retching." At the conclusion of the operation patient breathing quietly with good pulse. She became conscious and spoke before surgeon left. Vomited twice and coughed slightly. Cyanosis began about half an hour after patient put back to bed. "The symptoms seem to have come on gradually, the lungs slowly completely filled with fluid." Three hours after beginning of operation she was "bringing up frothy blood-stained mucus," with much cough, increasingly rapid breathing (about 40 per minute), and pulse 150. This state lasted for about two hours. *Chest Examination.*—No dulness; air entering tubes; a large amount of mucous crepitation over both lungs; heart much dilated (*sic*). The face was livid; blood-stained mucus was coughed up for some time; then all cough ceased. "Patient quite conscious and recognising her suffocating condition until she dropped back dead 12 hours after operation." The ether used had been employed for other cases without ill effect.

Here again it is difficult to express a definite opinion; but it seems probable that there was excessive production of mucus, which was not expelled by cough, and became churned up. The change to a chloroform apparatus of *the suction type* increased the tendency to an asphyxial state, and asphyxial syncope ensued. This case is included in the present chapter because the mucus inundation which caused death was initiated by ether.

Although it is difficult in the present state of our knowledge to draw any hard and fast line between mucus-inundation on the one hand and so-called **acute pulmonary œdema** on the other, the latter term would seem to be most appropriately applied to cases of the following type, and not to those in which asphyxia is brought about either by excessive mucous secretion, as in the two foregoing cases, or by the entry of vomited fluids into the trachea and bronchi, as in the case referred to on p. 570. The subjoined case occurred during the author's term of office at the London Hospital, and is one of considerable interest.[1]

Illustrative Case, No. 15.—The patient was a male of fourteen years of age. About three months before admission he contracted typhoid fever and the attack was a severe one. He subsequently developed symptoms of appendicitis and was admitted to the hospital to be operated upon for that affection. On the day of operation the boy appeared to be in very fair health; he had good heart sounds, there was no cough or difficulty in breathing, and the abdomen was not distended. Ether was given to him by means of a Clover's inhaler, and the administration lasted forty minutes. The induction of anæsthesia was perfectly smooth and there was no difficulty of any kind, but when the patient was fully under ether I noticed a great peculiarity about his breathing. The abdomen, instead of rising with inspiration, as is usual, receded, and respiration was wholly thoracic, although a plentiful supply of air was allowed. Slight cyanosis persisted throughout. No other abnormality noticed. Pupils moderately contracted. No abnormal secretion of mucus. Later in the day it was noticed that more mucus than usual seemed to be present in the air-passages; that the respiration was 32 per minute; and that the pulse was 112. The breathing did not improve during the night. Patient slept fairly well, but complained of pain at base of left lung anteriorly. At 8 A.M. next day, pulse 160; respiration 40; a good deal of "rattling" in the chest, at 12 noon the breath sounds were harsh with râles and rhonchi all over the chest, except at the base of the left lung anteriorly, which was dull to percussion. The heart sounds were almost indistinguishable. There was no increase of vocal resonance. The apex beat of the heart was not displaced. There was no sign of fluid or definite pneumonia. The respiration was 52. Stimulants were given, the inhalation of oxygen was employed, and the patient was propped up in bed. At 4 P.M. the respiration was 81, the pulse was 150, and the temperature was 102° F. At 10 P.M. the patient grew very dusky and he was bled, but only one and a half ounces of blood issued. No tubular breathing was audible, but both bases posteriorly were dull and the breath sounds were deficient. Strychnine and digitalis were injected every two hours,

[1] This case was published in the *Lancet*, 19th March 1898, p. 772.

but there was no improvement, and the patient died thirty-four hours after the operation. Unfortunately no post-mortem examination was allowed, but everything seems to point to acute pulmonary œdema as the cause of death.

According to Pasteur[1] the explanation of this case and of several similar to it in the Middlesex series is as follows. Massive collapse may result either from paralysis of the diaphragm, or in consequence of acute inflammation or acute pain in the immediate neighbourhood of the diaphragm. Sometimes collapse is the direct result of paralysis—for example in cases of post-diphtheritic paralysis; sometimes of reflex inhibition, which is not uncommon after abdominal section, and has been demonstrated by *x*-ray examination. Operations on any part of the abdominal cavity, or on the kidneys, may determine this accident, irrespective of sepsis; and hence may cause massive collapse. This type of collapse may closely simulate pneumonia, for which it is undoubtedly often mistaken. Sometimes it develops with such dramatic suddenness and intensity as to suggest pulmonary embolism; and on the other hand it may give rise to so few symptoms that, unless looked for, it may be missed altogether. It does not of itself seriously endanger life, as a rule, but is occasionally rapidly fatal, as in the above illustrative case. It must be remembered that collapsed lung readily becomes inflamed, and a proportion of these cases subsequently develop into a real broncho-pneumonia. Indeed Pasteur holds that massive collapse, or deflation of the pulmonary bases, resulting from reflex inhibition of diaphragmatic movement, is an essential factor in the causation of post-operative pneumonia; and that the rôle of the anæsthetic is only a very secondary one.

As far, then, as ether is concerned, it would seem that the causation of after-effects is somewhat complex. Cutaneous exposures, incautious ventilation, and the conveyance of patients through draughty corridors have probably very little share in the production of these sequelæ; but are nevertheless all to be avoided as far as possible. The hyper-secretion of mucus, which is almost characteristic of ether anæsthesia by closed methods, is one of the chief factors with which we have

[1] *Loc. cit.*

to reckon in most cases of ether bronchitis and ether pneumonia. Doubtless patients with pre-existing bronchial, pulmonary, or pleural disease, if anæsthetised with ether in contravention of well-established principles, are more liable than others to this excessive mucous secretion and its consequences. But even in healthy subjects hyper-secretion has its special risks; and these risks increase when, as after abdominal operations, coughing is rendered painful or impossible, and the diaphragm may be reflexly inhibited.

It is claimed on behalf of the open method of etherisation that the liability to respiratory complications is diminished very greatly. In so far as there is less mucus poured out, this is probably to some extent true. When atropine has been given beforehand, mucus is seldom troublesome. But if Pasteur's hypothesis of the origin of post-operative pneumonias is correct, it is unlikely that these latter will be abolished by any alteration in the method of giving ether.

In addition to these factors the duration of etherisation doubtless has its influence. Thus, after a comparatively short administration the air-passages, even though considerably blocked by mucus, will generally be cleared by cough before the patient regains consciousness. After prolonged etherisation, however, the reflexes may remain much longer blunted; and the result may be that the smaller bronchi tend to become more and more invaded by the frothy mucus. Minor degrees of bronchial catarrh are by no means uncommon after protracted ether anæsthesia, and the step from a bronchitic to a broncho-pneumonic state is very easily effected. The condition to which the term **mucus inundation** has been applied is most likely to arise when deep anæsthesia is maintained for some time by means of a close inhaler in a patient who secretes mucus freely. It is quite conceivable, too, that the use of imperfectly cleansed inhalers (*vide* p. 262) may conduce to the onset of ether-pneumonia. It is one of the virtues of the open method of ether anæsthesia that the mask can be so easily sterilised after every anæsthesia; whereas the rubber face-piece, bag, and heavy metal ether-container of Clover's inhaler are all difficult or impossible to sterilise efficiently. As to the passage of blood, vomited fluids, or septic material through the larynx, these are factors not peculiar to ether anæsthesia, and their influence need not be discussed here.

As already stated the production of mucus in excessive quantities is much more common when the breathing is nasal than when it is oral in character, so that by securing an oral air-way the risk of respiratory complications may be reduced. Other preventive measures, *e.g.* changing the patient's posture from one side to the other during the first twenty-four hours after an operation, the adoption of the sitting up or Fowler posture, and the avoidance of morphine or other sedatives during the recovery period are discussed in subsequent pages.

With regard to the frequency of **renal complications** after ether it is difficult to speak with certainty, owing to the fact that the statements made by those observers who have specially studied this point are very conflicting. The author has not, to his knowledge, met with any cases in which such complications have occurred; but it is only fair to say that the anæsthetist's opportunities for ascertaining the condition of patients after anæsthesia are very limited. It is contended by some writers that there is a greater risk of renal symptoms arising after ether than after chloroform; that this risk is increased in the case of patients with previously damaged kidneys; and that complications of this character are most likely to arise when the anæsthetic has been unnecessarily pushed. It must be remembered, however, that patients with pre-existing albuminuria are constantly being subjected, in our hospitals and elsewhere, to ether narcosis without any unfavourable after-effects arising.

Dastre,[1] Fueter,[2] and Roux[3] have urged the infrequency of these complications. Weir met with after-albuminuria in 9 out of 34 ether administrations, the patients having been free from this symptom prior to the anæsthesia. Wunderlich,[4] who studied 125 cases of ether and chloroform anæsthesia, found albuminuria *less* common after ether than after chloroform in non-albuminuric subjects; whilst in those in whom albuminuria pre-existed, ether augmented the condition. Barensfeld[5] met with two cases of albuminuria (one being very marked)

[1] *Op. cit.*
[2] *Klinische und exper. Beobachtungen über die Äther-narkosa*, p. 28.
[3] Julliard, *op. cit.* [4] *Annals of Surgery*, May 1894, p. 630.
[5] *Year-Book of Treatment*, 1896, p. 174.

in 150 ether administrations to non-albuminuric subjects, and failed to find any increase of albumin in two patients with pre-existing renal symptoms. In 500 non-albuminous subjects to whom ether was given, Butler [1] met with one case of albuminuria; while Kute in 600 such administrations noted six cases. Ogden [2] found that albuminuria appeared in a considerable percentage of etherised patients whose urine was previously non-albuminous. Buxton and Levy [3] are unable to satisfy themselves that ether, when properly administered, exerts any unfavourable influence upon the kidneys. The researches of Drs. H. Pringle, Maunsell, and S. Pringle and of J. W. Bovee have already been considered (p. 75).

A case of total suppression of urine and subsequent death has been reported privately to the author from New Zealand. Ether was given in a Clover's inhaler for a total period of under half an hour; the operation was curetting. The patient was apparently healthy, though the urine does not seem to have been tested beforehand.

During the last few years certain cases have been recorded in which a peculiar condition known as **acid-intoxication** or **acidosis** has appeared after the use of anæsthetics. This complication, which seems to be far less common after ether than after chloroform, will be considered in Chapter XXI. of this work (p. 634).

Transient **mental and muscular excitement** may arise after ether, and is more particularly liable to do so in hysterical, neurotic, or alcoholic subjects who have been but a short time under the anæsthetic. In very rare instances **mania** and **dementia** have been recorded.[4] Choreiform movements lasting three weeks have also been reported.[5]

As stated above (p. 369), there is a slight but distinct risk of cerebral hæmorrhage occurring during the etherisation of certain subjects, and, as a result, **hemiplegia** may follow.

Lastly, there is some evidence that ether anæsthesia predisposes to **thrombosis**. Some years ago the late Dr. Moxon [6] reported a case in which, according to his view, a

[1] *Gould's Year-Book*, 1897, p. 246.
[2] *Year-Book of Treatment*, 1898, p. 165.
[3] *Brit. Med. Journ.*, 22nd Sept. 1900, p. 833.
[4] See Sir G. Savage's paper, *Brit. Med. Journ.*, 3rd December 1887, p. 1199; also *Boston Med. and Surg. Journ.*, August 1889; also *American Journ. Insanity*, Utica, April 1890. For further remarks on the subject see p. 303.
[5] See Dr. Jacob (*Lancet*, 16th October 1879, p. 539).
[6] See *Lancet*, 17th April 1886, p. 731, and 24th April 1886, p. 809.

thrombotic state of a branch of the coronary artery was brought about by the administration of ether (for a rectal operation). The patient regained his health, but three weeks subsequently sudden death took place, the only discoverable cause being a slight recent extension of the thrombosis into the main vessel. Apparently a large area of cardiac muscle had suddenly thus become deprived of its blood supply. The author has been furnished with notes of a case of (?) cerebral thrombosis following prolonged etherisation in the Trendelenburg posture. The cases of pulmonary infarction after ether are also suggestive of this thrombotic tendency (*vide supra*).

CHAPTER XII

THE ADMINISTRATION OF CHLOROFORM

The reader is referred to Chap. I. p. 9, for a short account of the early use of this anæsthetic; to Chap. II., p. 25, for information upon its chemical and physical properties; to Chap. IV., p. 98, for a *résumé* of the chief experimental work that has been done concerning its physiological action; and to Chaps., V., VI., and VII. for remarks as to its safety and suitability in general surgical practice.

A. APPARATUS AND METHODS OF ADMINISTRATION

Section I.—The Administration of Chloroform Vapour with Atmospheric Air

Sir James Simpson, to whom we are indebted for the introduction of chloroform as an anæsthetic, first administered the drug by means of a simple handkerchief arranged in a cup-like form. An unmeasured quantity of chloroform, usually about a drachm, was poured into the hollow thus formed, and the handkerchief applied to the patient's face. He recommended that the vapour should be exhibited "powerfully and speedily," to use his own words,[1] and considered a gradual administration objectionable, owing to the frequent occurrence of inconvenient excitement. Subsequently he used a folded cloth or towel, and he continued to adopt this mode of administration for several years. In 1860, however, he again modified his procedure, apparently recognising the necessity of providing

[1] *The Works of Sir James Y. Simpson*, vol. ii., Edinburgh, 1871, p. 177.

for a freer admixture of air with the vapour. He therefore advised that a *single* layer of a towel or handkerchief should be laid over the patient's nose and mouth, and that the anæsthetic should be added drop by drop.

§ 1. Regulating or Percentage Methods of Administration

Snow was the first to draw attention to the fact that in order to obtain uniform results, and to avoid too concentrated a vapour, it is advisable to use some plan by which the proportions of chloroform vapour and air may be regulated. As already mentioned (p. 99), he made experiments with different percentages of vapour, and carefully recorded his results.

Snow's inhaler consisted of a double metal cylinder, the outer space containing water, and the inner one serving for the evaporation of chloroform from bibulous paper arranged in coils. The inner cylinder, which had holes at its upper part for the free admission of air, communicated by means of a flexible india-rubber tube with a face-piece containing inspiratory and expiratory valves. The inhaler was contrived to supply, at about 60° F., and in the ordinary process of inhalation, about 5 per cent of vapour; but it possessed an arrangement by which more air might be admitted if desired.

In 1849 Snow employed, in a few cases, a bag of known capacity, which could be inflated by bellows, and in this bag a measured quantity of chloroform was placed. He so regulated the proportions that an atmosphere containing 4 per cent of vapour resulted. He found this plan of administration, however, somewhat inconvenient, and preferred the inhaler just described.

Clover agreed with Snow as to the advantages of working with a known percentage of vapour, and for many years successfully administered chloroform upon these lines.

Clover's chloroform apparatus[1] consisted of a bag holding 8000 cubic inches of air, and connected by a flexible tube to a face-piece. The bag was charged before use by means of a bellows holding 1000 cubic inches. On its way from the bellows to the bag the air was made to pass through a warm chamber containing chloroform. Thirty to forty minims of chloroform were added to this chamber, by a graduated

[1] Described in Erichsen's *Science and Art of Surgery*, vol. i., 1877, p. 18.

syringe, for every thousand cubic inches of air pumped through. This would give from $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent of chloroform vapour. The face-piece and tube of the apparatus were almost identical with those used by Snow.

Working upon the lines of Snow and Clover, Paul Bert subsequently came to the same conclusions as these observers, and administered, by means of special gasometers,[1] definite proportions of chloroform vapour and air. Bert's "méthode des mélanges titrés" has been already considered (p. 100). A number of operations were performed by M. Péan upon patients anæsthetised with the 8 : 100 mixture (= 8 gm. of chloroform : 100 lit. of air, or about one and a half per cent of chloroform vapour). It is stated that the excitement period was generally absent or but slightly developed; that there was no resistance on the part of the patients; and that deep and satisfactory anæsthesia was usually produced in seven minutes.

One of the most accurate instruments for delivering to the human subject chloroform atmospheres of definite strength is that known as **Dubois' apparatus**, already described (p. 101). This apparatus has the great merit of supplying weak and easily regulated chloroform atmospheres without imposing upon the patient the suction action which is inseparable from certain other instruments. The author has used Dubois' apparatus in several cases at St. George's Hospital in conjunction with Dr. Waller, and with satisfactory results. One patient, a potman, who had previously given trouble with the nitrous oxide-ether sequence, passed into anæsthesia with very little excitement; but the induction lasted 18 minutes, and there was some reflex movement with the first incision. Dubois' apparatus is costly, heavy, and complicated; whilst two persons are required to work it. Moreover, the induction period is usually inconveniently long with this as with other regulating chloroform instruments. Dr. P. M. Chapman of Hereford is an enthusiastic advocate of this apparatus.[2]

Waller's chloroform balance has already been described (p. 103). Like Dubois' apparatus it can be used clinically, delivering to the patient definite chloroform atmospheres without imposing any respiratory exertion. The author has used this

[1] See Dastre, *op. cit.* p. 105.

[2] *Lancet*, 9th Jan. 1909, p. 9.

instrument at St. George's Hospital in conjunction with Dr. Waller and with excellent results. For the past year, indeed, a chloroform balance has been installed in the out-patient department of the hospital. By means of an electric motor and fan connected with the balance it has been found possible to supply the patient with accurately adjusted chloroform atmospheres on the Plenum system. The rarity of after-effects—a point of great importance in out-patient practice—has been a conspicuous feature of these adminstrations.[1]

Within the last few years many attempts have been made to devise a portable chloroform inhaler capable of delivering dilute chloroform atmospheres of known strength; and Mr. A. Vernon Harcourt has introduced the apparatus described below, which, in his opinion, fulfils these requirements.

The **Vernon Harcourt Inhaler.**[2]—The Harcourt inhaler provides, in sufficient quantity for full and free respiration, a mixture of air and chloroform which is automatically limited to a maximum strength of 2 per cent, and can be diluted at will with additional air down to any smaller proportion.

The two-necked bottle is filled with chloroform to near the top of the conical part, and two coloured glass beads are dropped into the liquid to indicate when the temperature is within the range 13°–15° C. If the temperature of the chloroform is below 13° both the coloured beads will float: if it is above 15° both will sink: in the former case the proportion of chloroform inhaled will be less than the pointer of the stopcock indicates: in the latter case it will be greater. The proportion is also increased by any agitation of the bottle. During inhalation the chloroform is cooled by evaporation; its temperature may be kept between 13° and 15° by now and then holding the bottle in the hand till the blue bead has sunk and the red bead is beginning to sink. The dimensions of the bottle have been arrived at after a great deal of experimental work and careful analysis. The diameter of the upper portion has been proportioned to the average rate of human respiration and to the rate of evaporation of chloroform between 13° and 15° C. To compensate for varying rates of respiration the inlet and outlet of the bottle are placed near together and at some distance from the surface of the liquid; while to compensate for the lowering of the liquid surface by evaporation the vessel widens as the surface of the chloroform descends. The nearness of the two necks one to another, and the distance between

[1] In an Appendix to the Report of the Anæsthetics Committee of the British Association for the Advancement of Science, 1912, Mr. G. R. Phillips, Resident Anæsthetist at St. George's Hospital, has described these cases.

[2] This description is copied from the circular supplied by the makers of the apparatus, Messrs. J. J. Griffin & Sons, Ltd

them and the surface of the chloroform, diminish the variation in the proportion of inhaled air to chloroform vapour which is caused by abnormally shallow or deep breathing. When the flow of air is gentle, much of it passes in at one neck and out at the other without reaching the surface of the chloroform or displacing wholly the mixture of air and chloroform which occupies the upper half of the bottle. On the other hand, the strong current caused by deep breathing drives out all the vapour which has been formed and promotes further evaporation by stirring the surface of the liquid. With bottles of the present dimensions this correction is only partial. If the rate of breathing is voluntarily reduced to 3 litres a minute instead of the normal 4 or 5 litres, or raised to 7 or 8 litres a minute, the proportion of chloroform may be raised to about 2·5, or lowered to about 1·5 per cent. It would not be difficult by lengthening the cylindrical part of the bottle to correct more completely for variations in the rate of breathing. But it is believed to be advantageous that the proportion of chloroform should vary thus, in order that there should be less variations in the total quantity of chloroform administered. Two ratios have to be considered in judging of the probable effect upon a patient, that of chloroform vapour to air, and that of the mass of chloroform inhaled to the mass of the body through which it is distributed.

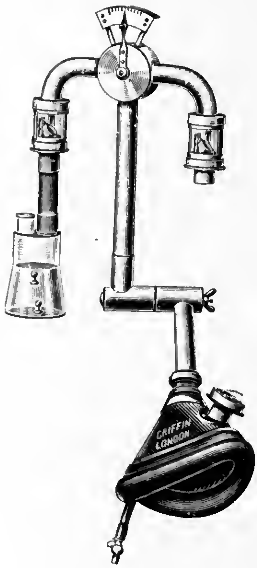

Fig. 48.—The Vernon Harcourt Inhaler.

The stopcock is so made, that when the pointer is at the end of the arc nearest the bottle of chloroform, the maximum quantity is being administered—namely, 2 per cent. When the pointer is at the opposite end, only air will be inhaled; and when it is midway, dilution of the 2 per cent mixture with an equal volume of air will make the proportion 1 per cent. The shorter lines on either side indicate intermediate quantities—namely, 0·8, 0·6, 0·4, 0·2; and towards the chloroform bottle, 1·2, 1·4, 1·6, 1·8.

The valves on the two branches prevent the entrance into the apparatus of expired air, and also serve to show whether the stopcock is working rightly. Only one valve opens when the pointer is at either end of the scale, both equally when the pointer is midway, and for all other positions one valve opens more and the other less, in the degree indicated by the position of the pointer on the scale. The movement of these valves shows also how full and regular the breathing is, and the slight click which they make conveys this information to the ears when the eyes are otherwise occupied.

It is generally found that beginning with the pointer at 0·2 and moving it on towards the chloroform bottle at the rate of one division about every half-minute up to 1·6 or 1·8 produces narcosis as quickly as is desirable.

For the maintenance of narcosis it is believed that 1 per cent or even less will be found sufficient. The stopcock can be moved by a touch of the finger so as at once to increase or diminish the dose.

If by fall of temperature or agitation of the bottle the yield of chloroform is diminished or increased, this may be allowed for at once by a movement of the stopcock.

The face-piece, which is provided with an expiratory valve, and can be fixed in any position, is either attached directly to the inhaler, which in this case is held in the hand and should be kept as nearly vertical and as steady as possible, or can be connected by about 20 inches of half-inch rubber tubing; the inhaler in this case being supported on a stand or hung on to the back of the bed.

The mask is made of solid toughened rubber, fitted with a rubber air-cushion. It can be washed, or boiled, and as it becomes plastic in hot water the shape can easily be modified, if required, so as better to fit the patient's face.

Certain cases may occur in which a stronger dose is required than that afforded by the apparatus as above described. For increasing the strength of the vapour inhaled a small tube is provided which fits into the open neck of the bottle, raising the possible maximum dose to 2·5 or 3 per cent. To obtain a 2·5 per cent mixture the larger end of the tube, marked 2·5, must be inserted in the bottle, and for 3 per cent the smaller end, while the pointer is kept at the end of the scale nearest the chloroform. At intermediate positions of the pointer the dose will be increased in the same proportion as the maximum.

No chloroform evaporates excepting that which is inhaled by the patient; and only that which is exhaled passes into the air of the room. *A great economy of chloroform is thus effected, which should in a short time repay the cost of the apparatus to Institutions or medical men in large practice by whom it may be used.*

The apparatus must be carefully examined to see that the parts are adjusted, and the administrator should inhale or incline the instrument sideways to see that the valves are working properly. About $1\frac{1}{2}$ oz. of chloroform should be poured into the conical bottle, and the beads introduced. The face-mask should then be carefully applied. This is best done when the head is turned to one side. Breathing taking place freely and the air inlet valve and expiratory valve flapping properly, the inhaler should be grasped at the horizontal cross-piece with the right hand, while the lower jaw is pressed forward by the left hand placed behind the angle of the mandible. Firm pressure is necessary, as absolute co-adaption of the mask to the patient's face is essential. If the pressure used is equal over the whole area of the face, the patient will not complain. It is a common fault to allow air to enter by the sides of the bridge of the nose. Absolute fitting of the face-piece having been secured, the strength of the vapour may be gradually increased by turning the pointer. This is done slowly, but unless the patient is restless and struggles, not too slowly. Struggling is an indication for the lessening of the strength of the vapour, but not for removal of the face-piece, unless duskiness supervenes. When narcosis is attained, the usual signs being relied upon, in most cases the maintaining of anæsthesia can be effected with 1·5, 1 or even ·5 per cent, according to the physique of the patient and the requirements of the operation. After prolonged administration, slight duskiness may appear, and in this case the apparatus may be lifted for a few breaths and then replaced.

An ingenious attachment for delivering oxygen continuously or intermittently, according to the decision of the anæsthetist, has been devised by Dr. Llewelyn Powell. This is of use especially in cranial cases, and a full description of the apparatus can be found in a paper by Sir Victor Horsley.[1]

Mr. Vernon Harcourt's ingenious apparatus has been extensively employed. It has, however, certain disadvantages: (1) the current through it depends upon the respiratory action of the patient; (2) the face-piece pressure, which is often necessary in order to obtain proper chloroform percentages, may seriously interfere with free respiration; (3) it takes a long time to induce anæsthesia; (4) it cannot be used for many operations; and (5) it cannot be readily sterilised. Reference has already been made (p. 106) to the disadvantages of making the respiratory pump of the patient also the pump of an apparatus. In the interesting case referred to the respiratory arrest was almost certainly attributable to intercurrent asphyxia largely dependent upon the type of apparatus. The writer cannot too strongly dissent from the view that chloroform accidents are to be entirely prevented by regulating chloroform percentages. However perfect an apparatus may be in its mechanism, however accurately it may deliver this or that percentage of vapour, it cannot prevent that state of intercurrent asphyxia which is liable, in certain cases, to complicate anæsthesia. On the other hand for certain special operative procedures, such as those of cranial surgery, where a light anæsthesia is required, this inhaler (with the oxygen attachment) has proved itself of the greatest utility.

Other regulating inhalers have recently been introduced, amongst which may be mentioned that of Dr. **Levy.**[2]

Junker's Inhaler was originally[3] intended by its inventor for the

[1] *Brit. Med. Journ.*, 25th Aug. 1906. [2] See *Lancet*, 27th May 1905, p. 1413.

[3] See *Med. Times and Gaz.*, 1867, vol. ii. p. 590; and 1860, vol. i. p. 171. Although Junker's apparatus when carefully used probably lessens the risk of

administration of "bichloride of methylene." The principle of the apparatus is simple. Air is pumped by means of a hand-bellows and tubes through chloroform, and the air, carrying with it a varying quantity of vapour, is transmitted to a face-piece. In the original inhaler there was a vulcanite face-piece with an air-slot. In the models which are now made (Fig. 49), the face-piece is of flannel stretched over a wire-frame; there is a filling funnel introduced by Dr. Buxton, and a little stopcock between the bellows and the chloroform reservoir which converts the intermittent into a continuous air-current. Dr. Buxton and Mr. Hilliard have also devised foot-bellows. The bottle for the chloroform is graduated to hold from 1 to 8 drachms, and having been charged with somewhat less than the latter quantity, is suspended by a little hook from the coat of the administrator. The india-rubber tube leading from the bellows to the bottle may be termed the afferent

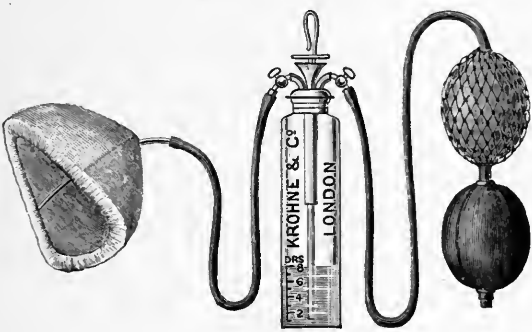

Fig. 49.—Junker's Inhaler.

or bellows-tube; that leading from the bottle to the face-piece the efferent or face-piece tube. Vulcanite and leather face-pieces, capable of closely adapting themselves to the face, should not be employed.

When it is desired to keep up chloroform anæsthesia without employing a face-piece, as in certain mouth and nose operations, the face-piece is disconnected, and a mouth-tube (Fig. 52) or nasal catheter is adapted to the efferent tube. When the hand-bellows is worked, air will be heard to bubble up through the chloroform. It is very important, in using the inhaler, **to see that the afferent and efferent tubes are attached to the corresponding metal tubes of the bottle.** It is also important not to have more than the proper quantity of chloroform in the bottle, otherwise some of the liquid may possibly gain access to the efferent tube. And lastly, care should be taken lest the bottle containing the chloroform become tilted during the administration.

chloroform narcosis, several deaths have occurred in connection with its employment. It is not a suitable inhaler for infants or young children. For accounts of fatal cases see *Brit. Med. Journ.*, 29th Sept. 1888, p. 719; 15th Sept. 1888, p. 625; 21st Dec. 1889, p. 140; 31st July 1889, p. 88; 10th June 1882, p. 889; 24th Jan. 1903, p. 195; *Trans. Soc. Anæsthetists*, vol. vi. p. 57.

It has, on more than one occasion, happened that, by an oversight, the india-rubber tubes have been adapted to the wrong metal tubes of the bottle containing the chloroform. The result has been that the liquid chloroform has been pumped into the face-piece, and in some cases into the nose or mouth of the patient.[1] A somewhat similar accident has also been known to occur by the chloroform bottle becoming tilted during the administration. As one or two fatalities have arisen from these accidents the author thought it worth while to modify the inhaler, with the object of preventing the possibility of the tubes being wrongly adjusted, and rendering the bottle less likely to become tilted during use. Fig. 50 shows this modification. Air enters as usual through the hand-bellows. The afferent india-rubber tube is made much larger than that ordinarily used. The efferent tube is contained within the afferent, and emerges from the latter at right angles immediately above the hand-bellows. Arrows show the direction of the currents. The air entering the bellows passes along in the afferent tube system and bubbles up, as shown, through the chloroform. It then escapes by the efferent system. The stopcock shown in the figure controls both the afferent and efferent tubes. When it is turned off, the bottle may be placed horizontally, or packed away in a bag, without any of the chloroform leaving the bottle. The apparatus is conveniently worked as represented in Fig. 51. By this modification there is no possibility of the flexible tubes being interchanged; and

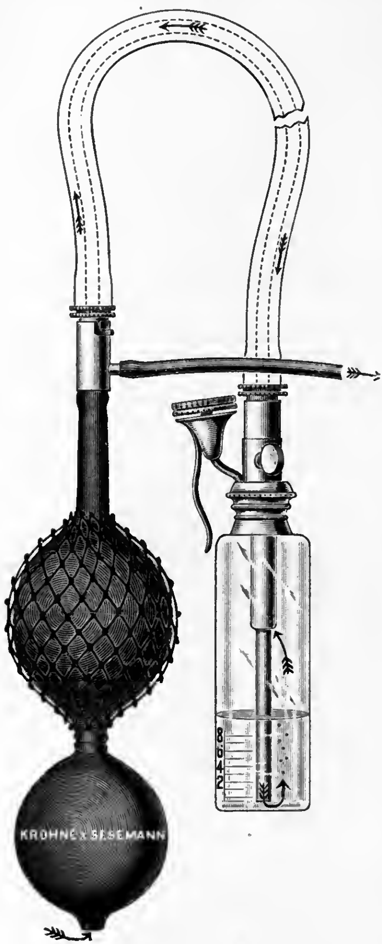

FIG. 50.—The author's Modification of Junker's Apparatus.

[1] Death has resulted in more than one case. On one occasion at a London Hospital tracheotomy became necessary in order to restore respiration after liquid chloroform had thus gained entrance to the upper air-passages.

there is no likelihood of the bottle becoming tilted during the administration.

It is practically impossible to say what percentage of chloroform vapour is usually inhaled from the mask of Junker's apparatus. The percentage will depend upon a variety of circumstances. Foremost among these must be mentioned the quantity of air taken in with each inspiration. All kinds of breathing are met with during chloroformisation, from the deep regular respiration of the broad-chested and stalwart patient to the feeble and almost imperceptible breathing of the ill-

Fig. 51.—The Modification of Junker's Apparatus in actual use.

developed and fragile child. Moreover, respiration may vary in amplitude from time to time in the same patient, even though the same level of anæsthesia be maintained. The next most important factor is probably the manner in which the face-piece fits, or the degree to which air gains admission through it when it is adapted accurately to the features. Then we must take into account the temperature of the chloroform at the time; and this will greatly depend upon the rapidity with which the air is forced through the liquid. Professor Zengerle of Constantz conducted, at Kappeler's request, some interesting experiments on this point.[1] His figures are here reproduced:

[1] Kappeler's *Anæsthetica*.

Experiment.	Compressions of Bellows per Minute.	Quantity of Air Supplied.	Chloroform evaporated.
1	120	4 litres	·7 gm.
2	60	2·2 ,,	1·2 ,,
3	40	1·6 ,,	1·4 ,,
4	30	1·2 ,,	1·5 ,,
5	24	1·0 ,,	1·6 ,,
6	20	·9 ,,	1·7 ,,
7	17	·8 ,,	1·7 ,,
8	15	·7 ,,	1·7 ,,

The temperature of the chloroform used was 63·5° F. From the experiments it is concluded that *the speed of pumping is in inverse ratio to the percentage of chloroform in the issuing air*—a point of some importance in practice. Lastly, the temperature of the room will also exert a slight influence.

Before **using Junker's inhaler** the administrator must see

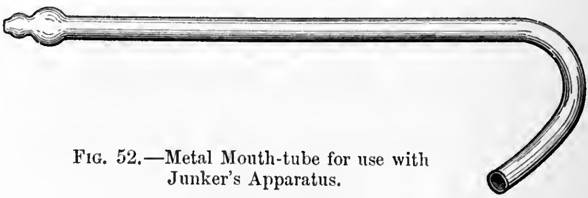

Fig. 52.—Metal Mouth-tube for use with Junker's Apparatus.

that it is in good working order. Having satisfied himself that it works properly, he should at first hold the face-piece at some little distance from the face, and gently compress the bellows. He will soon see whether his patient can breathe without discomfort the vapour he thus presents to him. The bellows should be compressed during the inspiratory phase of breathing. Gradually the face-piece may be brought closer to the face. By avoiding jerkiness in pumping, and by more or less rhythmically compressing the bellows, a tolerably constant chloroform atmosphere may be maintained. Rapid pumping, as pointed out above, is open to objection. When more chloroform seems indicated, the face-piece should be more continuously or more closely applied.

Junker's apparatus is very useful, one might almost say indispensable, in many operations within or about the mouth, nose, or pharynx. As already mentioned (p. 179), it is best in these operations first to secure deep ether anæsthesia, and then to continue with Junker's inhaler when the patient commences

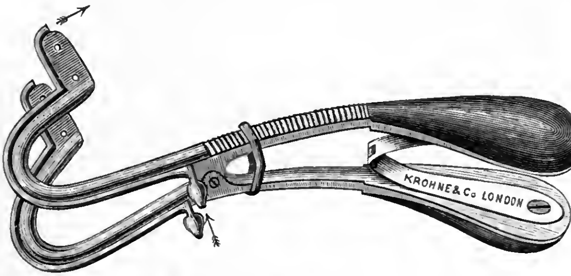

FIG. 53.—The author's Modification of Mason's Gag for use during operations within the Mouth and Nose.

to emerge from the ether narcosis. Should the administrator decide upon this course, he must either give the chloroform vapour through the mouth by means of a metal tube (Fig. 52)

FIG. 54.—Gag of Fig. 53 in position.

attached to the efferent rubber tube of the inhaler, or through the nose by means of a rubber catheter similarly attached, or by means of the useful combination of a tongue-lever and delivery tube invented by Mr. F. W. Longhurst (Fig. 21, p. 259).

Whenever possible, the delivery of chloroform vapour is best effected by means of a nasal catheter, the end of which should be felt projecting just beyond the soft palate. When, however, this course is impracticable, the mouth-tube must be used and one or both of the anterior nares temporarily plugged with sponge or lint in order to secure oral breathing. The most frequent cause of "coming round" during intra-nasal or intra-oral operations is the delivery of chloroform vapour into the *oral* cavity whilst respiration is taking place through the *nasal* channels. When the mouth is to be used for the introduction of the vapour, the appliance shown in Fig. 53 may be useful. It consists of a Mason's gag carrying metal tubes for the transmission of chloroform vapour, the efferent tube of the Junker's inhaler being fitted to one of the metal tubes of the gag. This mode of anæsthetisation is shown in Fig. 54. In those cases in which the surgeon wishes the patient's head to be turned completely upon its side in order that he may operate upon the cheek or jaw thus rendered easily available, some difficulty in keeping a gag in position may be met with. It is obvious, in the first place, that some form of gag is necessary; and, in the second place, that the gag should be upon that side of the mouth which is lying against the pillow. A Mason's gag invariably becomes dislodged in these cases by reason of its handles resting upon the pillow. The author has found the gag of Fig. 55 to be useful on these occasions. It should be inserted between the canine or first bicuspid teeth on that side which is to lie upon the pillow. By

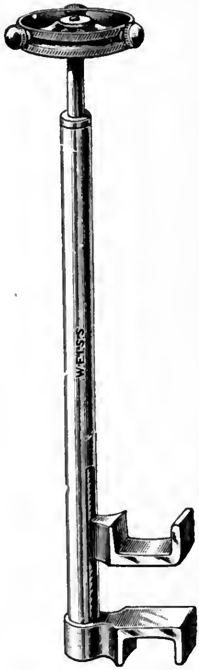

Fig. 55.—The author's Screw-gag for use in certain nose and mouth operations.

Fig. 56.—The author's Chloroform-prop.

rotating the wheel at the end, the mouth can be opened to any desired extent, and a mouth- or nose-tube used to keep up anæsthesia. In the removal of the upper jaw and in tongue cases this arrangement answers well. Another plan is to insert one of the aluminium mouth-props shown in Fig. 23, p. 260, upon the side next the pillow; this plan is useful in antrum cases. When it is particularly necessary to avoid stretching the lips, the little appliance of Fig. 56 is very useful. It consists of a solid metal prop, of wedge-shaped form, to which is connected

FIG. 57.—The Chloroform-prop in position.

a mouth-tube for the transmission of chloroform vapour from a Junker's inhaler. The surfaces of the prop upon which the teeth rest are covered with lead. The orifice through which the chloroform vapour enters the mouth looks backwards and inwards. Fig. 57 represents the chloroform-prop in position. The stretching of the lips in operations upon the antrum, and the pulling down of the anterior nasal openings in intra-nasa operations, are both avoided by this method of anæsthetising. For cleft palate cases Arbuthnot Lane's gag is often very useful (Fig. 9, p. 187); and Doyen's gag with tube attached is another very useful apparatus for various operations, especially for the removal of tonsils and adenoids (Fig. 10, p. 188).

§ 2. **Open Methods of Chloroformisation**

We have already referred at the commencement of this chapter to Sir James Simpson's simple methods of chloroform administration. To such methods, and in fact to all those in which atmospheric air is allowed to freely mix in unknown proportions with the chloroform vapour, the term "open" is generally applied. It must be remembered, however, that this term is not always strictly appropriate; for it may happen, as when a cup, cone, or cup-shaped handkerchief is used, that the air supply to the patient is not as free as the word "open" would suggest. Ever since the days of Simpson there have been and still are advocates of the simple or open as opposed to the complex or regulating methods of giving chloroform. The late Lord Lister in past years devoted much attention to the administration of chloroform by open methods. Writing in 1861 he recommended that a common towel, as suggested by Sir James Simpson, should be so folded as to make a square of six layers; that an unmeasured quantity of chloroform, sufficient to moisten a surface the size of the palm of the hand, should be poured upon the towel; that the latter should be brought as close to the nose and mouth of the patient as could be comfortably borne; and that more chloroform should be added from time to time. As Snow had drawn attention to the danger of too concentrated a chloroform vapour, and had from numerous experiments fixed the maximum proportion of chloroform vapour which should be inhaled at 5 per cent, Lord Lister was led to estimate experimentally the percentage of vapour given off from the under surface of a cloth moistened with $1\frac{1}{2}$ drachms of chloroform and placed immediately above the face. Snow had stated that as much as 9·5 per cent of vapour might be inhaled from a cloth at 70° F.; but Lord Lister's observations led him to state that the percentage of chloroform vapour breathed from a moistened cloth held close to the face was below 4·5 per cent, and therefore distinctly below the percentage employed by Dr. Snow in his inhaler. When we consider the numerous circumstances which may influence the percentage of vapour inhaled from a cloth moistened with chloroform, we cannot help receiving with some hesitation any statements made as to the percentage breathed in actual practice. This is indeed the weak point in the administration of chloroform from a folded towel. It is true that the risk of too concentrated a vapour may be greatly reduced by providing for the free access of air; but should this precaution be not continuously borne in mind, difficulties may arise. As Lister pointed out, a large surface moistened with chloroform, such as that which may be presented to the patient when employing a folded towel, handkerchief, or large piece of lint, will supply a much higher percentage of chloroform in the inspired air than a smaller surface. This consideration seems to have led him in later years to use the corner of a towel drawn through a safety-pin, or otherwise constricted at a point a few inches from the corner itself, in preference to a folded towel or piece of lint. By using the corner of a towel in this way, a concave mask suitable to the size of the patient is formed, and the anæsthetic is added in small, but not too small, quantities at a time. In this way the greater part of the mask becomes saturated, and the moist condition is maintained till anæsthesia is produced. The little mask or cap should extend from the root of the nose to the point of the chin. It differs in no material point from Skinner's or Esmarch's mask of open shape. From calculations which Lord Lister made, he estimated the volume percentage of chloroform inhaled to be about 1·2—a smaller percentage of vapour than that which he calculated was inhaled when he adopted the folded cloth for administering the anæsthetic.

Of all the open methods, that in which **Skinner's mask** (Fig. 33, p. 335) or **Schimmelbusch's mask** (Fig. 58) and a **drop-bottle** (Fig. 59) are employed gives the best results. The particular mask shown in Fig. 33, p. 335 is a slight modification of Skinner's original pattern. It is covered by a single layer of flannel, and is collapsible. Its transverse wire arc, when adjusted as in the figure, keeps the flannel well away from the face, so that blistering by the contact of liquid chloroform is prevented. In Schimmelbusch's pattern the same result is even more efficiently achieved by a broad but shallow metal gutter which runs all round the edge of the mask where it comes in contact with the face. The drop-bottle is one which the author devised some years ago, and which he finds to be very useful. The chief point about it is that the flow of chloroform can be regulated by the degree to which the tap is turned. When the tap is fully turned on there is a small but continuous stream; when it is less open the stream is not

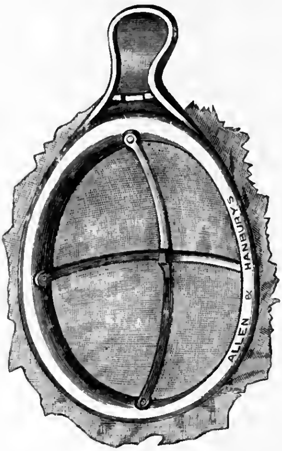

FIG. 58.—Schimmelbusch's Mask.

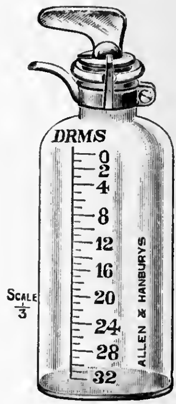

FIG. 59.—The author's Drop-bottle.

quite continuous; when it is nearly closed chloroform can only be obtained by gently shaking the bottle. By this simple arrangement the administrator—who unconsciously acquires a habit of adding chloroform at certain intervals—can adjust the dropping and strength of vapour to the requirements of each case. In anæsthetising an alcoholic man, for example, it may be necessary to allow chloroform to moisten the mask freely; whilst in a susceptible subject a few drops at a time may suffice.

In a series of densimetric observations Waller[1] has shown that Skinner's mask usually supplies to the patient an atmosphere containing from 1 to 2 per cent of chloroform

[1] *Lancet*, 9th July 1904, p. 80.

vapour. In a similar investigation,[1] Mr. W. Legge Symes found that at ordinary room temperatures and with moderate quantities of chloroform, Skinner's mask yielded vapour of fairly uniform concentration between the desirable limits of 1 and 2 per cent, the concentration reaching 3 and 4 per cent when the anæsthetic was copiously applied. Better results were obtained by dropping than by douching chloroform upon the mask. It was found that a fall in the frequency and depth of respiration might lead to the inhalation of dangerously concentrated vapour, even when the amount of chloroform was apparently not excessive. Open fabrics yielded higher percentages than close fabrics.

Some kind of wire frame, such as that of a Schimmelbusch or Skinner's mask, is greatly preferable to the corner of a towel, piece of lint, folded napkin, or other extemporised inhaler, for it is much more manageable, it delivers a more equable vapour, and is far less likely to allow liquid chloroform to redden or blister the skin. Where it is necessary to open the jaws widely with a gag, the ordinary Skinner or Schimmelbusch mask may fail to cover the mouth and nose effectively, especially in male patients. For such cases the frame introduced by E. V. Dunkley is useful. It is essentially similar in construction to the masks mentioned, but its width is much greater than its length; and it adapts itself well to the face from the tip of the nose to the chin, and from the angle of the jaw on one side to that on the other, when the mouth is widely open (Fig. 60).

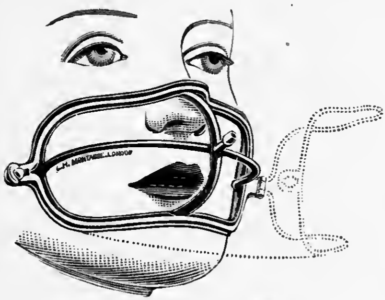

FIG. 60.—Dunkley's Mask.

Fig. 61 shows a Skinner's mask in use.[2] The drop-

[1] "Note on the Concentration of Chloroform Vapour in Air drawn from beneath a Skinner's Mask" (*Lancet*, 9th July 1904, p. 81).

[2] The little bottle-rest shown in the figure is made by Messrs. Mayer and Meltzer. It consists of a flat piece of wood which can be inserted under the pillow, and the projecting end is furnished with a metal holder for the drop-bottle. The author has found this arrangement very useful in hospital practice.

bottle should be adjusted so as to deliver chloroform in successive drops at appropriate intervals according to the type of subject. At the very commencement a rate of one drop per second is generally suitable, but no definite rule can be laid down. The patient should be requested to turn his head to one side, and to breathe quietly through the mouth. Children may be asked to count aloud. The anæsthetist should aim at administering continuously, and without the slightest hurry,

FIG. 61.—Chloroformisation by means of Skinner's Mask.

an equable and mild chloroform vapour. We have good evidence that the heroic plan of administration already discussed is not unattended by risk. But we must not lose sight of the fact that an intermittent and too sparing use of chloroform is also open to objection. Any holding of breath or coughing must be met by a partial withdrawal of the mask. The inhalation should not, however, be wholly discontinued. The administrator should steer between the two extremes, the too rapid and the too slow plans of administration. The various effects produced by chloroform will be specially discussed below (*vide infra* **B.**). If indications of excitement and struggling appear, the anæsthetic should on no account be pushed. The best line of procedure is to lessen the strength of vapour by partly removing the mask and to wipe out the lips with the corner of a towel in order to favour regular respiration. The special risks of the excitement stage will be subsequently considered (pp. 411 and 423). It is of paramount importance to secure a free and unembarrassed air-way, and to hear or feel the respiratory current throughout the administration. The level at which the anæsthesia should be maintained will depend upon circumstances. This part of the subject is also specially dealt with below (*vide infra* **E.**). When once the excitement stage has been passed the anæsthetist will have to guard against over-dosage, auto-asphyxia, and surgical shock, all of which can be prevented, at all events in the vast majority of cases, by a careful study of the phenomena of deep anæsthesia (pp. 78 and 413), by maintaining an absolutely free air-way (p. 257), and by adopting those measures which, as we have seen (p. 70 and Chap. VIII.), are capable of preventing or counteracting the effects produced by surgical procedures upon anæsthetised patients. The author has found that by using the Skinner's mask and drop-bottle described, about $1\frac{1}{2}$ to 2 oz. of chloroform per hour are consumed by adult subjects, *i.e.* about 1 drachm every four or five minutes. Children and weakly patients require less than this; whilst in the case of alcoholic persons much more may be needed. The average given is that for the first hour. Less will be required for the second, and less again for the third, should the operation be of this duration.

§ 3. A comparison of the various methods of administering Chloroform Vapour with Atmospheric Air

Whether we administer chloroform by the regulating or percentage system, or whether we give it by the open or drop-bottle system, our first aim should be the conservation of human life. This was the argument adduced when considering the selection of anæsthetics and methods for routine use, and it applies with equal force in this connection. Given that chloroform has to be employed, the method which is adopted should be one which, in the hands of the particular administrator, is least likely to imperil the patient's safety, always provided, of course, that such a method is quite compatible with the surgical requirements of the case.

Let us first briefly consider the advantages and disadvantages of the regulating or percentage system of administering chloroform. Amongst the advantages claimed for the percentage system may be mentioned: the difficulty of administering an overdose; the infrequency with which excitement and struggling occur; the even character of the anæsthesia; the rarity with which surgical shock takes place; and the lessened tendency to unpleasant after-effects. The disadvantages of the percentage system are chiefly connected with the apparatus which has to be employed. Percentage instruments often impede respiration by face-piece pressure (p. 106); they are only capable of being used in certain cases; they are often complex in construction, cumbersome in form, and liable to get out of order; their use occasionally involves considerable waste of time during the induction period; the anæsthesia they produce is often inconveniently light in type;[1] they deliver, when shaken or moved, irregular percentages of vapour; they are by no means convenient when, as in hospital practice, the patients anæsthetised by their means have to be moved from the anæsthetising room to the theatre; they frequently occupy too large a share of the administrator's attention; they often become fouled by blood; and they are incapable of sterilisation. Moreover, as pointed out above, some of them depend for their chloroform intake upon the patient's own respiration—a state of things which is open to considerable objection in certain cases.

The advantages of the open system of chloroformisation are: that by its use the administrator can easily keep the patient's air-way free from obstruction; that it is simple; that the mask and drop-bottle are exceedingly convenient and portable; that when once experience has been gained with these appliances it is possible to present to the patient dilute and more or less equable atmospheres of chloroform; that anæsthesia is quickly induced; and that the chloroform mask

[1] See, for example, *Clinical Journal*, 31st March 1898, p. 363.

when soiled may be thoroughly cleansed and sterilised. The disadvantages of the system are: that unless the anæsthetist be experienced and watchful, irregularities in vapour percentage may favour the occurrence of excitement, struggling, embarrassed breathing, surgical shock, and overdosage.

Such being the respective advantages and disadvantages of the two systems of chloroformisation, let us next discuss what may be termed the personal factor in the administration of this anæsthetic. Medical students who, under the present schemes of instruction, are taught to administer chloroform, should certainly be taught methods which they will be able to apply in practice. To insist upon their administering this anæsthetic by means of some comparatively complicated instrument which will, with rare exceptions, be unattainable in practice, is obviously unfair both to themselves as students and to the general public with whom they will subsequently have to deal. It is doubtless an excellent thing to allow all those who are receiving instruction to see in action and even to use chloroform inhalers capable of delivering definite percentages of vapour. By such means one of the great principles of chloroformisation—that of the continuous administration of a dilute and definite vapour—may be readily demonstrated. But as such students will almost certainly be called upon in after-life to administer chloroform in circumstances in which only the simplest methods of anæsthetisation will be applicable, and as there are in general surgery many cases in which, even though a regulating inhaler be at hand, chloroform can only be given by these simple methods, students certainly have a right to expect from their instructors tuition in open chloroformisation. House surgeons and other resident hospital officers who, amongst their other duties, have to administer anæsthetics for general surgical operations, and who have presumably learnt the principles of chloroform-giving, employ, as a rule, the methods which are in vogue in the institutions with which they are associated. There is much to be said, however, for the adoption by such officers of methods by which it is difficult or impossible to administer an overdose of chloroform. Hospital work is often carried on at high pressure, whilst the surgeon in charge of a case not unfrequently prescribes the anæsthetic to be used. There is, therefore, special need for caution during this period in the educational career of a medical man, and the comparatively inexperienced house surgeon or house physician who is requested by the surgeon to give chloroform and chloroform only to all or certain of his patients, will probably be taking the wisest course in using a quantitative method. In the case of the practitioner who is only occasionally called upon to administer chloroform, and who has had no special experience in this department of practice, more satisfactory results will probably be obtained by the employment of some simple method with which he is familiar than by the use of a special inhaler with which he is unacquainted. Fortunately, cases are becoming less and less frequent in which comparatively inexperienced practitioners administer chloroform for general surgical operations.

Let us finally consider the question of chloroform administration by those who have acquired considerable practice. All experienced anæsthetists know that by avoiding chloroform as an agent for *completely inducing* anæsthesia and by employing it only for *maintaining* anæsthesia its risks are so greatly reduced that there is little or no point in using a percentage inhaler. Were it necessary, in the cases requiring chloroform, to induce full anæsthesia with this agent the position would be changed, and it might be imperative in the interests of the patient to use percentage methods invariably. But by the employment of one or other of the excellent induction methods at our disposal (Chap. XVI. p. 498), and by continuing the administration by means of chloroform, the open system carefully applied fulfils all requirements. The greater the experience which has been acquired in the simple or open methods the more equable will be the chloroform atmosphere presented to the patient; in other words, the more nearly will the administration approach to that which is possible with a regulating inhaler.

From the above considerations it is clear that there is no one method of chloroform-giving which is applicable under all circumstances. In addition to the numerous points to which reference has just been made there are others which may also influence the administrator in his choice of a method.

Thus, in the surgery of the upper air-passages Junker's apparatus has become an almost indispensable instrument. Again, when portability is of vital importance, as in time of war, the simplest and lightest appliance for chloroform administration must be chosen.

SECTION II.—THE ADMINISTRATION OF CHLOROFORM VAPOUR WITH OXYGEN AND ATMOSPHERIC AIR

The system of administering mixtures of chloroform vapour and oxygen was introduced by Neudörfer of Vienna, who is stated to have excluded all air during his administrations.[1] Neudörfer's method has been modified by employing a Junker's inhaler, to the hand-bellows of which a bag containing oxygen is fixed, so that this gas instead of atmospheric air is pumped through the chloroform on its way to the face-piece. By this plan certain proportions of air are necessarily breathed with the oxygen.

For some time past an ingenious apparatus has been in use upon the Continent, and particularly in Paris, for the quantitative administration of chloroform vapour, oxygen, and air. It is known as the **Roth-Dräger-Guglielminetti apparatus.**[2] It consists of (1) an oxygen cylinder; to which is attached (2) an arrangement for reducing the oxygen pressure from 150 kgm. to ·5 kgm., and for registering the flow of the gas; (3) a contrivance by which so many drops of chloroform per minute may be added to the oxygen current; (4) a bag of gold-beater's skin for receiving the mixture of chloroform vapour and oxygen; and (5) an inhaling tube and face-piece, the latter being provided with an air-slot and valves, so that air may be breathed with the oxygen and chloroform vapour. During the induction stage, which generally takes about 8 or 10 minutes, chloroform is added to the oxygen stream at about the rate of 60 drops per minute for men and 50 drops per minute for women. For the subsequent maintenance of anæsthesia, 30, 25, or even 15 drops per minute will generally

[1] See *Brit. Med. Journ.*, 25th January 1896; *Centralbl. f. Chir.* No. 35, 1887; *Centralbl. f. klin. Med.* No. 35, 1888; *Colonial Med. Journ.*, June 1896.

[2] See Dr. J. Lucas-Championnière's description in the *Journ. de Médecine et de Chirurgie*, 10th January 1905, p. 35.

suffice. According to Dr. Championnière, the mixture that is usually breathed by the patient is one consisting of 2 parts of air and 1 part of chloroform-laden oxygen. Although there is no arrangement in the apparatus by which the chloroform percentage may be ascertained, this percentage is undoubtedly well within the limits of safety.[1] The advantages claimed for the apparatus are that by its use excitement is greatly reduced; that syncope never occurs; that patients retain their natural colour; and that recovery takes place quickly. By the kindness of Dr. Guglielminetti the author tried this apparatus at St. George's Hospital. Although an exceedingly interesting and ingenious instrument, it is, as will be gathered from the description, far too complicated for general use.

It is doubtful whether there is any great advantage in the addition of oxygen to atmospheric air during the administration of chloroform, save perhaps in cases in which much respiratory difficulty is present, and in these cases the use of any tightly-fitting inhaling apparatus would almost certainly neutralise the theoretical advantages of using oxygen. For patients who are so desperately ill that the administration of oxygen is considered advisable, it is probable that the open ether method will answer the requirements better than any other system of anæsthetisation. (See Illust. Case, No. 12, p. 337.)

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF CHLOROFORM

First Degree or Stage.—When chloroform vapour is well diluted, *i.e.* when it is present in air to the extent of about ·5 per cent, the mixture has a sweetish taste and is pleasant to inhale. With a carefully adjusted and dilute vapour there are, as a rule, no objective phenomena during this stage. With concentrated chloroform atmospheres, however, breath-holding, cough, resistance, and other indications of unpleasant sensations will occur. The more dilute the vapour, the longer will this stage last. Feelings of numbness

[1] Dr. Waller and Mr. W. L. Symes (*Brit. Med. Journ.*, 24th December 1904, p. 1687).

and "tingling" in the extremities and fulness in the head are not uncommon, whilst some patients complain of the increased cardiac action which the anæsthetic produces.

Second Degree or Stage.—Incoherent talk, gesticulation and even shouting may be met with in excitable or alcoholic subjects. Muscular patients who have led outdoor lives and smoked to excess, as well as those who are hysterical, may give trouble, not only by struggling and attempting to rise into the sitting posture, but by suspension of breathing. Muscular spasm of the jaws, neck, chest, and abdomen should be treated with great caution, air being freely allowed during and immediately after the embarrassed breathing incidental to such a spasm. Any clonic movements should be specially noted; they are generally of an asphyxial nature during this stage, and indicate a need for more air (p. 74). The frequency with which temporary respiratory embarrassment occurs in vigorous patients, particularly when chloroform vapour is administered to them in irregular percentages, probably explains the numerous fatalities which have occurred in such patients early in the administration. There is little doubt that when all the muscles of the body are contracted and the respiratory movements are, for the moment, suspended, the right heart is somewhat over-full; and air is needed in order to allow of that free pulmonary circulation which is essential for the escape of the imprisoned blood to the left cavities. The continuous inhalation of a dilute vapour will generally ensure an absence of most, if not all, of the excitement phenomena here mentioned. In those cases in which no suspension of breathing occurs, the natural respiration simply becomes somewhat augmented, and in many subjects softly snoring, as the third degree of anæsthesia approaches.

It occasionally happens that, instead of respiration undergoing the usual changes above described, it becomes inaudible and almost imperceptible, although the patient is not fully anæsthetised. With this shallow breathing there is often slight pallor and some pulse depression, whilst the corneæ may be nearly or quite insensitive to touch. To this state, which has been termed "false anæsthesia," reference has already been made (pp. 66 and 79). Its true physiology is not thoroughly understood. It is most likely to appear when chloroform has been given sparingly and irregularly. It is least likely to manifest itself when some stimulus to respiration is in operation, as when an equable and properly adjusted vapour is being given, an apparatus involving increased respiratory work is being used, or some surgical procedure is in progress. There is a close connection between false anæsthesia and the act of vomiting; but what the precise connection is it is difficult to say. When, as frequently happens, this condition culminates in vomiting, the pallor and shallow breathing quickly disappear. It is not improbable that the chief factor in false anæsthesia is blood accumulation within the splanchnic area dependent partly upon vaso-motor effects produced by the anæsthetic and partly upon emotional disturbances before the administration. If this view be correct it is easy to explain the pallor, the lessened cerebral blood-supply, and the shallow breathing, and to see how a vicious circle may become established, the shallow breathing—originally caused by the abnormal accumulation of blood within the abdomen—favouring this accumulation by reason of lessened diaphragmatic movements. Whether the act of vomiting is in any way dependent upon an abnormal exudation of gastric fluids caused by this blood accumulation within the abdominal veins, it is difficult to say. The treatment of false chloroform anæsthesia is discussed on p. 539, where illustrative cases will be found.

In some instances loud palatal stertor comes on early in the second stage, and should be disregarded, as it does not indicate the profound anæsthesia which it might suggest. In others, the respiration is very deep and hurried throughout, but such cases are exceptional.

The state of the circulation will depend upon many circumstances. In most cases there is a tendency, as surgical anæsthesia approaches, for the initial acceleration of the pulse to subside, and for a soft regular pulse of about the normal rate to become established. Any marked interference with free respiration, such as that which arises from tonic spasm of the respiratory muscles during the period of excitement, reflex laryngeal closure, etc., will quickly modify the rate, regularity, and fulness of the pulse. The half-asphyxiated condition into which a patient passes when his air-way is intermittently occluded, or rendered temporarily useless for respiratory purposes in consequence of muscular spasm, rapidly tends to embarrass the heart's action during the inhalation of chloroform. Provided that all respiratory embarrassment be avoided and that the cornea be sensitive to touch, the circulation will remain perfectly satisfactory during this stage.

The pupils during this part of the administration are, as a general rule, mobile and more or less dilated. They react sluggishly, or possibly not at all, to light. As the third stage of anæsthesia approaches they usually show a marked tendency to become smaller and more fixed. The author finds, in notes taken by the late Dr. Sheppard, 53 cases in which the pupil was observed before full chloroform anæsthesia was established. In 26 it was "moderately dilated" or "dilated"; in 15 "moderately contracted"; and in 12 "contracted."

The ocular globes may, as the result of tonic or clonic spasm, move in this or that direction, or nystagmus may be present. According to Warner, the movements in this stage are always co-ordinate. Dastre states that somewhat later the globes may follow a light passed backwards and forwards before them.

Third Degree or Stage.—The **respiration** is usually regular, softly snoring, and somewhat quicker and deeper than normal.[1] It usually takes place through the nasal channels (see p. 535). Generally speaking, more of the anæsthetic will produce a louder stertor, and less will lead to quieter breathing. In some cases there is loud stertor, whilst in others the respiration, though satisfactorily performed, is almost or wholly inaudible. Plethoric, flabby, and stout subjects are more liable to stertor than others, and in these patients it may be necessary to push the jaw well forwards in order to maintain free respiration (see p. 554). A crowing laryngeal sound may accompany inspiration in some cases. This sound has already been discussed (p. 54). The presence of even a

[1] All varieties of respiration may be met with. The author has, for example, notes of a case in which, during deep anæsthesia for an abdominal section, the patient—a female aged forty-two, of average appearance—breathed at the rate of 62 per minute.

trace of corneal reflex indicates that the nervous mechanism of breathing is active, and that, provided no obstruction exist, respiration will proceed satisfactorily.

Much discussion has arisen concerning the **circulation** in deep chloroformisation. When the administration has been conducted in the proper manner, and temporary cardiac depression consequent upon too sparing a use of chloroform, or upon respiratory embarrassment, has been avoided, the administrator will find that the pulse becomes slower and steadier than it was during the first and second stages, and that it settles down to about the normal rate, or even less than this.[1] Dr. Leonard Hill finds that his "sphygmometer" indicates a rapid and persistent fall of blood-pressure to the extent of about $\frac{1}{3}$ or $\frac{1}{5}$ of the normal. Much will, of course, depend upon the posture of the patient (pp. 238 *et seq.*). Moreover, as already indicated (p. 251), one of the commonest causes of pulse depression during surgical anæsthesia is surgical shock.

During deep chloroform anæsthesia the **eyeballs** are either fixed, or one may be fixed whilst the other slowly moves, or both may slowly move. The loss of associated movements was pointed out by Dr. F. Warner[2] in 1877, and generally indicates a considerable and proper depth of narcosis. The author has, however, met with a case in which, even though the patient was deeply and properly anæsthetised, co-ordinated movements persisted. The eyeballs, if fixed, are usually in the horizontal plane.

The state of the **pupil** during the stage of surgical

[1] An abnormally slow pulse may point to an unnecessarily deep anæsthesia. The author has frequently found that when the pulse is very slow less of the anæsthetic will increase its rate. A normally slow pulse will still be slow during deep anæsthesia. The author has known a pulse of 46 per min. throughout the administration, the patient, a woman of 75 years, normally possessing a slow pulse. In 20 patients in whom Kappeler compared the pulse of deep chloroform anæsthesia with that observed a few hours before the administration when the patient was not excited, he found a diminution in rate of from 4 to 30 beats per min. Thus, in a child of 12, a pulse of 80 fell to 50; in a man of 60, a pulse of 60 fell to 52; and in a man of 56, a pulse of 72 fell to 48. The reader is referred to Kappeler's book for sphygmographic tracings of the pulse under chloroform. The Glasgow Anæsthetics Committee of the British Medical Association found that of 50 cases in which chloroform was given for surgical operations, 5 presented a pulse of 64, 7 of 60, 5 of 56, and 1 of 48 during deep anæsthesia (*Brit. Med. Journ.*, 18th Dec. 1888, p. 958).

[2] *Brit. Med. Journ.*, 10th March 1877, p. 292.

anæsthesia under chloroform has given rise to much comment, and is well worthy of careful study. Budin and Coyne were the first to direct particular attention to the pupil as a guide. All observers agree that it is usually contracted in full chloroform anæsthesia, but the term "moderately contracted" seems to be more appropriate. By taking measurements with a pupillometer, the author finds that in most cases the pupil measures from 2 to 3 mm. in diameter, usually being about $2\frac{1}{2}$ mm. The average chloroform pupil is therefore decidedly smaller than the average ether pupil. The two resemble one another, however, in that they behave in a similar manner in response to an increase or decrease in the quantity of the anæsthetic given, and in that they are similarly affected by light and other stimuli. As will be pointed out below, the pupil is often of great service as a guide in chloroform administration. Occasionally it remains widely dilated throughout this stage, even though the anæsthetic has not been pushed too far. This is often the case during operations upon cervical glands. A very small pupil (1 or $1\frac{1}{2}$ mm.) in most cases indicates a light anæsthesia; whilst a somewhat dilated pupil ($3\frac{1}{2}$ to $4\frac{1}{2}$ mm.) usually means either that the anæsthesia is very profound, or more probably that the dilatation is of reflex origin, and is associated with a somewhat light anæsthesia. Very little reliance is to be placed upon the pupil as a guide until after the operation has been in progress some little while, and until the administrator has satisfied himself as to its behaviour with more and with less of the anæsthetic.[1]

It is generally taught that the **lid-reflex** should be absent; but a very slight tendency towards lid closure when the cornea is lightly touched with the finger may generally be allowed to manifest itself during surgical operations.

The **muscular phenomena** of deep chloroform anæsthesia are of interest particularly in relation to the onset of dangerous symptoms. Speaking generally we may say that as the third stage approaches, any muscular rigidity which may have been present during the second stage gradually subsides and general

[1] For further information see an interesting article in the *Lancet*, vol. i., 1875, p. 550. Also a paper by Dr. H. J. Neilson, *Brit. Med. Journ.*, 20th July and 1st Oct. 1887.

muscular relaxation takes place. Sometimes, however, certain parts of the muscular system remain rigid, or rigidity may be reflexly provoked by surgical interference. Occasionally it is exceedingly difficult—indeed it may be unsafe—to abolish all reflex muscular spasm (p. 546). The most interesting of the muscular phenomena of the third stage of chloroform anæsthesia are certain clonic movements which may occasionally be observed early in that stage. These have already been referred to when discussing the muscular phenomena of anæsthesia in general (p. 74). Thus, there may be "piano-playing" movements of the fingers. Or there may be slow co-ordinated movements of the fingers, hands, and arms. Or, again, there may be jerky adductor movements of both upper extremities, the arms being spasmodically drawn to the sides at irregular intervals, apparently by spasm of the pectoral muscles. The last-mentioned arm movements may be associated with a widely dilated pupil and shallow breathing. It is probable that these clonic contractions of the pectoral muscles should be regarded as the result of impulses originating in the respiratory centre; they are significant of slight asphyxia. The jerky movements referred to are most conspicuous when the arms are hanging down on each side of the operating table. It is important to bear in mind that, if an operation be in progress when these clonic muscular phenomena are observed, the mistake may easily be committed of regarding them as indicating a return to the second degree of anæsthesia, and the administrator may continue the administration with the object of securing greater quietude. Such a mistake may readily lead to grave consequences. Muscular phenomena of the type just described are generally referable to a somewhat inadequate air-supply. They should be taken to indicate a need for more air and less anæsthetic. Should they be associated with an insensitive cornea, the anæsthetic should be completely withdrawn till they have subsided.

The **colour of the face and lips** will depend upon the circumstances. As a general rule it is somewhat paler than normal. If the respiration be deep, quick, and unembarrassed there may be little or no alteration in the normal colour: if it be obstructed, a degree of duskiness, varying with the extent of the obstruction, the patient's natural colour, and the efficiency of the circulation at the moment of observation, will result. There is far less tendency to pallor in the Trendelenburg than in the horizontal posture. Should surgical shock arise, the colour of the face and lips will necessarily be modified.

Mucus and **saliva** are rarely secreted in sufficient quantities to attract attention.

The **bodily temperature**, according to Kappeler, who made many observations on this subject, is invariably reduced during the administration of chloroform. In thirty cases in which operations were performed the reduction varied from 0·02° C. to 1·1° C., the average being 0·59° C. These result are confirmed by Davis (see p. 236).

C. THE CHLOROFORMISATION OF INFANTS AND CHILDREN

The upper air-passages of these subjects are so sensitive that the administration of an anæsthetic, even though carefully conducted, generally causes the breath to be "held" both before and after unconsciousness. Should crying occur, a rapid intake of anæsthetic will ensue, and care must be exercised when employing choloform to allow a very free admixture of air during this stage. It is a good plan, in fact, to withdraw the chloroform altogether directly the crying *begins* to show signs of abatement. If the administration be conducted without thus anticipating an excessive intake, an unnecessary, or even a dangerous, degree of anæsthesia may ensue. Guthrie[1] points out that after the crying stage infants often pass into chloroform "sleep," with contracted pupils, convergent eyeballs, insensitive corneæ, and flaccid limbs. This false anæsthesia has been already alluded to (pp. 66, 79, and 411). For illustrative cases and treatment see p. 540. The peripheral circulation of infants is often difficult of appreciation under chloroform, especially if the extremities be normally cold. It is important, however, to keep a finger upon the radial pulse in all cases in which there is any doubt as to the depth of anæsthesia. The author has frequently found the

[1] *Clinical Journ.*, 7th April 1897, p. 377.

circulation to be a valuable guide, especially in hare-lip and cleft-palate cases. In addition to the pulse quickly showing evidences of depression when too much chloroform is given, it also soon becomes feeble, or disappears, as the result of embarrassed or arrested breathing.

It is not a very difficult matter when the circumstances are favourable to **anæsthetise infants and children during sleep.**[1] The author has successfully accomplished this in several cases; but he has not always succeeded. A drop or two of chloroform should be placed upon a Skinner's mask held five or six inches from the child's face; a drop or two more should be added from time to time and the mask very gradually brought closer. In this way it is generally possible to increase the strength of the chloroform atmosphere so gradually that beyond an occasional act of swallowing, or possibly a little unconscious restlessness, the patient passes into deep chloroform anæsthesia without the slightest break separating the natural from the artificial sleep. The reader is referred to p. 247 for remarks upon the transference of children, when under anæsthetics, from the bed to the operating table.

D. THE VARIOUS FACTORS WHICH, INDIVIDUALLY OR COLLECTIVELY, MAY LEAD TO DANGEROUS OR FATAL SYMPTOMS DURING CHLOROFORMISATION: POST-MORTEM APPEARANCES IN FATAL CASES

(a) *Introductory Remarks*

In preceding pages we have discussed what has been termed the experimental physiology of chloroform anæsthesia, and have considered, in some detail, the effects produced upon the mammalian organism by toxic quantities of this anæsthetic. We have now to study the numerous clinical facts which may throw light upon the important problem of how and why chloroform accidents occur, and to see to what extent these facts harmonise with those to which attention has already been directed. At the first blush it might seem that we possess, in

[1] See *Lancet*, vol. ii., 1872, pp. 514, 594. See also a letter from Dr. John G. Marshall in *Lancet*, 24th April 1886.

the vast number of physiological researches which have been conducted, a key to the correct interpretation and understanding of all the chloroform accidents in practice. This, however, is not so. If we wish to obtain a clear insight into the various modes of onset of dangerous or fatal symptoms during the use of chloroform in surgical practice, it is of paramount importance that we should bear in mind that, *in a considerable proportion of accidents, overdosage, in the usual sense of the term, is conspicuously absent.* It would, of course, be wrong to ignore the influence or to minimise the risks of the presence within the circulation of dangerous quantities of this anæsthetic. All the author would point out in this connection is that we have before us not merely the simple question of chloroform toxæmia, but other questions whose importance is equally as great or even greater.

The Committee appointed by the Royal Medical and Chirurgical Society in 1864, to inquire into the uses and effects of chloroform, collected and analysed 109 fatal cases which occurred in the years 1848-1863 inclusive. Kappeler, in his valuable work on anæsthetics, gives a similar analysis of 101 additional fatalities, which have been recorded in various journals as having taken place in the years 1865-1876 inclusive. These two collections together include 210 fatalities. Of the 210 cases referred to, the period at which death occurred is stated in 75 cases only, *and in* 68 *of these* (*i.e. in* 90 *per cent*) *the patients died within the first fifteen minutes.* Comte[1] collected 232 deaths under chloroform. In 224 of these the time at which the fatal event occurred was mentioned; and of these 224 deaths, 112 (50 per cent) took place before anæsthesia was complete. The author finds 130 chloroform deaths reported in the *Lancet* and *British Medical Journal* from 1880 to 1889 inclusive; and of these, 54 took place either before the operation or during some short and trivial operation.

Before proceeding to consider the various factors which may individually or collectively lead to fatal symptoms under chloroform it is necessary that we should fully appreciate what happens in arrested breathing arising independently of the

[1] Quoted by Julliard, *L'Éther, est-il préférable au chloroforme?*

presence within the circulation of a toxic substance such as chloroform. Sudden spasm of the glottis, for example, will destroy life within a few minutes, the exact duration of the fatal phenomena varying with the special circumstances present. The arrested breathing leads to a stasis of the pulmonary circulation, to over-distension of the right heart, and finally to failure of this organ, partly from its inability to propel blood through the lungs, and partly from poisoning of its muscular substance by the non-oxygenated blood. In patients with a vigorous and normal circulation several minutes may elapse before cardiac action finally ceases; whilst in very feeble persons and in those with valvular or other cardiac affections the heart may fail almost immediately after cessation of breathing. In some cases, indeed, death comes about so suddenly as to suggest the supervention of cardio-inhibitory or vaso-motor effects as the immediate sequel of arrested breathing. We have seen in a preceding chapter that one of the most important physiological phenomena of chloroform inhalation is cardiac dilatation, and that this dilatation arises independently of all asphyxia; in other words, from the direct action of chloroform upon the heart muscle. Supposing, then, that just before the full effects of chloroform have been produced, and whilst corneal reflex is still present, any intercurrent asphyxial state arises, not only do we have to reckon with pulmonary engorgement, secondary distension of the right heart, and the widespread effects of non-oxygenated blood, but we have an additional factor to deal with, viz. the continuous absorption of the incarcerated anæsthetic within the lungs and the action of this upon the already embarrassed cardiac muscle. It is hence easy to see that in certain patients a slight asphyxial strain under chloroform may cause sudden and fatal syncope, and that, even in the most vigorous subjects, death may take place within a minute or two of respiratory arrest.

(*b*) *The Possible Factors*

1. **The Factor of Susceptibility: Idiosyncrasy.**—The susceptibility of the particular patient to chloroform is a

matter of some importance in any inquiry concerning the supervention of dangerous symptoms. Billroth, Robert, and other competent authorities believed that, as with morphine iodide of potassium, and other drugs, patients may display very marked susceptibility to chloroform, and may thus exhibit toxic symptoms from doses which, in the vast majority of cases, would have no such deleterious effects. This is quite in accordance with the author's own experience. (See Illustrative Cases, Nos. 38, 39.) In addition to the recognised differences which exist between alcoholic, neurotic, plethoric, and well-developed patients on the one hand, and temperate, placid, anæmic, and feebly developed persons on the other, one is often surprised by the very large or very small quantity of chloroform, as the case may be, which some particular patient requires; and, unless the administrator take the measure, so to speak, of each patient, he will be liable, when dealing with an extremely susceptible subject, to overstep the boundaries of safety. The term "chloroform idiosyncrasy" may properly be applied to cases displaying this abnormal susceptibility. Whether the "status lymphaticus" should be regarded as disposing to chloroform idiosyncrasy is a doubtful point, discussed in Chapter VI. (p. 155).

2. **The Psychical Factor.**—Prior to the introduction of anæsthetics it was not an unknown event for death to take place from fright immediately before an operation;[1] and it is quite possible that in a few instances profound psychical disturbance has led to a fatal result during the first few inhalations of chloroform vapour, *i.e.* before the patient has become unconscious. But there is good reason to believe that the frequency of this so-called "fright-syncope" at the very outset of chloroformisation has been greatly exaggerated; for there are

[1] An interesting case is recorded by Kappeler (*Anæsthetica*, p. 118). The patient was a man, æt. 40; an amputation had to be performed. He was so feeble that chloroform was not considered advisable: a pretence was made to administer the agent by means of a cloth, but no chloroform was used. After four inspirations, respiration and circulation suddenly ceased: the man was dead. This case is interesting because it is in the highest degree probable that a similar result would have attended the use of chloroform, and that the death of the patient would have been attributed to the drug. Sir James Simpson refers to a somewhat similar case, in which a patient suddenly expired during the shaving of the groin, preparatory to an operation for hernia. Other instances of the kind might be quoted. See *Sir James Simpson's Works* vol. ii. p. 144.

few, if any, accounts of similar accidents under nitrous oxide or ether. Admitting, for the sake of argument, that emotional states may, *per se*, prove fatal during the first two or three breaths of an anæsthetic, it is difficult to see why such fatalities should arise almost exclusively under the agent we are now considering. It is, in fact, in the highest degree probable that in many of the cases of supposed "death from fright under chloroform" the fatal symptoms have arisen during *unconsciousness*, and that influences far more potent than the mental disturbance itself have been at work. Errors as to the precise moment at which consciousness disappears under an anæsthetic are very common. The author has, for example, often heard the medical attendant of a patient address to the latter words of comfort or reassurance when to his certain knowledge consciousness has been in abeyance for several minutes, and the patient has been nearly or quite ready for the operation. It is, therefore, by no means improbable that in many of the recorded cases the patients have died whilst absolutely unconscious of their surroundings, *i.e.* in the second rather than in the first degree of anæsthesia. We must not, however, lose sight of the possibility of psychical influences, originating during the conscious stage, prejudicially affecting the patient after consciousness has been destroyed. A complicated machine may be set going by a touch; but when once it has been started, it may be impossible to correct any faulty working which may manifest itself in time to prevent the machine coming to a standstill. So it may be with the half-anæsthetised subject. Emotional influences arising during consciousness often set in action certain respiratory and circulatory mechanisms which still remain in operation even when all consciousness has been abolished; and these mechanisms may, under certain favouring conditions, bring about complete arrest of breathing, which, in the case of chloroform, may be rapidly followed by cardiac paralysis. It is a matter of everyday experience that highly nervous, emotional, and apprehensive subjects present peculiar and almost characteristic symptoms during and after the induction of anæsthesia; and so marked may be the initial modifications in respiration and circulation that the subsequent course of the anæsthesia may be altered. It would seem, indeed, that acute mental disquietude, with its concomitant pallor or lividity, its feeble and quick pulse, and its restricted or excessive breathing, may introduce into the administration an element which may, especially in patients of certain physical types, lead to the development of dangerous or even fatal symptoms when all consciousness has been annulled by the anæsthetic. With nitrous oxide and with ether psychical disturbances are of practically no importance; but this is not so with chloroform. With the last-named anæsthetic, hampered and suspended breathing is, for reasons elsewhere considered, specially dangerous.

3. **The Factor of the Local Action of Chloroform Vapour.**—The question of the possibility of reflex cardiac inhibition taking place as the result of the contact of chloroform vapour with the mucous membrane of the air-passages has already been discussed (p. 118). Whilst many eminent physiologists are inclined to regard vapour concentration as likely to inhibit cardiac action, clinical observers are by no means agreed as to this explanation of certain early chloroform accidents. A strong chloroform vapour may doubtless induce "holding the breath," coughing, swallowing, and other symptoms; and it is quite conceivable that suspension of breathing thus arising may, in certain subjects, be dangerous (*vide infra*). It is highly probable, however, that the chances of accident from this source are very remote. A concentrated atmosphere is dangerous, not so much because of its power of reflexly arresting breathing, but because it may, if it reach the lungs, lead to toxic symptoms.

4. **The Factor of Intercurrent Asphyxia arising from other causes than the posture or the surgical procedure.**—When excitement and struggling are well marked, as they frequently are in alcoholic, nervous, or vigorous subjects, respiration may become embarrassed in the course of the general muscular contraction, and secondary syncope may arise. It is a significant fact that healthy and muscular patients are more liable than feeble subjects to display dangerous symptoms during the induction of chloroform anæsthesia. Children, old persons, and those patients who have become weakened by disease generally take chloroform

well. Other things being equal, the greater the vigour of the patient, the greater will be the tendency to the development of muscular spasm, not only of the extremities but also of the respiratory muscles, masseters, muscles of the floor of the mouth, larynx, and other parts. It is in this way that chloroform kills the perfectly healthy subject; the fatal symptoms commencing when the corneæ are sensitive, and the circulation failing before the anæsthetist can re-establish breathing. It was in this way that many of the fatalities recorded by Snow doubtless took place, although a totally different explanation of them was at the time advanced. The "spluttering at the mouth," lividity, and other indications of impaired respiration were, in fact, erroneously regarded as signs of primary heart-failure.

It is by no means uncommon for clonic muscular phenomena to arise during the second and third stages of chloroformisation, more particularly in cases in which the breathing is somewhat obstructed by stertor, jaw-spasm, laryngeal closure, etc. In some of the recorded cases of this kind patients are reported to have had a "fit," or to have been attacked by "epileptiform convulsions."[1] As already indicated, when discussing the muscular phenomena met with under chloroform (pp. 74 and 416) clonic contractions often indicate the approach of danger. The author has on three occasions known cessation of respiration to be preceded by these movements.

Spasmodic tongue retraction causing stertor, and laryngeal spasm causing stridor may arise during chloroformisation and lead to dangerous symptoms (p. 554). Although usually dependent upon surgical stimuli, they may occur from other causes. Lord Lister drew attention to the importance of recognising laryngeal obstruction under chloroform. He stated[2] that a falling together or spasm of the arytæno-epiglottidean folds not unfrequently took place, and that almost noiseless obstruction to respiration might thus result. He regarded this condition as indicating a dangerous depth of narcosis; and

[1] See Lord Lister's account of a chloroform fatality (*System of Surgery*, vol. iii. 3rd edition, p. 615). In this case the respiration ceased during an epileptiform spasm. A similar condition has been observed under ether (*Brit. Med. Journ.*, 2nd May 1885, p. 887).

[2] *System of Surgery*, vol. iii. 3rd edition, p. 604.

there can be no doubt that when symptoms of laryngeal closure commence, they may often be relieved by giving less anæsthetic.[1] In certain cases laryngeal spasm may be relieved by pulling the jaw away from the sternum with the fingers close to the hyoid in the soft tissues of the neck. This stretches the folds and counteracts their spasm. Some patients become dangerously stertorous in deep anæsthesia, whilst in others the presence of mucus, saliva, vomited matters, blood, etc., within the upper air-passages may introduce an asphyxial element into the administration.

5. **The Factor of Posture.**—This factor has been already fully considered (p. 238).

6. **The Factor of the Surgical Procedure.**—We have already studied in Chapter III. (pp. 65 to 71) the physiology of the reflex respiratory and reflex circulatory phenomena of anæsthesia; we have in the same chapter discussed the circumstances in which the three varieties of surgical shock—the respiratory, the circulatory, and the composite—may arise; and in Chapter VIII. (p. 250 *et seq.*) we have brought to a clinical focus the whole question of the influences of surgical procedures upon anæsthetised patients. Given that the power of appreciating pain has been destroyed by chloroform, whilst full anæsthesia has not yet been secured, the commencement or the continuance of a surgical procedure is far more likely to disturb respiration than circulation—to bring about respiratory rather than circulatory shock. The time-honoured theory that dangerous or fatal *circulatory* shock is specially likely to take place from surgical interference during light chloroform anæsthesia must now be abandoned. Were reflex cardiac arrest readily produced by commencing operations during light anæsthesia, deaths would be far more common than they are; for thousands of patients are annually operated upon whilst only partially anæsthetised by chloroform. That

[1] Snow does not seem to have recognised this particular danger, though he states (*op. cit.* p. 234) that, at a trial in France, M. Devergie urged that chloroform was capable of causing death by closure of the glottis. See also a pamphlet by Dr. Black, *Chloroform: How shall we ensure Safety in its Administration?* London, 1855. Dr. Black believed that all accidents under chloroform are due to closure of the glottis, but attributed this closure to the pungency of the vapour. More recently Ricord, Yvonneau, and Stanelli have dwelt upon the dangers of epiglottic and laryngeal obstruction under chloroform.

there is little or no risk from this quarter is shown by the fact that some surgeons habitually perform certain operations during light anæsthesia. It is, moreover, a matter of common observation that in very exhausted patients—the subjects who might be considered to be eminently liable to reflex cardiac arrest—it is safer to operate with a light than with a deep anæsthesia. When, however, full chloroform narcosis has been produced, surgical shock of a circulatory type is by no means uncommon, particularly during certain operations to which reference has been made, and it is this form of shock which is of special interest to the anæsthetist. It is of special interest partly because its symptoms, which are almost identical with those of true chloroform syncope, are frequently mistaken for the latter condition, and partly because its treatment, preventive and immediate, is largely in the hands of the anæsthetist. That many deaths have taken place from the commencement of operations before full chloroform anæsthesia has been produced there can be no doubt; but it is submitted that such deaths have come about from respiratory and not from circulatory shock. On the other hand, it is certain that in a considerable number of the cases in which alarming or even fatal symptoms have arisen in patients deeply anæsthetised by chloroform, the surgical procedure in hand has been the immediate or exciting cause.

7. **The Factor of Vomiting.**—Incipient or actual vomiting during or immediately after chloroformisation may be attended by respiratory or circulatory depression which, under certain circumstances, may prove fatal.[1] The factor of vomiting would appear to admit of consideration from three different points of view. (i.) It has already been pointed out (p. 412) that pallor, feebleness of pulse, dilated pupils, and shallow breathing are not uncommon early in chloroformisation, particularly when this anæsthetic has been given sparingly, and that these phenomena, which are often erroneously ascribed to the toxic action of the anæsthetic, often indicate the approach of vomiting. In some cases, and particularly when undigested food is present in

[1] As illustrative cases see *Brit. Med. Journ.*, 21st July 1888, p. 135, and 14th June 1884, p. 1162. There is also a well-recorded example in the *Lancet*, 3rd March 1900, p. 632.

the stomach, very eccentric circulatory symptoms may occur. Whilst it is doubtful whether the circulatory disturbance here indicated ever culminates in fatal syncope without some other factor coming into play, it is in the highest degree probable that this disturbance has often paved the way, so to speak, for the lethal operation of some other factor, *e.g.* slight intercurrent asphyxia. (ii.) During the act of vomiting, laryngeal closure generally occurs, and suspension of breathing, sometimes of considerable duration, takes place. Whilst this suspension may be of little moment in a patient whose general condition is satisfactory, it may be hazardous in weakly subjects, and in those whose heart muscle is unable to withstand even a slight strain. The writer has on more than one occasion known the violent diaphragmatic contraction and the laryngeal closure incidental to vomiting to arrest completely the radial pulse of a patient suffering from moderate shock at the conclusion of a severe operation, the explanation doubtless being that which is advanced on p. 59. It is in the highest degree probable that in most of the cases in which fatal vomiting-syncope has been recorded, death has taken place from intercurrent respiratory interference prejudicially affecting cardiac action. (iii.) The entry of vomited fluids into the larynx and trachea is elsewhere discussed (p. 569).

8. **The Factor of Simple Chloroform Toxæmia: Fourth Degree or Stage in the Action of Chloroform.**—Simple chloroform toxæmia, that is to say, the condition produced simply and solely by the presence within the blood of dangerous quantities of chloroform, is probably less common in practice than is generally believed. It is here contended that in the majority of cases usually regarded as belonging to this group some obstruction to the free entry or exit of air is present. As already indicated (p. 39), simple chloroform overdosage is very easily obtained in the physiological laboratory, owing to the common practice in experimental work of introducing chloroform vapour directly into the trachea. In man, however, this method of anæsthetisation is comparatively rare. When the air-passages are free, when there is no obstacle to the action of the respiratory pump, and when the percentage

of chloroform in the air breathed by the patient is beyond the limits to which reference has already been made (pp. 107) certain symptoms will make their appearance.[1] When studying the experimental physiology of this subject we saw (p. 111 *et seq.*) that the usual sequence of events in chloroform toxæmia is (1) progressive fall of blood-pressure; (2) paralytic failure of respiration; and (3) cessation of the heart's action. In practice it will be found that the symptoms of simple chloroform overdosage will depend upon the degree of vapour concentration, the rate and amplitude of respiration, and the state of the pulmonary blood stream. Should the administration have been conducted rapidly, recklessly, and without any attempt to limit vapour concentration, the patient may so suddenly die that all attempts to recognise the order in which the fatal symptoms have arisen may be completely futile. But when toxic quantities of chloroform are more gradually given, the symptoms displayed by the patient will be more capable of differentiation and analysis; although the period which elapses before such symptoms culminate in total cessation of respiration and peripheral circulation will still be very short. In most cases of overdosage complete corneal insensibility, dusky pallor, dilatation of pupils, separation of eyelids, feebleness, slowness, irregularity, or imperceptibility of pulse, and shallow breathing immediately precede respiratory arrest. Just as respiration ceases, the pupils often return to medium size. As already pointed out (p. 111) cessation of breathing in chloroform toxæmia is largely dependent upon circulatory depression. As regards the pulse disappearance in simple chloroform overdosage it must be borne in mind that this phenomenon by no means necessarily implies cardiac arrest. In the great majority of cases the disappearance of the radial pulse simply indicates an extremely low blood-pressure. In those cases in which the symptoms of overdosage come about comparatively gradually the indications of the colour, pupils, and pulse are of great value, for if they be observed in time, respiratory arrest may often be averted. Cardiac inhibition and vaso-motor paralysis from the direct

[1] One of the best reported cases illustrating the mode of death from a concentrated chloroform atmosphere is to be found in the *Brit. Med. Journ.*, 25th October 1884, p. 811.

effects of chloroform upon these centres are among the final phenomena of chloroform toxæmia.

Some observers have contended that chloroform is essentially a respiratory poison, and that the circulatory element in chloroform toxæmia should therefore be disregarded. As we have seen, however, respiration does not fail till the arterial pressure has greatly fallen. It is perfectly true that respiration generally, if not invariably, ceases before the heart muscle is finally paralysed, and that in chloroform administration attention should *primarily* be directed to the respiration, but the clinical fact remains that in all threatening or fatal conditions dependent upon simple chloroform toxæmia circulatory depression is the characteristic and dangerous symptom. Death usually takes place not from our inability to restore respiration but from our helplessness in reinstating cardiac action.

9. **Pathological Factors.**—The various pathological states which may favour or determine respiratory or circulatory arrest under chloroform are discussed in Chapter VI. (pp. 159 and 165).

10. **Conclusions.**—From the foregoing considerations, four important deductions are permissible :—

(1) Dangerous or fatal symptoms during chloroformisation may take place either during light or during deep chloroform anæsthesia, *i.e.* when the cornea is sensitive or when it is insensitive to touch.

(2) Simple chloroform toxæmia, *i.e.* the state produced by overdosage apart from any intercurrent respiratory or circulatory derangement, is comparatively rare in practice.

(3) Dangerous or fatal symptoms may arise from the operation of one or more of the factors to which reference has been made.

(4) Most of the factors referred to have this in common —they are capable of bringing about in the semi-anæsthetised or fully anæsthetised patient, a state of intercurrent respiratory embarrassment or asphyxia, the risks of which are greater under chloroform than under other anæsthetics, and it is this intercurrent asphyxial state which is the key, so to speak, to the true nature and treatment of the great majority of the chloroform accidents of practice.

(c) *Post-Mortem Appearances*

It is a mistake to suppose that there is anything characteristic in the post-mortem appearances of patients who have died during chloroformisation; nor is it possible, as a general rule, to state precisely from these appearances what has been the particular mode of death in any given case. The conditions found post-mortem naturally vary considerably, according to the stage of anæsthesia at which death has occurred, the presence or absence of intercurrent asphyxia, the state of the patient's heart and lungs prior to the administration, the nature of the remedial measures adopted, and other circumstances. Thus, in non-asphyxial cases in which the patient has died from an overdose of the drug gradually administered, the heart is usually found flaccid and empty, the lungs crepitant and not markedly engorged, and the brain not congested.[1] In deaths due largely to intercurrent asphyxia, general venous engorgement, distension of the right cavities of the heart, pulmonary congestion, and partial or complete emptiness of the left cardiac chambers will probably be met with. But when death results from some slight asphyxial complication in patients with feeble, fatty, or dilated hearts, there may be few if any of the ordinary evidences of asphyxia, owing to the right heart failing before any marked distension of its cavities has occurred. It is seldom possible to detect any odour of chloroform in the tissues. As regards the post-mortem appearances in animals killed by chloroform Snow stated, as the result of several observations, that the right cavities of the heart were always found filled with blood, whether they died suddenly or gradually, the left cavities never containing more than a small quantity of this fluid. The Royal Medical and Chirurgical Committee also found in their experiments that, as a general rule, all cavities contained more than the normal quantity of blood, but that the right contained more than the left. In the majority of cases the lungs were of a bright florid colour, and in many instances there were sub-pleural ecchymoses. The liver, spleen, and portal system were, as a

[1] For typical case see Snow, *op. cit.* p. 170.

rule, congested, and the superficial brain vessels contained more blood than usual. MacWilliam[1] states that from experimental observations on animals it is impossible to say from the post-mortem condition of the heart whether death under chloroform has been due to primary cardiac failure or to asphyxia. In numerous animals killed by chloroform Schäfer and Scharlieb[2] found that the post-mortem appearances were similar to those caused by asphyxia from air-deprivation, even though artificial respiration by perflation had been performed during the introduction of the anæsthetic. In all the animals examined by these observers immediately after death, all the heart cavities (sometimes excepting the left auricle) were found distended with blood, the right auricle and great veins of the thorax being specially engorged. "The left ventricle always contained a considerable quantity of blood, but rather less than the right ventricle. If, however, the examination were made some little time after death, the left ventricle was always found empty and firmly contracted." The pulmonary arteries were greatly distended with blood. Externally the lungs appeared healthy. In six out of twenty cases frothy bronchial mucus was noted. The abdominal viscera, and particularly the liver, were markedly congested. With regard to the amount of blood found within the lungs after death, Leonard Hill points out that much will depend upon whether respiratory arrest has taken place during inspiration or during expiration. He found that if the trachea were clamped at the height of a forcible expiration, there might be only $\frac{1}{60}$th of the weight of the blood of the body in the lungs; whereas, if the clamping were effected during a deep inspiration, there might be as much as $\frac{1}{10}$th. Kunkel[3] states that the heart killed by chloroform always stops in diastole, the contraction of the left ventricle, which has been so often reported, being simply a post-mortem appearance. Guthrie notes that Cooper, Binz, and Pritchard agree in their statements as to the blood after death under chloroform presenting a peculiar dark cherry colour, and being more fluid than usual.

[1] *Brit. Med. Journ.*, 5th April 1902.
[2] *Trans. Roy. Soc. of Edinburgh*, vol. xli. Part II. (No. 12).
[3] *Handbuch der Toxikologie*, Part I., 1899, p. 449.

Fränkel[1] states that the kidneys, liver, and heart are found homogeneously altered and their specific elements affected by cloudy swelling (coagulation-necrosis), whilst deposits of pigment are met with in the renal tubules and in the hepatic parenchyma. Ajello[2] also describes degenerative changes in the liver, kidneys, heart, and blood-vessels in four cases of fatal chloroform syncope.

We have elsewhere referred (pp. 158 and 421) to the fact that in a large number of the chloroform fatalities of recent years the condition known as lymphatism has been detected; but it is doubtful whether we are justified in ascribing all the accidents to the presence of this condition.

E. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

In deciding upon the depth of anæsthesia that should be maintained in any given case, the type and susceptibility of the subject, the nature of the operation, and the particular stage which the operation has reached must be taken into account. Much, too, will depend upon whether or not the patient has been subjected to preliminary narcotisation (p. 265). Another factor to be considered is the kind of induction which has been practised. Patients seem to be much more tolerant of a comparatively light anæsthesia when the nervous centres have been gradually invaded, than when irregular chloroform atmospheres have been employed. It may be accepted as a workable proposition that in the great majority of cases a trifling and almost imperceptible degree of lid-reflex in one or both eyes—preferably in one only—together with regular, softly snoring breathing may be taken as indicating the proper level of chloroform anæsthesia, though, as will be gathered from the subjoined remarks, no definite rules can be laid down which will apply in every case.

In order to maintain a proper level of anæsthesia the anæsthetist must be guided by—

[1] *Virchow's Archiv*, 129 (1893), 2 Heft.
[2] *Annals of Surgery*, March 1897.

(*a*) The respiration;
(*b*) The occurrence of swallowing movements;
(*c*) The lid-reflex;
(*d*) The state of the pupil;
(*e*) The strength and frequency of the pulse;
(*f*) The colour of the face and lips; and
(*g*) Rigidity of muscles in various parts of the body (hands, neck, etc.).

(*a*) When once a perfectly quiet or softly snoring form of regular automatic **respiration** has been secured, an endeavour should be made to maintain it. The withdrawal of the anæsthetic will lead to tranquil and inaudible breathing; whilst an increased quantity of chloroform will, in most cases, favour the continuance of (or even augment) the existing snoring. Unfortunately it is sometimes impossible to obtain this desirable state of respiration; and the administrator may be in doubt as to the depth of the narcosis. Other guides, however, are usually available, and by the assistance of an act of deglutition, a smaller pupil, slight lid-reflex, an expiratory noise, or a tendency towards tonic muscular spasm, the administrator becomes aware that the tranquil respiration is indicative of too light an anæsthesia. The conversion of inaudible into audible breathing and the advantages of such a conversion are considered on p. 539. As a general rule we may say that—

Inaudible breathing,
A good colour and pulse,
A moderately contracted or contracted pupil, and
A slight degree of lid-reflex,

collectively indicate the need for rather more of the anæsthetic; and, as the result of increasing the quantity of chloroform, respiration will quickly become audible and deeper. If the patient has been allowed to come so far out of a deep anæsthesia that the inaudible breathing is associated with pallor, feeble pulse, dilated pupil with active lid-reflex, and other indications of approaching vomiting, it may be difficult, or even impossible, to secure a deeper and noisier breathing till vomiting has taken place.

As regards the shallow and somewhat hampered breathing of deep chloroform narcosis, it may be said that this type of breathing must be carefully watched. It may be necessary in certain cases, and in certain subjects, to proceed to this degree of narcosis in order to avoid reflex difficulties. The breathing in question is usually associated with the absence of lid-reflex, slight duskiness of the features, and a rather slow regular pulse, which, although not so full as in a less profound anæsthesia, is not markedly feeble. When the patient has passed into this condition the administrator will find that by briskly rubbing the face and lips with a dry towel he can generally maintain efficient respiration. It must be remembered, however, that when chloroform is pushed to this degree *and the patient is horizontal*, intra-abdominal manipulations and certain other procedures are very liable to be attended by shock. The shallow breathing of profound chloroform anæsthesia is doubtless due in no small measure to reduced blood pressure.

High-pitched crowing breathing (inspiratory) is of considerable interest in connection with the administration of chloroform (*vide supra*, **D**. 4, p. 424). Generally speaking, profound anæsthesia prevents its occurrence. In certain operations, however, it is practically impossible to obviate the laryngeal stridor, even by very large doses of chloroform. Such are operative proceedings involving traction on the recto-vaginal and recto-vesical planes of tissue; in many of these operations laryngeal stridor is unavoidable. Should it tend to culminate in total occlusion of the air-tract, the best plan is to suspend the anæsthetic and to proceed as recommended on p. 557.

The manner in which expiration is performed will often assist the administrator, and the author cannot do better than quote from Dr. Sheppard's notes, in which he finds the following interesting remarks:—

It would be useful and of practical importance to get at the exact series of signs connected with the expirations, as they are of great use in the conduct of many cases. They seem to occur pretty regularly in the following order, as the patient emerges from the deep regular breathing of chloroform narcosis. (1) Slight holding of the breath before the commencement of expiration, soon developing a definite catch. (2) The expiratory catch becoming definitely vocal, but only occurring at the commencement of expiration. (3) Definite expiratory phonation, the vocalisation continuing all through the expiration, or it may still retain the character of (2), and develop into straining. (4) Movements of tongue and lips, etc., producing inarticulate mumbling. (5) Definite articulate phonation.

Cheyne-Stokes breathing, of a more or less typical character, is not uncommon under chloroform, especially in exhausted and senile subjects. Although it is generally met with in profound anæsthesia, the author has known it arise when a slight conjunctival reflex was present. He has notes of one case in which it disappeared directly the A.C.E. mixture was substituted for chloroform.

(*b*) All that has been said with regard to the occurrence of **swallowing movements** under ether will apply in the present instance (p. 371). A very slight wrinkling of the forehead is of similar import.

(*c*) The **lid-reflex** is an exceedingly useful indication of the depth of anæsthesia. In order that its value as a guide may be fully appreciated, the remarks already made (p. 371) must be borne in mind. The chief point concerning this reflex under chloroform is that, after the commencement of the operation, a very slight degree of lid-closure in response to a gentle touch of the cornea may usually be permitted to manifest itself without the occurrence of the inconvenient accompaniments of light anæsthesia. This particularly applies to cases in which a slow and gradual induction has taken place. Considerable experience, however, will be necessary before it is possible to work with such a fine adjustment of anæsthesia. Old people, feeble subjects, and those who have lost much blood, or have become otherwise exhausted by the operation, may usually be allowed to exhibit distinct lid-reflex towards the close of an administration. On the other hand, there are certain cases in which both corneæ must be kept insensitive throughout, otherwise inconvenient phenomena, such as retching, coughing, and abdominal rigidity, may occur.

(*d*) The average chloroform **pupil** is smaller than the average ether pupil. It is a useful sign when others are equivocal; as, for example, when the breathing is shallow and the lid-reflex absent. Moreover, when from the nature of the operation the breathing is deprived of its usual characters, variations in the size of the pupil in response to more or less of the anæsthetic may be very significant.

The following extract from Dr. Sheppard's notes is worth quoting in this connection:—

> The dilated pupil is an excellent guide as an indication of returning consciousness, but one must be *very certain* that the patient is recovering and not actually becoming more deeply narcotised. . . . On administering a fresh dose, 5 to 10 minims, of chloroform to a child with the dilated pupil of recovery, the effect is *not immediate*, but after five or six inspirations after cessation of chloroform, the pupil becomes contracted. The postponed operation of chloroform is better seen in this way than in any other. Hence the danger of even 5 minims to a child with the dilated pupil of deep narcosis.

Speaking generally, a dilated pupil *plus* conjunctival reflex calls for more chloroform; whereas a dilated pupil *minus* conjunctival reflex should be taken to mean immediate withdrawal of the anæsthetic till the pupil has become smaller, or the conjunctiva slightly sensitive.

(*e*) Like the pupil, the **pulse** is of value as a corroborative guide. Some writers, and particularly those of the Scotch school, have laid so much stress upon the importance of *never* feeling the pulse that one is naturally tempted to inquire upon what grounds such teaching is based. It is contended (1) that the whole attention should be directed to the respiration; and (2) that, as the pulse may become feeble immediately prior to vomiting, the anæsthetist may be misled, and suspend the administration, instead of continuing it. It is perfectly true, and even self-evident, that if the administrator's powers of observation are so limited that he cannot trust himself to watch more than *one* sign, that sign should be the respiration. But let us hope that such anæsthetists are rare. It is certainly possible for an administrator of average ability to attend to many other indications than the breathing, without relaxing the almost automatic vigilance which he should obviously bestow upon that function. With reference to the pulse-feebleness, which often marks the approach of vomiting, there is surely no harm in knowing that such feebleness is present (although, as will be pointed out below, pulse indications are of little or no value so long as the cornea is sensitive), nor is there any objection to treating this feebleness, when it is obviously connected with light anæsthesia, by an increase of the anæsthetic. When corneal reflex has been destroyed, and deep anæsthesia produced, the slow, regular pulse of chloroform narcosis generally becomes established, and it is from this point onwards that the peripheral circulation will afford valuable indications as to the depth of anæsthesia. A slow feeble pulse will, for example, call for less chloroform; and this treatment will soon be followed by better circulation. In rare cases it is impossible to proceed beyond a certain point without inducing an intermittent action of the heart; and such cases must be similarly treated. The administrator should occasionally consult the temporal, facial, or superior coronary pulse. If he can feel a fair pulse in either of the two former arteries, he may depend upon the wrist-pulse being better than he anticipates. The author has often been unable to distinguish a temporal pulse, although the radial was at the moment of fair volume. He finds that the superior coronary pulse is very accessible during chloroform administration. Furthermore, the pulse is a most valuable indicator of surgical shock; and should this be apprehended, the very slightest weakening of the pulse demands the substitution of open ether for chloroform.

One can quite understand the Scotch school and the Hyderabad Commission denying the value of pulse indications, for, according to their views, the administration should not be continued beyond the point at which corneal reflex disappears. The author fully admits that if a case can be conducted without destroying this reflex, and if breathing be unembarrassed and free, the pulse may be disregarded, except in cases of impending or actual surgical shock. But, as pointed out above, it is necessary in many cases to conduct the administration without allowing even a trace of lid-reflex to be present; and it is in such cases that the pulse gives valuable indications as to the depth of anæsthesia.

(*f*) **The colour of the face and lips** is generally of value as a guide, although too much reliance must not be placed upon it *per se* (see p. 416). Thus the author has notes of cases in which the wrist-pulse has vanished (from surgical causes) without any immediate alteration in colour; and it is a matter of everyday experience that a good peripheral circulation may coexist with pallor and lividity. A dusky or cyanotic aspect of the face is probably always indicative of deficient blood oxygenation and of the need of more air. Cyanosis in the *extremities* may, however, depend upon vascular stasis induced by surgical shock, and may coexist with a fairly florid complexion. Pallor occurring during a light anæsthesia generally means the approach of vomiting.

F. AFTER-EFFECTS

Provided that attention has been paid to the preparation of the patient (pp. 225 and 263), that the administration has been conducted either by some regulating inhaler or in such a way as to maintain an equable and properly adjusted state of anæsthesia, and that the administration has not been unduly prolonged, recovery from chloroform is generally unattended by after-affects. At the same time it must be remembered that there are certain subjects who even after a comparatively short administration invariably suffer from nausea and vomiting.

At the close of a chloroform administration patients generally pass into a heavy sleep. Although the percentage of patients attacked by vomiting after chloroform is comparatively small, the vomiting which occurs is not uncommonly of a persistent and severe type.[1]

Hiccough is uncommon after chloroform. A case is recorded, however, by Dr. J. H. Donnell,[2] in which it lasted ten days, in spite of the most varied and assiduous treatment.

Pallor and pulselessness may occur during recovery, particularly in association with nausea or vomiting. Such cases, however, are rare. Provided that the pulse is satisfactory at

[1] Snow and Clover reckoned that vomiting took place in 1 out of 7 chloroform administrations. They probably refer to severe cases only—not to transient vomiting. Mr. Rigden found vomiting to occur in 32 per cent of his cases, and of these it was noted as troublesome in 16 per cent. Snow refers to a case in which vomiting after chloroform proved fatal; and others have occurred.

[2] *Lancet*, 2nd Dec. 1905, p. 1619.

the conclusion of the administration, and that the breathing remains unembarrassed, there is no special liability to circulatory depression after chloroform. The author has known faintness to arise after an operation for the removal of tonsils and adenoids. The patient—a boy—had fully regained consciousness when the symptoms supervened. As the customary vomiting had not taken place after the operation the attack was probably vagal—due to the presence of swallowed blood within the stomach.

As **bronchial and pulmonary sequelæ** are far more frequently met with after ether than after chloroform, their incidence has been specially considered in Chapter XI. (p. 375 *et seq.*). The infrequency of these complications after chloroform is doubtless owing to the fact that mucus is rarely secreted in excessive quantities under this anæsthetic. Respiratory sequelæ may, however, occur when blood, vomited fluid, or septic matter has passed into the larynx, trachea, or bronchi during chloroform anæsthesia. It is in this way that septic pneumonia sometimes comes on after operations within or about the upper-air passages. Such sequelæ can hardly be fairly attributed to the action of the anæsthetic. Bronchial and pulmonary affections, more immediately due to the effects of chloroform vapour, may, however, occur in predisposed patients who have been subjected to prolonged anæsthetisation. Thus, the author has notes of a case in which an elderly gentleman, the subject of chronic bronchitis, died from acute bronchial catarrh after the administration of chloroform for upwards of an hour and a half for the operation of lithotrity. The respiratory sequelæ of ether-chloroform sequences are more frequently dependent upon the former than upon the latter anæsthetic.

Transitory **mental and muscular excitement,** similar to that referred to when dealing with the after-effects of ether, may occur in hysterical and neurotic subjects. **Delirium** lasting three days has been recorded.[1] **Loss of speech**[2] (attributed to

[1] See a case (*Ether as an Anæsthetic*, by Josiah de Zouche, M.D., of Otago), in which delirium lasting three days, in a boy of fourteen, was met with after chloroform inhalation. It is quite conceivable that this may have been a case of what is now termed "acid intoxication" (p. 634).

[2] *Lancet*, vol. i., 1870, p. 553. Chloroform was given for tooth extraction. The aphasia lasted five weeks.

cerebral hæmorrhage) has also supervened after chloroformisation. Persons who have had **maniacal attacks** before the administration of chloroform have been known to suffer from a recurrence of their mental disorder after the use of this anæsthetic.[1] Paralysis and coma due to **cerebral hæmorrhage** are rare.

There is no good evidence that **renal complications** of any importance are liable to follow the use of chloroform unless, indeed, we regard the peculiar condition known as **post-anæsthetic acidosis** (p. 634) as dependent upon renal inadequacy. According to Sokoloff[2] and Ajello,[3] temporary **albuminuria** is very common after the administration of this anæsthetic, and in patients with pre-existing albuminuria some increase in albumin may be produced. Thiem and Fischer[4] state that the urine may show traces of chloroform—the drug existing in an unchanged state—even twelve days after the administration.

Lastly, it would seem that the administration of chloroform may, under certain circumstances, be followed by so-called "**acid intoxication**" or "**acidosis.**" Reference has already been made in Chap. III. (p. 84) to the fact that certain **degenerative visceral changes** of a fatty character may, at all events in the lower animals, follow prolonged or repeated chloroformisation. According to many observers there is a close connection between these two conditions. This subject, however, will be fully discussed in Chap. XXI.

G. ILLUSTRATIVE CASES

The following cases will illustrate many of the points to which reference has been made in this chapter.

It may be well, in the first place, to cite a couple of normal cases.

Illustrative, Case, No. 16.—F. æt. 19. Tall: well developed: has a flabby appearance, especially about lower part of face: full lips: no

[1] See Sir G. H. Savage, *Brit. Med. Journ.*, 3rd Dec. 1887, p. 1199.
[2] *Wratsch.* St. Petersburg, No. 4, 1891.
[3] *Annals of Surgery*, March 1897.
[4] *Deutsche med. Zeitung*, Berlin, 2nd Dec. 1889. Also Dérémaux and Minet, *L'Écho Médical*, June 1904.

thoracic abnormality discoverable. Removal of caseous cervical glands. Administration lasted one hour. Skinner's inhaler. Breath held a little at first. No excitement or struggling. Respiration became gradually deeper and rougher. After 5-6 min. colour good, respiration regular and rough, pulse good and rather slow, pupils 3 mm., conjunctiva barely sensitive. Operation commenced. No reflex movement. Respiration continuing satisfactory, a slight lid-reflex was permitted, but when this reflex became at all marked more chloroform was given. Less chloroform caused the breathing to become quieter, the pupils smaller, and the lid-reflex more marked. More chloroform had exactly opposite effects. After stitches had been put in, and the anæsthetic withdrawn, the pupils enlarged, and the conjunctiva became very sensitive. In a second or two retching commenced, and a little mucus was ejected. Pupils then gradually became smaller.

Illustrative Case, No. 17.—Florid, intelligent girl, æt. 16 ; average height, and slim build : pupils 4½ mm. Removal of glands from neck. Administration lasted 46 min. Skinner's inhaler.

2.5 P.M. Administration commenced.

2.9 ,, Muttering and swallowing.

2.11 ,, Pupils 4 mm.

2.12 ,, Ready for operation. Pupils 3-3½ mm. Snoring, regular breathing. No movement with incision, but pupils went to 4 mm.

2.14 ,, Less stertor. More chloroform. Stertor more marked and pupils 5 mm. No lid-reflex. Very good colour and pulse.

2.16 ,, Pupils as before. Less chloroform seemed to make pupils, if anything, larger.

2.19 ,, Pupils still 5 mm.: doubtfully active to light. Florid colour.

2.20 ,, An act of deglutition. Pupils 4 mm. with lid-reflex. Increased quantity of chloroform now produces larger pupil.

2.23 ,, A slight cough. Pupils 4½ mm. Increased the chloroform. Cough subdued. Slight crowing with inspiration. Chloroform again increased to subdue it. Pupils 5 mm. No lid-reflex. Pulse good and regular, about 75.

2.28 ,, Whilst glands were being removed from neighbourhood of carotid and jugular the respiration became shallow, and pulse a trifle less full. This shallow respiration lasted 2-3 mins. Lips briskly rubbed, with good results. Pupils 4½ mm. No lid-reflex.

2.32 ,, Respiration stertorous and deeper again. Good pulse; doubtful lid-reflex.

2.35 ,, Pupils 3½ mm. No lid-reflex. A little moaning with expiration, and less stertor. Chloroform increased, with result of deeper stertor and larger pupil. (Obvious influence of more chloroform in causing a larger pupil.)

2.36 P.M. Slight cough and crowing breathing. Anæsthetic increased.

2.38 „ Pulse very good.

2.41 „ Pupils 4 mm. Doubtful lid-reflex. Administration continued. Pupils $4\frac{1}{2}$ mm.

2.42 „ Quieter respiration. Slight expiratory moan suggestive of impending cough, and pupils became $3\frac{1}{2}$ mm. Stitches now put in, and pupils at once dilated to 5 mm.

2.51 „ Administration discontinued.

The administration of chloroform to a patient suffering from dyspnœa due to an enlarged thyroid is exemplified in the following case. As the dyspnœa did not increase under the anæsthetic, but actually diminished, it was probably the outcome of laryngeal spasm rather than of pressure upon the trachea.

Illustrative Case, No. 18.—M. æt. 17. Tall: slim: full lips: rather nervous. Occasional distress in breathing. Prefers to be propped up somewhat. Dry sounds throughout both lungs. Occasional moist cough. Audible stridor on taking a deep breath. Large thyroid growth. Operation 10 A.M.: dry, bright, cold morning. Chloroform on lint. Administration, 1 hour 13 minutes; operation, 1 hour 5 minutes. Two oz. of chloroform used. Head and shoulders slightly raised. Anæsthetic cautiously given. Barely audible breathing became audible (both inspiration and expiration). Thought it best, as breathing seemed to be getting rather laboured, not to push anæsthetic. Long incision. Very slight reflex movement, and deeper breathing. Occasional swallowing. Rather free hæmorrhage. Breathing grew quieter, *although no part of growth yet removed.* Thyroid now removed. Pulse got slightly feeble during extraction of left lobe, which was deeply seated; it then improved. Conjunctival reflex often present, with large (5 mm.) pupil; more chloroform abolished reflex and made pupil smaller (3 or $2\frac{1}{2}$ mm.). Pupils hence good guide. Face rather pale. No movement throughout. During removal of left lobe, transient inspiratory stridor of high pitch, but no cyanosis. No flattening of trachea discovered.

The following case seems to indicate that the presence or absence of the lid-reflex may be dependent upon the nature of the operation in progress (see p. 66).

Illustrative Case, No. 19.—F. æt. about 50. Febrile. Spare build. Heart-sounds and chest expansion good. Exploration and evacuation of a tubercular kidney. Skinner's mask. Administration lasted 1 hour 20 minutes. An abdominal incision was first made, and subsequently a lumbar opening. After about one hour the patient's condition was as follows, the operator working at the lumbar opening :—Pupils contracted : lid-reflex either completely absent or only present in the slightest degree : pulse good, regular, about 72 : respiration quiet. The operator now passed in sponges through the abdominal wound, with the *immediate* result that the breathing became deep, the colour more florid, and so much lid-reflex appeared that the lids tightly contracted when the conjunctiva was touched. We might say that this patient was, at the moment referred to, sufficiently anæsthetised for the lumbar operation, but not for the abdominal. The interest of the case, however, lies in the reappearance of the lid-reflex as the direct result of a particular stimulus, namely, interference with the peritoneum.

CHAPTER XIII

THE ADMINISTRATION OF ETHYL CHLORIDE

The reader is referred to Chap. I., p. 10, for a short account of the early use of this anæsthetic; to Chap. II., p. 32 for information as to its chemical and physical properties; to Chap. IV., p. 127, for a brief epitome of the somewhat scanty experimental work which has been done concerning its action; to Chap. VI. for the indications, so far as the state of the patient is concerned, for its employment in practice; and to Chap. VII. for a description of the particular surgical procedures which may be appropriately performed under its influence.

It will be convenient in the present chapter to consider the administration of ethyl chloride *per se.*[1] The use of mixtures containing this anæsthetic will be discussed in Chap. XV.; and of sequences with ethyl chloride as one of the anæsthetics in Chap. XVI.

Ethyl chloride resembles nitrous oxide in the rapidity with which it abolishes consciousness; it is similar to ether in that its effects are intensified when moderate air-limitation is practised during its administration; and it is like chloroform in the suddenness with which it may kill when administered in an overdose. The problem before the anæsthetist is to use the drug in such a way that its advantages are secured whilst its disadvantages are avoided. Like other anæsthetics it has its special place or position in the field of modern surgery,

[1] For much interesting and valuable information concerning ethyl chloride the author is indebted to the writings of his friend Dr. W. J. McCardie, Anæsthetist to the General, Dental, and Ear and Throat Hospitals, Birmingham. See *Lancet*, 4th April 1903, p. 952; and *Lancet*, 7th Oct. 1905, p. 1023.

and it is a mistake to attempt to obtain with it results which can only be properly obtained with other agents.

From Koenig's experiments (p. 127), and from the clinical observations made by the author (p. 446) it would seem that, as with other anæsthetics, the effects produced by ethyl chloride primarily depend upon its vapour tension in the atmosphere presented to the patient. But the last-named observations tend to show that there is no definite percentage mixture the continuous inhalation of which will produce satisfactory results. With percentage mixtures sufficiently weak to be respirable without discomfort, an unsatisfactory type of anæsthesia results; whilst with mixtures sufficiently concentrated to produce narcosis satisfactorily, the initial sensations are so unpleasant as to proscribe such initial vapour concentration. So far as our present knowledge goes it would seem that, with this anæsthetic, the best results are to be obtained by a rational and cautious use of the close system of anæsthetisation (p. 44), the vapour being gradually but increasingly added to the to-and-fro respiratory current till anæsthesia takes place. We have yet to ascertain whether any special concentration of vapour should be aimed at, after consciousness has been destroyed, and if so, how such concentration may best be secured. We have also to determine by future research the relative influences of the oxygen limitation and the carbonic acid retention which are involved in close methods of administering ethyl chloride.

A. APPARATUS AND METHODS OF ADMINISTRATION

Experience has shown that if ethyl chloride be administered to adults from an open or semi-open inhaler, *e.g.* from a Skinner's mask, so that a low vapour percentage results, large quantities of the drug will be needed to bring about even partial anæsthesia. In many cases indeed an excited state is produced, and the third degree of anæsthetisation is not attained. On the other hand, children may usually be satisfactorily anæsthetised by a semi-open inhaler although, even in their case, a close method, carefully applied, is usually preferable.

In the course of a clinical investigation conducted by the author at St. George's Hospital a few years ago[1] ethyl chloride was administered by numerous methods.

It was found that when **percentage mixtures** of its vapour and air, of sufficient strength to produce anæsthesia, were administered through valves (p. 44), *i.e.* without re-breathing, swallowing movements and inconvenient apnœic pauses in respiration occurred, and that the results were unsatisfactory so far as the type of anæsthesia was concerned. The mixtures thus administered contained 9·3, 11·9, and 12 per cent of ethyl chloride vapour respectively. With this plan of anæsthetisation suffocative sensations were sometimes experienced at the commencement of inhalation. Definite quantities of certain percentage mixtures of ethyl chloride vapour and air were next administered in such a way that (1) about one-half of the quantity taken was breathed by the valvular plan when (2) the remainder was breathed by the close system. The percentages used in this method were 9·8 and 14·1. The results, however, were not satisfactory. In the next series of cases (1) a definite ethyl chloride and air mixture diluted with a further unknown quantity of air was breathed by the valvular system; (2) the pure mixture, of known composition, was then breathed by the same system; and finally (3) the remainder of the mixture was breathed by the close system. The mixtures employed contained 10·5, 10·7, 13·9 and 24·4 per cent respectively. Again the results were unsatisfactory, swallowing and shallow breathing characterising the administrations. It was clear from the results obtained up to this point that the continuous inhalation, without re-breathing, of mixtures of ethyl chloride and atmospheric air produced effects of an inconvenient type. A measured quantity (5 c.c.) of the drug was next administered by means of a Clover's ether inhaler, to which was attached a bag containing 10,000 c.c. of air, the expirations being at first allowed to escape but being retained during the second half of the administration. By this plan it was possible to increase the strength of vapour so gradually that there was little or no discomfort to the patient, and a better general result followed. Thirteen administrations were next conducted by the simple plan of allowing the patient to start to re-breathe the 3000 c.c. of air in a bag; and then gradually diffusing therein a measured amount of ethyl chloride contained in a small glass tube connected with the bottom of the bag. The results were now very satisfactory. The shallow breathing, apnœic pauses, and unpleasant after-effects which had characterised the uniform percentage cases failed to manifest themselves, and a good type of anæsthesia was produced. In 9 of these cases 5 c.c. of ethyl chloride were used; in one case 4 c.c.; and in 3 cases 3 c.c. It is difficult or impossible to say what percentages of ethyl chloride vapour actually reached the lungs in each of these administrations. Taking one of the 5 c.c. cases and assuming, for the sake of argument, the room temperature to have been 18·8° C.[2] and the administration

[1] For a full account of this investigation see *Lancet*, 19th Nov. 1904, p. 1408.

[2] The day was warm, but no record was made of the actual room temperature in this batch of administrations.

to have been conducted slightly differently, *i.e.* in such a way that the *whole* of the ethyl chloride was vaporised before the mixture was admitted to the patient's air-passages, the percentage of the mixture entering the naso-oral cavities during the first inspiration would have been about 35·5, this percentage falling with each subsequent inspiration by reason of the increasing dilution of the bag-contents with the gases originally present in the air-passages. But under the conditions which obtained the percentage composition of the earlier inspirations was obviously far below 35·5 owing to the ethyl chloride having been *gradually* added to the to-and-fro current. As regards the percentage composition of the later inspirations this would, as in the hypothetical case just considered, be also considerably below 35·5 owing to a similar and progressive dilution of the bag contents. Even if we knew the percentages of ethyl chloride actually reaching the lungs in methods of this kind we should still have to reckon with other factors—the progressive using up of oxygen and the retention of carbonic acid (p. 45) within the closed circuit. As regards the particular method of anæsthetisation now under discussion it is only right to add to what has already been said, that although it produced very good results in the 13 cases referred to, it was subsequently found to answer somewhat less satisfactorily than methods in which the patients' own expired air, as opposed to fresh air, was used to fill the inhaling bag partially prior to the introduction of the anæsthetic.

With the foregoing considerations to guide us it would seem that the **apparatus required for the administration of ethyl chloride for brief operations** such as those of dental or throat surgery should consist of (1) a graduated bulb or other contrivance by which the administrator may know the exact quantity of the drug he is employing; (2) an accurately fitting face-piece connected by wide bore channels with (3) a rubber bag, preferably of stout rubber, and sufficiently capacious to receive at least three or four full expirations of a well-developed adult patient; and (4) some simple arrangement of mechanism by which the ethyl chloride vapour may be so gradually admitted to the to-and-fro respiratory current that no distress in breathing or resistance results. Many of the inhalers now in use have their internal channels encroached upon by otherwise ingenious mechanisms for introducing the anæsthetic; others are intended to hold lint, absorbent cotton, or sponge, and are open to the great objection that when in use the medium for the absorption of the anæsthetic itself greatly interferes with free respiration; whilst others are provided with bags which by reason of their small size are quite unsuitable.

The author has found the small **glass tube** here figured of great use in administering ethyl chloride. The requisite dose is introduced into this tube from the glass spray-bulb in which the anæsthetic is obtained from the makers, and by attaching the little tube to the lower part of a rubber bag provided with a small stop-cock the ethyl chloride may be so gradually added to the bag that no discomfort to the patient results. As the vapour of this anæsthetic is heavy and tends to remain at the bottom of the bag, it more gradually diffuses into the to-and-fro current than when the ethyl chloride is introduced, as is so often the case, between the face-piece and bag.

One of the simplest and best forms of apparatus for the administration of ethyl chloride is here depicted (Fig. 63).

It consists of the face-piece and bag of a Clover's ether inhaler of the type shown in Fig. 37, p. 345, the bag being fitted below with a small vulcanite stopcock for the attachment to it of the little glass tube of Fig. 62. If the wide-bore ether inhaler of Fig. 42, p. 349, be used, it will be necessary to interpose between the face-piece and the bag a metal collar (supplied by the makers of the inhaler) for connecting these two together.

In **conducting the administration** with the foregoing apparatus, the glass tube is first charged with from 2 to 5 c.c. of ethyl chloride according to the type of patient: it is then attached to the vulcanite stopcock of the bag, the stop-cock being closed: a small mouth-prop is inserted between the teeth in order to retain command of the air-way should masseteric spasm occur; the face-piece is then applied, and is pressed more firmly during expiration than during inspiration, so that the bag becomes nearly filled with expired air: the vulcanite tap is then opened: the glass tube is gradually tilted so that its contents enter the bag: and the administration is continued till the signs of ethyl chloride anæsthesia appear. If these few simple directions be followed there will be little or no discomfort when the ethyl chloride vapour enters the respiratory current, although it is difficult on all occasions to eliminate completely the pungency of the vapour. Attention must be carefully paid to the avoidance of undue air-deprivation.

The **Ormsby inhaler** of Fig. 43, p. 352, without its sponge, also answers very well for the administration of ethyl chloride. The requisite amount of the drug is sprayed or poured into the bag; the face-piece, with its air-valve fully open, is applied as already described; the air-valve is gradually closed; and anæsthesia becomes rapidly induced. If preferred, the dose of ethyl chloride may be introduced into the bag of the inhaler

FIG. 62.—Graduated glass tube for administering ethyl chloride.

FIG. 63.—Face-piece and bag of Clover's inhaler, with glass tube of Fig. 62 arranged for administering ethyl chloride.

in a glass bulb, to be broken by the administrator at the commencement of the inhalation. As in other close methods, air must not be too rigorously excluded.

Clover's ether inhaler, and particularly its modification, figured on p. 349, may also be used for ethyl chloride. In warm weather the metal reservoir should be cooled by cold water or by vaporising a few c.c. of ethyl chloride in its interior before the administration commences. From 3 to 5 c.c. of the anæsthetic are then placed in the reservoir: the indicator is turned to "0": the bag is filled by a few expirations: to-and-fro breathing is commenced; the indicator is gradually turned to "1," and then more rapidly to "2," "3," etc., according to the special circumstances present. The remarks already made on air exclusion must be borne in mind. McCardie prefers Clover's inhaler to any other for this anæsthetic, owing to the ease with which the anæsthesia from ethyl chloride may be supplemented by that of ether, should occasion arise.

B. DOSAGE

The reader is referred to the general remarks on dosage on p. 47. The quantity of ethyl chloride required to produce anæsthesia will depend upon the type of subject, the extent to which air is permitted to dilute the vapour, and the system of anæsthetisation adopted. A comparatively small quantity of the drug will produce a powerful effect if the air-restriction and re-breathing factors are freely employed. Given that the method is a close one, and that the re-breathing is judiciously practised, 1 or 2 c.c. of ethyl chloride will suffice for children, 3 or 4 c.c. for average adults, according to their physique (p. 152), and 4 or 5 c.c. for strong men, alcoholics, excessive smokers, and those who are known to be insusceptible to anæsthetics.

C. EFFECTS PRODUCED: SIGNS OF ANÆSTHESIA

We have seen (pp. 446 and 447) that neither the open nor the valvular system of administering ethyl chloride produces good results. We shall therefore deal exclusively in this section with the effects produced by close methods, such as those just enumerated, and we shall limit our remarks to the effects of single administrations for short operations. The prolongation of ethyl chloride anæsthesia for more protracted cases is discussed in the following section.

When the administration has been conducted, according to the principles to which reference has been made (p. 448), the effects produced by ethyl chloride generally come about with remarkable rapidity. Consciousness is lost in a few seconds, and, as a rule, without any noticeable discomfort or resistance. If the vapour be not gradually admitted some breath-holding and unpleasant sensations will necessarily result. Sometimes there is a stage of excitement with or without muscular rigidity. Muscular men, those who are addicted to the excessive use of alcohol or tobacco, and excitable and nervous patients may give some trouble during this stage. As a general rule, however, respiration grows deeper, quicker, and more regular, stertor becomes increasingly audible, the features assume a flushed appearance, the globes become fixed, the pupils dilate, and the conjunctivæ, or even the corneæ, lose their sensibility to touch. Temporary respiratory embarrassment, from spasm of jaw and other muscles, is not uncommon in muscular and other subjects predisposed to this condition, and may lead to some cyanosis. Speaking generally, it may be said that when the breathing has become distinctly stertorous, the administration should either be discontinued or a breath of air admitted. McCardie states[1] that he finds it advisable to admit a breath or two of air rather earlier than this, *i.e.* when the patient's breathing has become regular, and this course he regards as important, especially in bad subjects. Ethyl chloride resembles other anæsthetics in that the respiratory phenomena which it produces will, if carefully observed, be the best guide as to the need for air. If the drug has brought about a profound effect, *e.g.* if it has led to deep, rapid breathing with stertor, to deep breathing and muscular relaxation, or to dilatation of pupils and insensitive cornea, there can be no question as to the advisability or even the necessity of admitting air or suspending the administration. In some cases muscular relaxation accompanies stertor, but there is more often some rigidity. In certain subjects rigidity may be so general as to culminate in opisthotonos. McCardie states that during narcosis the pulse is usually rather slower than normal, and that Malherbe and Roubinovitch, using Potain's sphygmomanometer, found that in man the arterial pressure

[1] *Brit. Med. Journ.*, 17th March 1906.

almost invariably fell. A rash somewhat similar to that of ether may sometimes manifest itself. Micturition, or even defæcation, may occur.

As is the case with other anæsthetics, the **rapidity** with which the signs of ethyl chloride anæsthesia come about will depend upon the susceptibility of the particular patient, the rate and depth of breathing, the rate at which the ethyl chloride is vaporised, the proportions existing between the quantity of anæsthetic vaporised, and the quantity of incarcerated expired air, and other factors. Ethyl chloride anæsthesia is liable to deepen after the removal of the inhaling apparatus, particularly if the breathing be in any way obstructed. This postponed effect, which is of importance in children and weakly subjects, is due to the continued absorption of vapour from the lower air-passages.

As regards the **length of the available anæsthesia** after a single administration of ethyl chloride, much will depend upon the quantity of anæsthetic used and the duration of the administration. In 77 dental administrations by means of an Ormsby's inhaler McCardie found the average induction period to be 51 seconds and the average available anæsthesia to be 71 seconds. In 197 tonsil and adenoid cases the average induction period was 52 seconds and the subsequent anæsthesia about 64 seconds.

D. THE PROLONGATION OF ETHYL CHLORIDE ANÆSTHESIA

Up to the present time the more or less continuous administration of this anæsthetic for comparatively lengthy and major operations has not been attended by that success which would alone warrant us in recommending it for general surgical work. The drug appears, in fact, to be chiefly if not exclusively applicable for brief operations not necessitating complete muscular relaxation. It is true that McCardie and others have pushed its administration to such an extent as to maintain an absent conjunctival or corneal reflex for a considerable period, and have even secured and kept up complete muscular relaxation by its free use. But, in general, ethyl chloride is not suitable for cases requiring this degree of anæsthesia.

Should it be desired to prolong anæsthesia, the inhaler, charged with more anæsthetic, must be intermittently applied, care being taken to avoid inconvenient recovery on the one hand and overdosage on the other. In these cases a few c.c. of the anæsthetic may, from time to time, be sprayed directly into the inhaler from the spray bulb. It is often possible to retain the conjunctival and corneal reflexes throughout the administration. McCardie states that the pupil tends to contract in lengthy cases. In most of the instances in which ethyl chloride has been administered more or less continuously, difficulty has been experienced in securing an equable and smooth anæsthesia, whilst considerable collapse has, not infrequently, attended the recovery period.

Some attempts have been made to keep up ethyl chloride anæsthesia during protracted throat operations, but here again other anæsthetics or sequences usually give better results.[1]

E. DANGERS CONNECTED WITH THE ADMINISTRATION: FATAL CASES: POST-MORTEM APPEARANCES

Given that the patient's general condition is satisfactory, and that the administration is conducted according to the proper principles of anæsthetisation, ethyl chloride anæsthesia may be safely produced. But in patients whose general condition is highly unsatisfactory, and especially in those suffering from any respiratory embarrassment, ethyl chloride must be regarded as an inappropriate or even a dangerous drug. Moreover, even in healthy subjects, this anæsthetic may, if administered without a due regard for those principles to which reference has been made, rapidly bring about threatening or even fatal effects. If attention be not paid

[1] See *Lancet*, 8th July 1905. By means of a metal cylinder charged with 250 grammes of ethyl chloride, and connected by means of tubing with the oral cavity, Dr. G. A. H. Barton has kept up anæsthesia for several minutes for throat operations. The patient is placed under ethyl chloride in the usual manner, and then, by immersing the cylinder in hot water, a sufficient supply of vapour is obtained.

to such points as the provision for and maintenance of unembarrassed breathing, the size of the inhaling bag, the introduction into the bag of sufficient quantities of expired air, the amount of anæsthetic used,[1] and the corneal reflex and other signs of anæsthesia, dangerous symptoms may evince themselves, their nature and degree varying with the special circumstances present.

There are two rather important points in connection with ethyl chloride narcosis which help, perhaps, to explain the often unexpected incidence of dangerous symptoms under this anæsthetic. In the first place, ethyl chloride narcosis is, by the methods now in use, so rapidly induced that it is usually difficult or impossible to recognise any stages or degrees in the administration. In the second place, the appearance of the patient during full narcosis is unattended either by cyanosis or by pallor—symptoms which with nitrous oxide and with chloroform respectively indicate that a sufficiently large quantity of the drug has been given. When these two points are borne in mind it will be readily seen that unless proper care be taken, the limits of safety may readily be overstepped, and that the patient may be plunged, with few if any intervening symptoms, from a safe to a dangerous degree of narcosis.

The following account of a case in which dangerous symptoms occurred under ethyl chloride may be taken as typical of others:[2]—

8 c.c. of ethyl chloride were administered by means of an Ormsby's inhaler to a spare woman for a minor operation. There was violent struggling. Quiet anæsthesia followed. The operation was performed. The breathing was regular with slight stertor. An occasional breath of air was given. In a few moments cyanosis and arrested breathing occurred. The tongue was pulled out. There was no jaw spasm. Artificial respiration was employed. There was no wrist pulse. The colour quickly improved and breathing recommenced. Screaming and struggling followed. Breathing and pulse again became feeble, and necessitated further artificial respiration. Jaw spasm and twitching of limbs now occurred. The patient gradually recovered.

[1] An interesting case is referred to by Mr. A. Beresford Kingsford (*Brit. Med. Journ.*, 14th April 1906, p. 893). About 12 c.c. of ethyl chloride were inadvertently placed in an inhaling bag, and the patient almost immediately developed stertor and an insensitive cornea.

[2] *Brit. Med. Journ.*, 24th March 1905, p. 679.

A considerable number of ethyl chloride **fatalities**[1] have now been recorded, and by the courtesy and kindness of Dr. R. Salusbury Trevor the author is enabled to give a *résumé* of a post-mortem conducted on a patient of 67 who died under ethyl chloride:—Body that of a well-nourished man. Neck short. Rib cartilages ossified. Cervical veins engorged. *Thorax:* on opening, strong smell of ethyl chloride. *Lungs:* Both deeply congested. Mucus in bronchi, but in small amount only. *Larynx:* chronic laryngitis ("clergyman's throat"); no obstruction to glottis. *Heart:* 17 oz.; flabby as a whole; muscle easily lacerable and very soft; dilatation of right auricle and right ventricle and of left ventricle. Mitral and tricuspid valves atheromatous but competent; muscle, marked fatty degeneration and fatty infiltration. *Vessels*: atheroma of aorta and of coronary arteries *Abdomen:* liver slightly nutmeg and fatty. Other organs congested only *Cranial cavity*: œdema of surface of brain. Brain congested.

It is probable that ethyl chloride may prove fatal in two distinct ways:—

(1) By **simple overdosage, ethyl chloride toxæmia,** or **ethyl chloride syncope**;[2] the prominent features here are pallor, pulselessness, arrest of breathing, wide dilatation of pupils, general muscular flaccidity and separation of lids, quickly followed by, or perhaps indicating, cardiac arrest; and

(2) By **intercurrent respiratory embarrassment** (asphyxia) depressing a circulation possibly already depressed by ethyl chloride; the prominent symptoms of this condition are spasm about the jaws, mouth, tongue, larynx, or respiratory muscles, leading to respiratory arrest with some cyanosis, and asphyxia culminating with greater or less rapidity in cardiac arrest.

The explanation of ethyl chloride being far more dangerous than nitrous oxide, and distinctly more dangerous than ether, is to be found in the fact that when freely pushed a considerable fall of blood-pressure may take place (p. 127).

There is no good evidence that the sitting posture is contra-indicated under ethyl chloride unless the drug be unnecessarily pushed.[3]

[1] Dr. Luke of Edinburgh, to whom I am indebted for much information, has collected evidence of twenty-two fatalities, but details of only seventeen of these are available (*Lancet*, 5th May 1906, p. 1233).

[2] See a case recorded by Flemming (*Bristol Med. and Chir. Journ.* vol. xxii.).

[3] Mr. A. Beresford Kingsford states (*Brit. Med. Journ.*, 14th April 1906, p. 893) that at the Central London Throat Hospital ethyl chloride or somnoform has been administered to 7000 sitting patients with only two cases of formal artificial respiration, in both of which recovery took place.

Both Lotheisen and Parker have successfully **treated** cases of ethyl chloride syncope by inversion and artificial respiration. In Lotheisen's case recovery is stated to have taken place three minutes after apparent stoppage of the heart.[1]

It is impossible to say in what proportion of cases dangerous symptoms occur under ethyl chloride, as so much depends upon the experience of the anæsthetist, the selection of appropriate cases, and numerous other circumstances. According to McCardie, Ware met with six nearly fatal cases in 1000 administrations.[1] In four out of 150 administrations to infants under one year of age Miss Flora Murray [2] met with arrested breathing. McCardie (writing in 1906) states that he has encountered neither asphyxia nor syncope in 2000 administrations. It is impossible, in the present state of our knowledge, to attach even an approximate death-rate to this anæsthetic. McCardie believes that the mortality is about 1 in 3000; other authorities place it at 1 in 7000.

F. AFTER-EFFECTS

One of the chief disadvantages of ethyl chloride is that its administration is not unfrequently followed by **headache, nausea,** and **vomiting**. Moreover, cases occasionally occur in which the recovery period is attended by considerable prostration or even by collapse. It is true that a short administration may usually be conducted without causing any very obvious after-effects. But in a series of short administrations it will generally be found that one patient in every five, six, or seven suffers from considerable discomfort, either immediately after the administration or some hours subsequently. The headache, which may not come on till some time afterwards, may be intense, and the vomiting distressing. McCardie [3] has drawn attention to these cases of vomiting. In one the symptom came on six hours after the administration, and continued for twelve hours. Headache and vomiting are

[1] See *Lancet*, 7th October 1905, p. 1023.
[2] *Ibid.*, 25th November 1905, p. 1543.
[3] *Ibid.*, 4th April 1903, p. 953.

much more common when ethyl chloride has been administered for a comparatively protracted operation than when it has been given for a short operation, such as that of tooth extraction.

Ethyl chloride seems to be more liable than other anæsthetics to be followed by **after-collapse.** This state appears to be most likely to occur when a full dose has been given with but little air, or when the drug has been somewhat extensively employed for a protracted operation.

CHAPTER XIV

THE ADMINISTRATION OF ETHYL BROMIDE, ETHIDENE DICHLORIDE, AND OTHER GENERAL ANÆSTHETICS

A. ETHYL BROMIDE

Administration and Effects produced.—The anæsthetic properties of ethyl bromide were first recognised by Nunneley of Leeds in 1849, who spoke highly of the drug. Rabuteau[1] and Turnbull[2] were the next to investigate its anæsthetic properties. The latter used it in a considerable number of cases, and on more than one occasion brought its anæsthetic merits before the notice of American surgeons, several of whom, including Dr. Chisholm,[3] Dr. Levis, Dr. Marion Sims, and others, employed it with more or less success. The late Sir B. W. Richardson[4] considered the bromide a good and efficient anæsthetic. Clover, however, who gave it a trial, was not favourably impressed with it.[5] Dr. H. C. Wood of Philadelphia is also opposed to its introduction into general use. Drs. Schneider and Herz,[6] as well as other German dentists, have used ethyl bromide in their practices, and speak highly in its favour for dental operations. Dr. J. F. Silk[7] has also investigated the properties of the bromide as an anæsthetic in this branch of surgery. He administered it in over 130 cases, and took notes of the effects produced. The author has therefore largely availed himself of the information and conclusions contained in Dr. Silk's paper on the subject.

All who have employed ethyl bromide in surgical practice agree that it is more adapted for operations of very short duration than for others. It often produces an analgesic rather than an anæsthetic effect, and has hence been somewhat extensively used in dental practice. It rapidly destroys consciousness: and recovery from its influence is correspondingly speedy.

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[1] *Lancet*, vol. i., 1877, p. 143.

[2] *Manual of Anæsthetics.*

[3] Dr. Chisholm has used bromide of ethyl in 3000 cases without a fatality. See *Maryland Med. Journ.*, 5th December 1880.

[4] *Asclepiad*, 1885, p. 264.

[5] *Brit. Med. Journ.* vol. i., 1880, p. 586.

[6] *Internationale klinische Rundschau*, 14th April 1889. See also *Lancet*, 27th April 1889, p. 848.

[7] *Trans. Odont. Soc. of Great Britain*, February 1891.

The administration may be conducted by means of Ormsby's inhaler (Fig. 43, p. 352). A drachm, or a drachm and a half, should be placed upon the sponge of this inhaler, and the apparatus applied to the face of the patient. Dr. Silk recommends that little or no air should be admitted for the first few inhalations, after which the air-cap of the apparatus may be opened. With regard to the time occupied in producing anæsthesia, Dr. Silk found this to be, on the average, 66 seconds; whilst the duration of anæsthesia was 46 seconds. When the inhalation exceeded two minutes, the after-effects were liable to be troublesome. Of 300 cases in which Dr. Chisholm administered ethyl bromide the time required to produce deep anæsthesia was not more than 60 seconds.

As to the signs of anæsthesia, the administration should be conducted till softly snoring breathing, or insensibility of the cornea, is produced. Should there be delay in the supervention of these signs, the inhaler must be removed on the detection of any feebleness or irregularity in the pulse. A single and continuous administration in this manner is not likely to be attended by any unpleasant after-effects; but a reapplication of the inhaler may induce nausea and vomiting. An intermittent administration, such as that which would be necessary for a prolonged operation, is therefore not to be recommended. Marion Sims[1] performed Batty's operation, using ethyl bromide as the anæsthetic, and the administration lasted $1\frac{1}{2}$ hours. Vomiting occurred several times; the conjunctiva was sensitive from the beginning to the end; opisthotonos, very rapid breathing, and violent straining were produced. Severe pain in the head followed the inhalation, and after attacks of diarrhœa, tenesmus, and convulsions, the patient died (21 hours after the operation). Levis of Philadelphia administered the bromide for 40 consecutive minutes with an expenditure of 11 drachms. Other observers have also recorded prolonged administrations.[2]

When ethyl bromide is administered as above recommended, respiration is generally well maintained. It may, however, become temporarily embarrassed by spasm of the masseters and adjacent muscles.[3]

Professor Wood of Philadelphia regards ethyl bromide as a cardiac depressant. During its administration the pulse usually becomes increased in rate, and somewhat diminished in force. In several of the patients to whom Dr. Silk administered this agent, he found that distinct irregularity and slowing of the pulse were to be detected.

Struggling and excitement are exceptional. Dr. Turnbull records hysterical excitement in 6 out of 100 cases. This absence of early excitement is by some regarded as a great point in favour of the bromide. The pupils usually dilate during the administration, and profuse salivation and sweating are not uncommon.

Dangers connected with the Administration.—Several deaths have occurred during or immediately after the administration of this

[1] See a paper read before the New York Academy of Medicine, March 1880, entitled "The Bromide of Ethyl as an Anæsthetic." By J. Marion Sims, M.D.

[2] See Norton, *Brit. Med. Journ.*, 15th May 1880, p. 735.

[3] See an article by Brown Kelly, *Brit. Med. Journ.*, 30th April 1902, p. 590.

anæsthetic; but as it is difficult or impossible to ascertain the number of times ethyl bromide has been employed, the actual death-rate is unknown. Some authors state that it is about 1 in 5000. There is good reason to believe that the risks attendant upon the administration have been over-estimated, and that if a pure drug be employed, and ordinary care exercised, the rapid induction of anæsthesia sufficient for the performance of a short operation is attended by little or no danger. Dr. Silk, who has investigated all the published fatal cases, says that in some of these (1) sudden and early heart-failure occurred; in others (2) respiratory paralysis took place somewhat later in the administration; and in others again (3) gastro-intestinal symptoms were recorded. Gleich [1] reports a case in which the face became cyanotic and pulse and respiration ceased together. The post-mortem showed no hyperæmia of the brain, but there was fatty degeneration of all the viscera. A fatal administration is also reported in the *Dental Cosmos*, August 1880. Jendritza [2] refers to a case in which unconsciousness, trismus, and dilated pupiis came on after recovery from this anæsthetic administered for tooth-extraction, the condition lasting 90 minutes.

After-Effects.—As with other agents, the after-effects bear a kind of proportion to the duration of the anæsthesia. A short administration is usually not followed by headache or nausea, the patient regaining consciousness very satisfactorily. It is not uncommon, however, for some degree of depression to be experienced, and in some cases actual fainting has been recorded. Hysterical outbursts may sometimes follow the inhalation. Nausea and vomiting are exceptional after a single administration; but they are not uncommon during or after a comparatively long inhalation.

Looked at from all points of view, ethyl bromide can hardly be regarded with much favour. As compared with nitrous oxide it is distinctly inferior not only in point of safety, but in the greater liability after its administration to headache, nausea, and other unpleasant effects. Its greater portability is necessarily a recommendation when we compare it with nitrous oxide; but its liability to decomposition quite outweighs this advantage.

As will be gathered from the above remarks ethyl bromide produces effects very similar to those obtainable by ethyl chloride. But as ethyl chloride is more stable and now readily obtainable in a convenient and portable form there would seem to be little or no point in using ethyl bromide for brief surgical operations.

B. ETHIDENE DICHLORIDE

Administration and Effects produced.—Ethidene dichloride was first employed as an anæsthetic by Snow,[3] who administered it on several

[1] *Deutsche med. Zeitung*, Berlin, August 1892.

[2] *Year-Book of Treatment*, 1897, p. 172.

[3] Most of the information which is here given concerning ethidene dichloride is derived either from the reports of the Glasgow Committee on Anæsthetics

occasions with good results. Snow found the effects to be nearly the same as those of chloroform. In 1870 it was used by Liebreich and Langenbeck in Berlin,[1] and by Sauer[2] and Steffen.[3] In 1879 the Glasgow Committee of the British Medical Association[4] drew attention to the merits of the anæsthetic, and, after a careful comparison of its action with that of chloroform, published their results in the following year. Fifty operations were performed under ethidene dichloride, fifty under chloroform, and the results tabulated. The Committee found the average dose of ethidene to be 40·3 c.c., or 1·8 c.c. for each minute during which the patient was under its influence. With chloroform the average dose was 31·8 c.c., or 1·7 c.c. per minute. The time taken to produce anæsthesia was, in the case of ethidene dichloride, 4·3 minutes; whilst with chloroform it was 5·4 minutes. Less excitement was observed than with chloroform. The Committee also found that both the pulse and the respiration under ethidene dichloride were less altered than when chloroform was used. They did not obtain the marked slowing of the pulse and the quick respiration which are often observed with chloroform. Ethidene dichloride was regarded by the Committee as midway, in point of safety and in other respects, between chloroform and ether; and after their favourable account of its action it was for a time largely used. Mr. Tom Bird[5] has recorded six administrations by means of Junker's apparatus. Mr. J. H. Palmer[6] has also reported his experiences with the agent administered upon lint or by means of a towel. He found that one ounce was required to anæsthetise a boy of eighteen for an operation lasting 35 minutes. We are indebted, however, to Clover[7] for the records of no less than 1877 administrations of ethidene dichloride, and his results are of great interest. Of the 1877 administrations, 287 were for major operations. Clover usually preceded the administration of ethidene by nitrous oxide gas, using his combined gas-and-ether inhaler for the purpose. The vapour of ethidene was gradually added when the patient was partly anæsthetised by nitrous oxide. By this method struggling was rarely met with. A little convulsive twitching occurred as anæsthesia approached, and this was quickly followed by stertor and dilatation of the pupils. Air was then admitted as occasion required; and the quantity of ethidene given was regulated by the general condition of the patient. Clover seems, in fact, to have administered ethidene in very much the same way as he employed ether, *i.e.* with a limited supply of air.

Dangers connected with the Administration.—Sauer, to whom

(*Brit. Med. Journ.*, 18th December 1880, p. 958); from a lecture given by the late Mr. Clover (*ibid.*, 29th May 1880, p. 797); or from Dr. Snow's article on "Monochlorurretted Chloride of Ethyle" (*op. cit.* p. 420).

[1] *Berlin. klin. Wochenschrift*, Nos. 31 and 33, 1870, p. 401.

[2] *Pharm. Centralblatt*, vol. xiv. p. 140.

[3] *Deutsche Klinik*, No. 44, p. 398; and *Jahresb. der Medicin*, 1870-1-2.

[4] *Brit. Med. Journ.* vol. i., 1879, p. 108.

[5] *Med. Times and Gaz.* vol. i., 1879, p. 62.

[6] *Lancet*, vol. ii., 1879, p. 637. Mr. Palmer obtained his ethidene from Kahlbaum of Berlin, through some London chemists.

[7] *Brit. Med. Journ.*, 29th May 1880, p. 797.

reference has already been made, has recorded a fatality under ethidene dichloride in a patient who was the subject of morbus cordis. Another fatality is reported by Clover [1]; but from the published account of the case the anæsthetic seems to have had but little share in bringing about the fatal syncope which followed the administration. The patient had a large flabby heart, and syncope took place whilst the head was being voluntarily raised after the operation was over. A third case is put on record by Dr. Mouillet.[2] The patient was the subject of empyema, and died with symptoms of syncope soon after the stage of struggling. A fourth fatality is mentioned [3] as having occurred during an ophthalmic operation. Pallor and disappearance of the pulse were noticed at the moment the cornea was incised. It may be incidentally mentioned that ethidene dichloride seemed at one time to be specially suited for ophthalmic operations, owing to the infrequency of struggling during its administration, and of vomiting afterwards. There can be no doubt, however, that this anæsthetic, although more stimulating than chloroform, is to be regarded in this respect as inferior to ether. Clover refers to three cases in which alarming symptoms presented themselves during the administration, and in his remarks on the fatality above alluded to, states his belief that ether would have been safer than ethidene dichloride.

After-Effects.—According to Clover, patients recover from ethidene dichloride anæsthesia very satisfactorily. He found vomiting to occur in one-third of his administrations for major operations, and in one-twentieth of those for minor operations. He further states that vomiting after this anæsthetic invariably ceases sooner than after chloroform. Of thirty-three patients mentioned by Sauer, two vomited, and two had nausea and headache after. The Glasgow Committee found that nausea and vomiting were about equal in frequency after ethidene dichloride and after chloroform, but that vomiting after the former agent was of shorter duration than that after the latter.

C. AMYLENE. PENTAL

Amylene

Administration and Effects produced.—For most of our present knowledge concerning the effects produced by amylene we are indebted to Snow, who, as already mentioned, was the first to employ this substance as an anæsthetic. Snow used it in 238 cases, and found that the best results were obtained by administering it with his chloroform inhaler (p. 387). The great volatility of amylene almost necessitates the use of some special apparatus. Snow found that three to four fluid drachms were required to cause insensibility in the adult, and that it was necessary to employ an atmosphere containing about 15 per cent

[1] *Loc. cit.* [2] *Brit. Med. Journ.* vol. i., 1881, p. 385.
[3] *Ibid.* vol. ii., 1882, p. 1267.

of the vapour. Amylene appears to differ from chloroform in that the continuous administration of a very dilute vapour does not lead to anæsthesia: it is necessary to exhibit the agent in a somewhat concentrated form. Owing to the sparing solubility of amylene in the blood, and to its great volatility, patients very rapidly emerge from its influence, so that a frequent renewal of the inhalation is necessary. Snow estimated that amylene was consumed at about the rate of one fluid drachm per minute, when administered by means of his apparatus.[1]

In most of Snow's administrations an analgesic and not a truly anæsthetic state appears to have been obtained. He declared, indeed, that he found it possible to secure an absence of pain with a less profound coma than that which characterised the use of chloroform or ether. The lid-reflex was not, as a rule, abolished, although muscular movements in reflex response to operative interference were usually absent. Both major and minor operations were performed during this comparatively light form of anæsthesia. The pulse was almost always increased in frequency and force. The respiration was often accelerated. The pupils were most commonly about the ordinary size. The colour of the features was heightened. Perspiration was met with in some cases. It was found that amylene could not be depended upon for producing complete muscular relaxation, and that it was not a very convenient anæsthetic for prolonged operations about the mouth or face. It appeared to answer best in short operations not requiring muscular flaccidity, such as those for the extraction of teeth. Less salivation was observed than under ether or chloroform.

Soon after the introduction of amylene by Snow, it was tried somewhat extensively both in this country and abroad. The conclusions arrived at by a Committee of the Academy of Medicine were[2]: That rigidity was the rule rather than the exception during amylene administrations; that a remarkably rapid recovery from its effects occurred; and that it was more suitable for brief operations than for others. Its unpleasant odour was regarded as a barrier to its general employment. M. Giraldès administered amylene to 79 children, and stated that two drachms were required in most cases to produce insensibility to pain. According to Kappeler,[3] amylene was given a fair trial by Spiegelberg and Lohmayer, who were unable to obtain complete anæsthesia with it; whilst Billroth and Jüngken found it answered well as an anæsthetic, even in major operations (resection of os calcis, amputation of leg, etc.).

Dangers connected with the Administration.—In Snow's 238 cases there were two fatalities; but in discussing these by the light of our present knowledge it is questionable whether they should be directly attributed to the influence of the anæsthetic. The occurrence of these two fatal cases had the effect of lessening the confidence of the profession in the new anæsthetic; and it does not appear to have been again employed, at all events as amylene. The body subsequently introduced as pental will be discussed below.

[1] *Med. Times and Gaz.*, 17th January 1857, p. 60.
[2] See *ibid.* vol. i., 1857, p. 623.
[3] *Op. cit.* p. 192.

After-Effects.—Patients recover with remarkable rapidity from the effects of amylene. Nausea and vomiting are quite exceptional. Of Snow's 238 cases there were only two in which vomiting occurred immediately after the administration; and sickness was only heard of subsequently in eight or ten cases.

Pental

The substance known by this name has been already referred to on p. 34. What the precise difference between it and its predecessor amylene may be, further experience must decide. Pental was somewhat extensively used in Germany as an anæsthetic in dental surgery, and the following remarks, for most of which the author is indebted to Mr. T. E. Constant,[1] apply to its employment in this branch of practice.

Administration and Effects produced.—A Clover's ether inhaler, or some similar apparatus, answers best. Two drachms, or a little more, should be poured into the reservoir. The bag being attached, the patient's expirations may be allowed partly to fill the bag. The indicator must be turned to "1" when the apparatus is applied to the face. No more air is given, but the patient breathes to and fro for about 40 seconds, the indicator being progressively pushed towards "F." The symptoms produced are similar to those recorded by Snow. The face flushes, the pulse becomes quicker and quicker, the pupils dilate, the eyes are fixed and open, the conjunctival reflex disappears, the breathing is quick and laboured, and there is slight cyanosis. There may be some opisthotonos. At the end of about 40 seconds, the inhaler is removed and the extraction commenced. Anæsthesia is stated to persist for about a minute after the removal of the face-piece. It is sometimes possible to obtain true analgesia, the patient retaining consciousness whilst a tooth is being painlessly extracted.

Dangers connected with the Administration.—Several fatalities in connection with the use of pental have been recorded.[2] A case has also been reported to the author in which the most alarming symptoms occurred immediately after the inhalation. Respiration grew shallow and then ceased, whilst the radial pulse became imperceptible. Inversion restored the pulse; but artificial respiration for 7 minutes had to be resorted to before recovery ensued. Looked at from all points of view, the use of amylene or pental seems to have but little to recommend it. As compared to nitrous oxide for brief operations it is certainly inferior, not only because of its greater danger, but because it is not so agreeable to inhale.[3]

After-Effects.—As with the amylene employed by Snow, after-effects are usually completely absent.

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[1] The pental used by Mr. Constant was procured from C. A. F. Kahlbaum of Berlin.

[2] See *Brit. Journ. Dent. Science*, 1st and 15th June 1892; *Lancet*, 4th Jan. 1896, p. 45; *Dental Record*, Nov. 1893, vol. xiii. p. 511.

[3] For further remarks see *Wiener klin. Woch.*, 21st and 28th Jan. 1892.

D. NITROGEN

Nitrogen is capable of producing insensibility to pain when inhaled free from oxygen, or with very small percentages of that gas. The anæsthesia must be regarded as the result of oxygen-deprivation, for it is obvious that we cannot assign any specific anæsthetic properties to nitrogen itself. In 1868 [1] Burdon Sanderson, John Murray, and Smith Turner administered nitrogen for tooth-extraction to six patients at the Middlesex Hospital. In the first two cases a considerable quantity of air appears to have been breathed with the nitrogen; and even in the remaining four cases there is good reason to believe, from the results obtained, that in some way or another unknown quantities of oxygen must have gained access to the lungs during the administration. Thus, insensibility did not occur till from 3 to 4 minutes after the commencement of the inhalation; no lividity of the features was observed; and in only two of the four cases was there an absence of pain during the operation.

In the year 1890, at the request of the late Sir George Johnson, the author administered nitrogen with ·5 per cent of oxygen (*i.e.* practically pure nitrogen) to nine patients at the Dental Hospital of London. There was no excitement in any case. An onlooker could not have detected any difference between the phenomena produced and those usually met with under nitrous oxide. The author used the same apparatus as that he employs for nitrous oxide (Fig. 26, p. 285), and took great care that the face-piece fitted well and that the valves worked accurately, so that no air whatever gained admission to the lungs. Anæsthesia was produced with remarkable rapidity in each case. The available period of anæsthesia for a dental operation was, with one or two exceptions, shorter than with nitrous oxide. There was reflex screaming in some of the cases; but this is common under nitrous oxide, especially in hospital practice. The nitrogen was administered in each case till slight epileptiform movements appeared. The recovery was quick and good. There was no nausea or vomiting. The pulse was usually rapid, and the author is inclined to think not so strong as under nitrous oxide.

In 1907 the author himself inhaled through valves two-thirds of a two gallon bag containing nitrogen with 0·7 per cent of oxygen. After six breaths he felt himself becoming unconscious, with a "thrilling"[2] sensation akin to that caused by nitrous oxide, and with a very slight feeling of constriction, or "*besoin de respirer.*" On emptying a two gallon bag, filled with the same mixture, in ten breaths, he became very nearly unconscious, with thrilling sensations all over the body, especially in the face, hands, and arms. Quickening of the pulse, deep respiration, and slight lividity of the face and lips were reported by Mr. H. B. Gardner, who witnessed the experiment. There was a slight headache twenty minutes afterwards. Mr. Gardner then himself underwent the same experiments with identical results.

[1] See *Brit. Med. Journ.*, 13th June 1868, p. 593. [2] *Vide* p. 291.

The author also administered nitrogen with 5 per cent of oxygen in five cases; and nitrogen with 3 per cent of oxygen in four cases. A longer time was taken to produce anæsthesia than with the practically pure nitrogen; but the period of inhalation was still remarkably short. The resulting anæsthesia seemed to be longer than that obtained by nitrogen alone. No excitement was noted in any case. During the administration there was less jactitation in these than in the preceding nine cases. In one case three teeth were painlessly extracted. There was some excitement after the inhalation in a few of the cases. One patient, a boy, complained of much headache, and cried with pain. In one case there was rapid tremor of one arm after the administration. This phenomenon was also observed in one of the pure nitrogen cases. All patients exhibited jerky and irregular breathing and cyanosis.

On a subsequent occasion the author administered nitrogen with 5 per cent of oxygen to one patient. The anæsthesia was not satisfactory. On the same day he administered in two cases nitrogen with about 6·6 per cent of oxygen. There was a longer period of inhalation than with the 5 per cent of oxygen, and some apparent discomfort. In one of these cases the administration was pushed till slight clonic movements, irregular respiration and cyanosis occurred. The anæsthesia was then complete for a short operation.

Finally, nitrogen with 7 or 7½ per cent of oxygen was administered to two patients. In both there was distinct anæsthesia. In one case, that of a woman, there was no jactitation, but some cyanosis, and the patient was quiet throughout. In another patient, also a woman, the symptoms were like those of pure nitrogen or nitrous oxide, coming on more quickly. There was definite anæsthesia.

Sir George Johnson, in his report of the above administrations of nitrogen with ·5 per cent of oxygen, stated that "the maximum period required to produce anæsthesia was 70 secs., the minimum 50 secs., and the mean time 58·3 secs." With regard to the cases in which 3 per cent of oxygen was present, he stated that "the time required to produce anæsthesia varied from 60 to 75 secs., the average time being 67·5 secs." Referring to the cases in which 5 per cent was present, he stated that "the time required for the production of anæsthesia ranged from 75 to 95 secs., the average being 87·5 secs." [1]

E. METHYL OXIDE

Methyl oxide, or methyl ether, $(CH_3)_2O$, is a gas which, when perfectly pure, has a pleasant, fruity odour. It has a specific gravity of 1·617 (referred to air), and is readily liquefied under slight pressure. It is very soluble in ethylic ether. Richardson [2] conducted some administra-

[1] For further information see *Lancet*, 11th April 1891, p. 815. Details will here be found of other cases in which Mr. Woodhouse Braine administered nitrogen.

[2] See *Med. Times and Gazette*, 30th May and 6th June 1868, pp. 581 and 609; see also *Asclepiad*, vol. ii. p. 270, and vol. iv. p. 135.

tions with methyl oxide thus dissolved, and doubtless obtained a mixed effect partly due to methyl oxide and partly to ordinary ether.

Wishing to ascertain the effects of the pure substance, and being fortunate enough, through the kindness of Mr. J. Addyman Gardner, to obtain a sufficient quantity of it for clinical purposes, the author anæsthetised several patients with this anæsthetic in the dental department of St. George's Hospital.[1] Unfortunately the results were not so satisfactory as one had hoped they might be, but they were nevertheless of interest. In some cases a mixture of about 33·3 per cent of methyl oxide to 66·6 per cent of air was employed; in others a 50 per cent mixture. It was found that when methyl oxide was largely diluted with air the mixture, which was not unpleasant to inhale, did not produce a satisfactory form of anæsthesia. On the other hand, mixtures sufficiently concentrated to produce satisfactory anæsthesia were too pungent to be pleasant. As compared with the anæsthesia obtained by the recognised anæsthetics, that produced by methyl oxide was of a lighter type and was more liable to be followed by nausea and distress. Although a comparatively long anæsthesia was attainable by a prolonged administration, unpleasant after-effects resulted. For further information the reader is referred to the original account of these cases.

F. HEDONAL

This drug appears to have been first described as a general anæsthetic by Jeremisch,[2] who used a solution containing 1 per cent hedonal and 5 per cent urethane for intravenous infusion. In this country it has been tried a good deal lately, especially at St. Thomas' Hospital, whence Mr. C. M. Page[3] reports favourably upon it. Hedonal is dissolved in normal saline at 70° C. to make a 0·75 per cent solution. This is filtered and then boiled for five minutes, and is then stored in sterile flasks.

The method of introduction is in principle similar to that described on p. 359 for the intravenous administration of ether. The rate of flow should be about 100 c.c. to the minute, during the induction stage; when anæsthesia is attained, a rate of 50 c.c. is sufficient. On an average 500 c.c. will suffice to anæsthetise an adult, and the same amount per hour will be required to maintain the anæsthesia. A preliminary injection of morphine, scopolamine, and atropine is advised, as for infusion ether administration.

Further experience with hedonal is necessary before any very definite pronouncement can be made as to its claims to rank as a general anæsthetic. Some surgeons who have employed it speak very highly of it, particularly for patients whose general condition is such that inhalation anæsthesia appears to be contra-indicated. Although comparatively few

[1] For a full account of this work see the *Lancet*, 19th Nov. 1904, p. 1408.

[2] *Deutsche Zeit. f. Chirurgie*, B cviii. 5 and 6.

[3] *Lancet*, 23rd March 1912.

administrations have taken place in this country three deaths have been reported up to June 1912. This, however, may readily be attributable to that want of knowledge which must inevitably attend the use of new drugs. In many of the cases in which hedonal has been tried the patient has slept for over twelve hours after the operation. Should future experience with hedonal be favourable it will probably be used much more extensively, particularly in hospital practice, and for operations about the upper air-passages. Further information as to the experience of continental authorities with this method of anæsthesia will be found in *The British Medical Journal*, 15th June 1912, p. 1378.

G. OTHER ANÆSTHETICS

Ethylene, or **olefiant gas,** was administered by Nunneley of Leeds in 1849 to four patients; but it was found to be unsatisfactory in its action.

Amyl hydride,[1] **amyl chloride,**[2] **ethyl nitrate,**[3] **benzene,**[4] and **turpentine**[5] have one and all been found to be capable of producing general anæsthesia when administered in the form of vapour. **Carbon tetrachloride** is also capable of producing anæsthesia. Attention was directed to this drug in England during 1909 by the occurrence of a fatality in a hairdresser's shop while carbon tetrachloride was being used as a hair wash. Professor Waller estimates the toxicity of this drug as double that of chloroform.[6]

[1] *Lancet*, vol. i., 1885, p. 101; *Asclepiad*, 1885, p. 168; *Med. Times and Gaz.*, 28th Dec. 1867, p. 694.

[2] Kappeler, *op. cit.* p. 190.

[3] Snow, *Med. Times and Gaz.*, 17th Jan. 1857, p. 61.

[4] Snow and Richardson, *Ibid.*, 17th Jan. 1857, p. 61; and 28th Dec. 1867, p. 694.

[5] *Med. Times and Gaz.*, 28th Dec. 1867, p. 694; and Kappeler, p. 193.

[6] *Lancet*, 7th Aug. 1909, p. 369.

CHAPTER XV

MIXTURES OF GENERAL ANÆSTHETICS

We now have to consider the administration and effects of certain definite or predetermined mixtures of anæsthetics with one another, and of anæsthetics with allied substances such as alcohol or petroleum ether. Although, strictly speaking, we administer anæsthetics in mixture whenever we employ these drugs in succession or in alternation it will be convenient to restrict the use of the word mixture to substances whose constituents have been mixed in known or definite proportions before the administration.

Mixtures consisting of chloroform and alcohol, of chloroform and ether, and of chloroform, alcohol, and ether, have been very extensively employed not only in this country but upon the Continent. The object in adding alcohol and ether to chloroform has been, not only to prevent too concentrated a chloroform vapour from being respired, but to counteract any tendency to circulatory depression. By mixing a small quantity of alcohol with chloroform it is obviously possible to administer a chloroform vapour considerably weaker than that which would result were the undiluted agent administered in precisely the same manner; whilst mixtures of ether and chloroform have been shown, by comparative experiments, to produce a better cardiac action than chloroform alone.[1] There is, however, a theoretical objection to these mixtures, and one which Snow particularly laid stress upon. It is that as the constituents have their own special rates of vaporisation, the more volatile ingredients will tend to vaporise first, the less volatile remaining behind to be subsequently respired. Ether and chloroform,

[1] *Trans. Roy. Med. Chir. Soc.* vol. xxix., 1864, p. 342.

for example, have very different boiling-points, whilst the rates of diffusion of their respective vapours will follow the same law as that which obtains in the case of gases—that is to say, they will be inversely as the square roots of the densities of those vapours. It is therefore clear that in using a mixture of equal parts by volume of liquid ether and chloroform, not only will the proportions of the anæsthetics in the mixed vapour be different from those in which the liquids were mixed, but there will be fluctuations in these proportions throughout the administration. In actual practice this separate vaporisation of constituents does not, as a rule, give rise to the irregular effects which might be anticipated, probably because it is customary to administer anæsthetic mixtures in small quantities at a time and to replenish the inhaler frequently. On an open mask such as Skinner's, which, as we have seen, is the most suitable appliance for administering the so-called C.E. mixture (*vide infra*), this fluctuation in composition of the inspired vapour may be regarded as negligible. Ellis overcame the objection in question by devising an apparatus which contained the anæsthetics separately, and their vapours were mixed in the desired proportions during the administration. The plan was very ingenious, but too complicated for general use.

A. MIXTURES OF CHLOROFORM AND ETHYLIC ALCOHOL

Sansom[1] recommended and used **equal parts of chloroform and alcohol**, and believed that the good effects he obtained were due to the alcohol restraining the volatility of the chloroform, and thus preventing too concentrated a vapour. Others, including Snow, have employed this mixture with success.[2] When alcohol is used with chloroform it is, however, generally added in smaller proportions, *i.e.* to the extent of **one-fourth** or **one-fifth**. If one-fifth of alcohol be added, and the mixture be administered by means of a Junker's inhaler, it will be found difficult to anæsthetise vigorous or alcoholic subjects, although more susceptible patients will be readily

[1] *Medical Times and Gazette*, vol. ii., 1870, p. 107.
[2] See Stephens, *British Medical Journal*, January 1888, p. 19.

affected. In the course of an experimental research Schäfer and Scharlieb[1] found that by adding one part of absolute alcohol to nine parts of chloroform the ordinary fall of pressure met with under the latter anæsthetic was largely prevented, and that respiration was less depressed than with chloroform itself. They also found that recovery took place more readily after this mixture than after chloroform. Better results were obtained with mixtures containing **one-tenth** than with those containing one-fifth of alcohol. The beneficial effects, according to these observers, are not due to the mere dilution of the chloroform vapour; for with ether instead of alcohol the blood-pressure tracings were similar to those of pure chloroform. They believe that the alcohol produces a stimulant effect upon both heart and respiration.

Mixtures of alcohol and chloroform should be **administered** in precisely the same manner as the undiluted anæsthetic.

B. THE "C.E. MIXTURE" AND OTHER MIXTURES OF CHLOROFORM AND ETHER

The C.E. Mixture

For several years the author has extensively used a mixture of **two parts by volume of chloroform and three parts of ether,** that is to say, the "A.C.E." mixture without its alcohol. Since the specific gravity of chloroform is more than twice that of ether, the proportions by mass are, ether three parts, chloroform (+) four parts. For purposes of brevity and description this is spoken of in these pages as the "**C.E.**" **mixture.** In actual practice the C.E. mixture gives better results than the A.C.E. mixture. There is apparently less excitement during the administration and a more satisfactory recovery afterwards—differences which are probably dependent upon the absence of the alcohol.

For the **administration of the C.E. mixture** a Skinner's or Schimmelbusch's mask (Fig. 58, p. 402) will suffice. The administration is to be conducted on exactly similar lines to those recommended for administering chloroform (see p. 402),

[1] *Trans. Roy. Soc. Edin.* vol. xli. part ii. (No. 12).

and care is to be taken not to crowd the anæsthetic at first, but rather to secure a gradual induction with a steadily increasing strength of vapour.

The **effects produced** by the C.E. mixture thus administered are very satisfactory. It is, of course, impossible completely to eliminate the stage of excitement in all cases; but by very gradually administering the mixture, this stage rarely becomes inconveniently pronounced. In rare cases patients are met with to whom large quantities have to be given to secure surgical anæsthesia. As a general rule women pass into deep anæsthesia without any struggling. The state of "false anæsthesia" is far less common than with chloroform. It is generally advisable to take from five to eight minutes in producing anæsthesia: if the administration be hurried, breath-holding and struggling will tend to arise. Except in the case of obese, thick-necked, muscular, or alcoholic subjects, the transition from the second to the third degree of anæsthesia is usually unattended by cough, hampered breathing, or cyanosis. When full anæsthesia has been secured, the respiration is generally regular and softly snoring, the pulse full, soft, and somewhat quicker than the chloroform pulse, the colour good, the corneæ very slightly sensitive to touch, the pupils of moderate size, and the muscular system flaccid. The ocular conditions are very similar to those observed under chloroform. The respiration, the lid-reflex, and the pupil are the best guides as to the depth of anæsthesia. High-pitched crowing breathing must be carefully treated. As a general rule the anæsthetic should be withdrawn for a while and the lips briskly rubbed (p. 582); but if the condition be obviously associated with imperfect anæsthesia, as will be ascertained by other signs, the administration may be cautiously continued, being at once stopped if the crowing does not subside. The anæsthesia of the C.E. mixture as already indicated (p. 207) is particularly appropriate in abdominal surgery. The after-effects of the mixture appear to be slightly more pronounced than those of chloroform.

The cases in which the C.E. mixture may with advantage be used have been considered in Chaps. V., VI., and VII.; whilst the sequences containing this mixture as a constituent will be dealt with in the following chapter. Speaking quite generally, and assuming that an open mask is to be employed, the mixture is to be preferred to chloroform. At the same time we have seen that there are numerous cases in which the ether element is disadvantageous or even inadmissible, and that such cases can only be satisfactorily conducted with chloroform itself.

The **signs of overdosage** by the C.E. mixture are similar in their main features to those observed in the case of chloroform. Other things being equal, surgical shock is perhaps less likely to arise under this mixture than under chloroform.

It is sometimes useful in certain desperate cases to administer **oxygen in conjunction with the C.E. mixture.** This may be very conveniently done as represented in Fig. 45 (p. 356).

Other Mixtures of Chloroform and Ether

A mixture consisting of **one part of chloroform and two parts of ether** was examined and used by the Committee of the Royal Medical and Chirurgical Society who found it to be very similar in its action to the A.C.E. mixture referred to below.

A mixture containing **one part of chloroform and three parts of ether**, often known as **the Vienna mixture**, has been extensively used abroad, a large number of administrations having been recorded without a casualty. Observers in this country, however, have stated that it is uncertain and irregular in its action.[1]

A mixture consisting of **one part of chloroform and four parts of ether** was examined by the Committee above mentioned, and was reported to be very similar in its action to ether itself.

These mixtures of chloroform and ether should be administered by means of "open" inhalers. Bag-inhalers should not be employed. The greater the proportion of chloroform, the nearer should the mode of administration approach to that described on p. 402. Above all, frequent additions of small doses are essential. Some anæsthetists[2] employ Junker's

[1] *Lancet*, vol. ii., 1872, p. 828.
[2] See Tyrrell, *Clinical Journ.*, 26th Jan. 1898.

system of administration (p. 392), using one bottle for ether and one for chloroform, and varying the proportions of the two vapours from time to time.

C. THE A.C.E. MIXTURE AND OTHER MIXTURES OF ALCOHOL, CHLOROFORM, AND ETHER

The A.C.E. mixture consists of one part of alcohol, two of chloroform, and three of ether. It was originally suggested and used by Dr. George Harley. Some years later the Committee of the Royal Medical and Chirurgical Society made a careful trial of it, and with very favourable results. They recommended it as preferable to chloroform; but it is nowadays very seldom used, as it has no advantages over the C.E. mixture.

When freshly prepared from the purest ingredients, and inhaled gradually with plenty of air, the A.C.E. mixture possesses an agreeable, somewhat fruity odour. It is fairly stable, and there is no evidence that any chemical action takes place when its ingredients are mixed together.

Billroth's Mixture.—Mixtures of alcohol, chloroform, and ether, containing these agents in somewhat different proportions to those of the A.C.E. mixture, have also been employed. Billroth's mixture consists of one part of alcohol, three of chloroform, and one of ether. It is administered very much as chloroform is administered, and is said to be rarely followed by vomiting.

D. THE SO-CALLED "BICHLORIDE OF METHYLENE," OR "METHYLENE"

Composition. — The so-called "bichloride of methylene," or "methylene," was brought before the notice of the profession in 1867 by Sir B. W. Richardson,[1] who gave it the formula CH_2Cl_2, and strongly recommended it for producing surgical anæsthesia. The "methylene" supplied by Messrs. Robbins and Co. distils over at about 127°-128° F.,[2] and the temperature is stated not to vary more than 3° from first to

[1] See *Asclepiad*, 1888, p. 201—"Methylene as an Anæsthetic."
[2] See *Brit. Med. Journ.* vol. ii., 1883, p. 271.

last during distillation. As supplied by the manufacturers, "methylene" is a colourless fluid, with an agreeable odour very similar to that of chloroform. Much discussion has taken place as to the precise chemical composition of "methylene." Whilst on the one hand Sir B. Richardson maintained that the drug sold under that name was, with the exception that it contained traces of alcohol and water, chemically pure CH_2Cl_2, very strong evidence has been adduced to show that "bichloride of methylene" is nothing more than a mechanical mixture of chloroform and methylic alcohol.

Effects.—Whatever may be the chemical constitution of Richardson's "methylene," it certainly produces effects which deserve careful consideration from a clinical point of view. The first operation under its influence was performed by the late Sir Spencer Wells, who, after a very large experience,[1] still considered "methylene" to be superior to all other agents. For several years after its introduction into practice, it was used somewhat extensively not only in this country but on the Continent. Its rapidity of action,[2] the speedy return to consciousness after its use, and the striking rarity of after-effects rendered it specially serviceable in abdominal, ophthalmic, and dental operations. Dr. Day,[3] who administered "methylene" for Sir Spencer Wells and other surgeons in 1230 cases, most of which were cases of abdominal section, spoke in very high terms of the agent. He found that it was less likely than chloroform to cause vomiting; that it was more agreeable to inhale; that rarely more than 3 to 4 drachms were required for an operation lasting half an hour; that consciousness returned very soon after the inhalation had been discontinued; that it might be used when serious heart and lung affections existed; and that, so far as his experience went, "methylene" was the best anæsthetic. Others have spoken in similarly favourable terms.[4] There are, however, two sides to every question; and many surgeons have tried "methylene" and have discarded it. It enjoyed, for example, a long reign at the Samaritan Hospital, but was eventually replaced by its former rival chloroform. Nussbaum of Munich, who, in 1868, had administered "methylene" 15,600[5] times without any accident, found its effects very similar to

[1] See *Lancet*, vol. ii., 1890, p. 898; and vol. ii., 1887, p. 191.

[2] The author cannot agree with those who state that "methylene" is a rapidly-acting anæsthetic. It may quickly destroy consciousness when given in a somewhat concentrated vapour. But when administered by means of Junker's apparatus, 10, 15, or even 20 minutes may be required to induce anæsthesia. Indeed, the author met with a case in which he had to resort to another agent, as he was unable to secure tranquil and perfect anæsthesia with "methylene." The drug he used was freshly prepared. The patient was a tall, vascular, and powerfully-built woman of 60. After pumping with Junker's inhaler for about 20 minutes the patient was only partially anæthetised. The author then had recourse to another anæsthetic, and in 3 minutes the patient was ready for operation.

[3] "Methylene as an Anæsthetic" (*Brit. Med. Journ.*, 14th July 1888, p. 72).

[4] *Lancet*, vol. i., 1882, p. 371.

[5] *Med. Times and Gaz.* vol i., 1868, p. 111.

those of chloroform, but, according to Kappeler,[1] he met with considerable excitement, rigidity, and nausea in many cases. Hégar and Kaltenbach, who largely used "methylene" with Junker's inhaler, did not consider it safer than chloroform, but found less vomiting after its use. Kappeler endorsed these views.

Administration.—With regard to the administration of "methylene," Junker's apparatus (p. 392) has been found to be the best for the purpose. The administration should be conducted as has been already described when considering chloroform. Difficulty may be experienced in obtaining true surgical anæsthesia in many cases, especially when using Junker's inhaler. It must, therefore, be borne in mind that in operations upon very sensitive parts, and when dealing with patients who are not easily affected by anæsthetics, it may be necessary either to give more of the anæsthetic than can be administered by Junker's inhaler—that is to say, to use some other inhaler—or to change to ether, chloroform, or the C.E. mixture.[2] The anæsthesia produced by "methylene" is, in fact, comparatively superficial, and would hardly satisfy most surgeons of the present day.

Dangers.—Several deaths have occurred during the use of "methylene";[3] the symptoms were almost identical with those which characterise chloroform fatalities. Inversion has been successfully tried in a case of threatened death.[4]

E. SCHLEICH'S MIXTURES

Amongst the numerous other mixtures which have been employed, those introduced by Schleich[5] in 1898 deserve notice. This observer states that by mixing chloroform, ether, and petroleum ether,[6] an anæsthetic liquid may be produced which boils between 38° C. and 42° C., according to the proportions of the ingredients, and that, by slightly adjusting these proportions in accordance with the body temperature of the patient, absorption and elimination may be so balanced that no accumulation of the anæsthetic within the circulation is possible. Theoretically, each inspiration of an anæsthetic boiling at the blood temperature would be eliminated by a corresponding expiration. Anæsthetics with high boiling-points, such as chloroform, are rapidly absorbed and slowly eliminated, owing to the temperature of the blood being below such boiling or maximum evaporation points. The more

[1] *Anæsthetica*, p. 105.

[2] Two cases (rectal operations) are reported by Mr. Martin Coats, in which he found it necessary to replace "methylene" by chloroform (see footnote, p. 475).

[3] See *Lancet*, 23rd Oct. 1869; *Brit. Med. Journ.*, 7th May 1870, 29th April 1871, 16th Sept. 1871, 31st Aug. 1872, 12th Oct. 1872, 19th Oct. 1873; *Lancet*, 2nd Dec. 1874, p. 881; and *Brit. Med. Journ.*, 24th July 1875.

[4] *Lancet*, vol. ii., 1876, p. 462.

[5] See *Therap. Gazette*, 1898, p. 98.

[6] It is stated that the petroleum ether should have a boiling-point between 60° and 65° C.

volatile the anæsthetic, the less will be absorbed by the blood in a given time, and the more rapid will be its elimination. Schleich's "No. 1" mixture consists of—

Chloroform	45 parts
Petroleum Ether	15 ,,
Ether	180 ,,

and boils at 38° C. "No. 2" consists of—

Chloroform	45 parts
Petroleum Ether	15 ,,
Ether	150 ,,

and boil at 40° C. "No. 3" consists of—

Chloroform	30 parts
Petroleum Ether	15 ,,
Ether	180 ,,

and boils at 42° C. So far as the author is aware, these mixtures have not been employed in this country. A modified form of Schleich's mixture, however, has been tried in a small number of cases by Dr. R. J. Probyn Williams, and later by Dr. Silk. This consisted of—

Chloroform	1 part
Petroleum Ether	1 ,,
Sulphuric Ether	2 parts

The results were fairly satisfactory, and may be studied in the *Transactions of the Society of Anæsthetists*, vol. iv. p. 98. One observer [1] has published his experiences in 700 cases, and these are by no means encouraging. The weak point in Schleich's argument is the assumption that his mixtures are definite anæsthetic liquids capable of yielding definite vapours. This assumption, however, is not warranted, and although we are not perhaps justified in criticising his system of anæsthetising without having tested it, there is no reason to believe that Schleich's mixtures possess any tangible advantages over those already discussed.

F. MIXTURES CONTAINING ETHYL CHLORIDE

A few years ago several mixtures containing ethyl chloride as their chief ingredient, and possessing attractive titles such as "Somnoform," "Narcotile," etc., were extensively exploited not only upon the Continent but in this country. "**Somnoform**"—a mixture of sixty parts of ethyl chloride, thirty-five parts of methyl chloride, and five parts of ethyl bromide—was stated by those who introduced it to be absolutely safe, and to produce an anæsthesia free from all after-effects. Its disagreeable odour, however, its tendency to decomposition, its liability, like ethyl chloride, to cause headache and vomiting, and its risk to life when administered by inexperienced persons, have combined to remove this agent from the already overcrowded list of

[1] See Dr. Rodman's interesting paper, *New York Med. Rec.*, 1st Oct. 1898.

general anæsthetics.[1] In two cases in which the author witnessed the administration of "**Narcotile,**"[2] a body stated to be bichloride of methyl-ethylene, and obtained by distilling mixed ethyl and methyl alcohols with hydrochloric acid, a very unsatisfactory form of anæsthesia resulted. "**Anæsthol**" has been a favourite with some American anæsthetists. It is a mixture of alcohol, ether, and ethyl chloride in molecular proportions.

Mr. Harvey Hilliard[3] speaks well of a mixture consisting of **half-a-drachm of ethyl chloride in one ounce of chloroform** for all cases in which the latter anæsthetic is indicated. He states that this mixture is safer than chloroform, and that the patients whom he has anæsthetised with it have displayed less excitement and a better colour, pulse, and respiration than are usually observed with the latter anæsthetic. He specially advises its use in midwifery, in patients with obstructed breathing, in operations for the removal of tonsils and adenoids, and in cases in which the sitting or prone posture has to be adopted.

G. ILLUSTRATIVE CASES

The following illustrative cases may be of interest as showing the value of the A.C.E. or C.E. mixture:—

Illustrative Case, No. 20.—(This case occurred in the practice of Mr. Marmaduke Sheild, to whom the author is indebted for the following notes.) "Patient an engine-fitter, aged 42. A brawny, heavily-built man. Neck practically obliterated by an enormous swelling, reaching from the malar bones to the sternum, livid in colour, and hard and board-like to palpation. Much dyspnœa. Face livid and bedewed with sweat. Pulse weak and quick. Unable to speak or open mouth. Nitrous oxide had been given and an exploratory incision commenced; but the man had so nearly died that the operation was abandoned. It was obvious he was suffering from pressure upon the larynx and trachea. I ordered him to be given the A.C.E. mixture with a plentiful supply of air. I further requested that the administration should be very gradual. It was quite ten minutes before slight rigidity and struggling took place. The patient seemed unconscious to pain, but was not completely flaccid. I made a

[1] Several deaths have taken place in connection with the use of "somnoform." For further information see *Lancet*, 19th Nov. 1904, p. 1408, and *ibid.*, 25th April 1903, p. 1168.

[2] Mr. J. Addyman Gardner, F.I.C., kindly examined a specimen of this substance for the author. He reports that it is not the bichloride of methyl ethylene, and that it seems to be a mixture of methyl chloride, ethyl chloride, and ether.

[3] *Med. Mag.*, Feb. 1906.

free incision on the right side of the neck. The tissues did not bleed. The deep fascia was carefully incised, and I then passed my finger behind the carotid sheath into a large abscess cavity, from which a quantity of of pus gushed out. The inspiration instantly became more free, but as there was still some difficulty, I made a free incision in the middle line of the neck. Instantly the patient began to respire deeply and easily. The anæsthetic had been discontinued at the commencement of the operation, and consciousness was returning. The man was able to speak, though with a hoarse intonation, and he expressed his gratitude at his relief. The subsequent progress of the case was perfectly satisfactory."[1]

Had this patient been placed very deeply under the anæsthetic, or had a close method of inhalation been adopted, respiration would in all probability have come to a standstill.

The C.E. mixture is often of great use in patients in whom grave respiratory difficulties from other causes than tracheal narrowing are present. The following case, in which the breathing was embarrassed by the most extreme abdominal distension that the author has ever witnessed, may be quoted :—

Illustrative Case, No. 21.—F., æt. 37. Thin anxious face: slightly dusky complexion: very breathless and orthopnœic: hands cold: pulse quick and feeble: chest walls thin: abdomen enormously distended with ascitic fluid and large ovarian tumour: heart much pushed upwards. As the patient was sitting upright upon an operating-table I had to administer the anæsthetic standing upon a chair. Judged it best to work with two different stages of anæsthesia: (1) Light anæsthesia during removal of ascitic fluid; and (2) deep anæsthesia during removal of tumour. Stage (1) conducted with A.C.E. mixture: ether tried, but not well borne. Several gallons of fluid evacuated gradually: patient analgesic rather than anæsthetic. One by one pillows removed as fluid evacuated. Breathing gradually improved. During stage (2) patient recumbent, and chloroform given on Skinner's mask. Pulse got rather weak, but improved with hot-water flushing. Subsequently weaker again. Patient removed to bed.

In cases of peritonitis, intestinal obstruction, etc., with a fixed and inactive abdomen, and some respiratory difficulty, the C.E. mixture is often the best anæsthetic; the alternative being ether by the "open" system, with preliminary atropine. The following is an example :—

[1] An almost precisely similar case to the above is reported in the *Brit. Med. Journ.*, 29th Oct. 1892. Ether was used and the patient succumbed under its influence. See also another death, *Lancet*, 23rd March 1895 (chloroform), and also *ibid.*, 21st Feb. 1903 (nitrous oxide). Open methods are alone permissible for these cases of deep suppuration in the neck.

Illustrative Case, No. 22.—F., æt. about 19. Ill for one week with peritonitis. Abdomen distended. Slightly under morphine. Rather lethargic. Pulse fair and full, but compressible and quick. Colour good. Occasionally vomits blackish fluid. Abdominal section. Operation lasted half an hour. A.C.E. given on Skinner's mask. Took it well. After some minutes changed to ether (Clover's inhaler), but this was not well borne, so went back to A.C.E. Kept her lightly under. Nearly all the time she was as follows:—Pupils 2 mm.: some conjunctival reflex, which was allowed to disappear for a few seconds at a time: respiration fairly regular, not stertorous, but deeper and quicker than before administration: colour good: pulse quicker and quicker, getting from about 90 to 120: right hand and arm moved occasionally. She vomited once on operating-table. Whilst intestine and ovary were being manipulated respiration grew quicker, and a kind of "catch" in breathing was noted. No crowing respiration. After removal of anæsthetic colour not so good, though fair: hands warm: pulse quick: conjunctiva soon sensitive. Patient remained lethargic for some time.

As already indicated (p. 167), the C.E. or A.C.E. mixture is a valuable anæsthetic in most cases of advanced cardiac disease. It seems particularly useful when mitral stenosis is present. The following case illustrates the difficulty of uncompensated heart lesions from the anæsthetist's point of view, and the usefulness of C.E. mixture in surmounting it.

Illustrative Case, No. 23.—M., æt. 70. Chest rigid. Pulse very irregular; epigastric pulsation, large liver. Old mitral disease—no murmurs. Bluish veins on face. Dyspnœa: for which the patient was propped up with three or four pillows. C.E. mixture was given on a Skinner's mask; there was no excitement stage, but vomiting occurred once during the induction. Within two minutes the corneal reflex had vanished, and respiration was not at all good. The pillows were removed and the anæsthetic suspended; but breathing remained difficult, and some cyanosis developed. The corneal reflex then returned, but the extremities were cold; the pulse very feeble, and cyanosis could not be entirely prevented. There was no reflex when rectal manipulation began. The operation lasted about twelve minutes, and scarcely any anæsthetic was given; the patient was in fact largely anæsthetised by asphyxia. After the operation concluded the symptoms soon improved.

What the effect of ether by the "open" system would have been is not easy to judge. Possibly the stimulating properties of the ether might have improved the pulse and respiration; but on the other hand, a very slight addition of mucus to the respiratory passages might have had serious effects upon the sorely taxed respiratory system.

The C.E. mixture is also the best anæsthetic for patients with advanced emphysema and bronchitis attended by fatty degeneration and dilatation of the heart. The following case is of interest, as it was a particularly anxious one, so far as the anæsthetic was concerned. The question, in fact, had arisen as to whether it was advisable to give any anæsthetic at all.

Illustrative Case, No. 24.—M., æt. about 70: average build: looks 80. Half propped up in bed. Breathing rather hurried: expiration distinct and audible. Respiratory movements almost wholly diaphragmatic. Chest front hyper-resonant: wheezy sounds over it. Heart sounds "flapping": an occasional murmur in apical region: much epigastric pulsation. Pulse very irregular and intermittent. Face congested: bluish-red colour. He is subject to seizures of difficult breathing and cyanosis. Has a large prostate, and catheter has to be used every 2 hours. Operation supra-pubic cystotomy. Admiuistration lasted 35 minutes. A.C.E. mixture. Gradually given on Skinner's mask. Respiration deeper and expiration more wheezy. No distress. Pulse improved, and became more regular and fuller; but never got quite regular. Face remained flushed. Some perspiration. Muttering. Conjunctiva still sensitive. Eyes commenced turning upwards. Then slight rigidity. No struggling. Catheter passed. Little if any reflex effect. Abdominal muscles tense, and respiration jerky. Distension of rectum by bag caused slight but not inconvenient movement. Skin incision also caused slight reflex movement, but absolutely no effect on wrist-pulse. During most of administration his condition was as follows:—Conjunctiva just sensitive, once or twice insensitive: respiration wheezy, with noiseless inspiration and difficult expiration: pulse as before: pupils about $4\frac{1}{2}$ mm. The hands gradually got chilly, and perspiration increased. No nausea or vomiting after.

The next case shows the advantages of the C.E. mixture and a slow induction over other methods of anæsthetising a certain type of florid, free living, muscular subject.

Illustrative Case, No. 25.—Male patient of alcoholic habits. About nine months previously he was anæsthetised (after preliminary morphine) with the nitrous oxide-ether-chloroform sequence, changed after eight minutes to ether by the "open" system. The whole administration was very difficult, and the resulting anæsthesia by no means ideal. On the present occasion he received morphine ($\frac{1}{4}$ gr.), and atropine ($\frac{1}{120}$ gr.) beforehand. He was then anæsthetised with the chloroform-C.E. sequence (3 minutes and 75 minutes respectively). There was no coughing, straining, or struggling, and an excellent anæsthesia was induced and maintained throughout. The colour was very good; no mucus; no stridor. A very slight corneal reflex was often present. The operation was an exploration of the upper part of the abdomen; perfect relaxation was secured.

CHAPTER XVI

SEQUENCES AND ALTERNATIONS OF GENERAL ANÆSTHETICS

§ 1. Sequences of General Anæsthetics

When certain anæsthetics are administered in succession according to a preconceived scheme, with the object of obtaining narcosis in as smooth a manner as possible with the anæsthetic last administered, we say that such anæsthetics are administered in sequence, and we speak of the anæsthetics collectively as a sequence. Amongst the developments which have recently taken place in general anæsthesia, that of employing certain sequences of anæsthetics is one of the most noteworthy. By the successive administration of appropriate agents, many of the disadvantages incidental to the simpler methods of anæsthetisation may often be eliminated. But anæsthetics are also frequently used in succession or sequence without any such preconceived plan. Thus a change from one agent to another may be indicated owing to certain symptoms on the part of the patient, or to certain requirements on the part of the operator. In all such cases it is obviously advisable that the anæsthetist should know how to steer his patient safely out of one anæsthesia into another. In some of these changes, indeed, as in the change from deep ether anæsthesia to chloroform anæsthesia, considerable care and judgment are needed if difficulties directly dependent upon the change are to be avoided.

There are two kinds of sequences: (*a*) the **simple**, and (*b*) the **compound**. In the simple sequence, two anæsthetics only are employed, one being the initial and the other the terminal agent. In the compound sequence, which is a development or extension of the simple sequence, three or more agents are successively administered: these may be called the initial, the transitional or intermediary, and the terminal agents respectively.

The sequences most frequently used may be divided into four groups, viz.: (1) those which terminate with *ether*; (2) those which terminate with *chloroform*; (3) those which terminate with the *C.E. mixture*; and (4) those which terminate with *ethyl chloride*.

GROUP I

SEQUENCES TERMINATING WITH ETHER

1. The C.E.-Ether Sequence

Owing to the fact that a large number of patients object to the odour of ether, numerous simple sequences have been devised, having as their initial anæsthetic some agent of a less pungent odour. It is true that when the administration of ether is exceedingly gradually conducted upon strictly open lines very little discomfort results. Nothing, however, can render ether vapour positively agreeable. We have in the C.E. mixture, when added drop by drop to an open mask, an agent which, firstly, is by no means unpleasant to inhale; secondly, is safer *ceteris paribus* than chloroform; and, thirdly, is more rapid in its action than ether similarly administered. Moreover, as the very slight risk which attends the administration of this mixture is one which principally comes into operation during the induction period, and as we have, in the terminal constituent of the sequence under consideration, the very agent which is capable, when substituted for the mixture at the right moment, of warding off this particular risk, it is clear that the C.E. ether sequence is one of no small value. We have already seen that there are certain subjects who, during the gradual administration of the C.E. mixture, become excited; they may then struggle and thus introduce an auto-asphyxial risk into the anæsthetisation. There are others who pass into a state of so-called false anæsthesia with shallow breathing and indifferent colour (p. 411). In either case we have in ether the appropriate agent with which to meet the difficulty. The liberal use of ether during incipient excitement and struggling will generally cut short the excitement stage, but even if the struggling continues, there will be practically no risk from this quarter under the substituted anæsthetic. Similarly, the state of false anæsthesia vanishes under the stimulating influence of ether.

There are numerous ways in which this sequence may be applied, but the following has proved to be the best in the hands of the author. The appliances needed are: (1) a mask of the Skinner, Schimmelbusch, or Esmarch type (Fig. 33, p. 335) covered with a single layer of flannel or lint or with several thicknesses of gauze; (2) a drop-bottle capable of delivering its contents either drop by drop or in a small and almost continuous stream (Fig. 59, p. 402); (3) the face-pad and oval collar used for the administration of ether by the perhalation method (Fig. 35, p. 339); and (4) a bottle capable of sprinkling or pouring ether upon the mask (Fig. 34, p. 335).

The mixture is first added drop by drop to the mask and the patient is encouraged to converse or to count aloud, the latter plan being useful in the case of children. Oral respiration is to be preferred to nasal. The slightest indications of discomfort should be met by lessening the frequency of the drops. In from 2 to 6 minutes, according to the susceptibility of the patient and the type of breathing, consciousness will usually have become sufficiently dulled to admit of a few drops of ether being added to the mask without the patient detecting the substitution. Care must be exercised, however, not to make the addition or substitution till the proper moment has arrived. There is no objection to carrying the administration of the mixture to that point at which incoherent muttering, slight muscular rigidity, or other expressions of the excitement stage manifest themselves, although it is better if possible to effect the change just before any such symptoms occur. The cardinal principle to be borne in mind is that of continuously presenting to the patient a mild and equable anæsthetic atmosphere. Any great irregularity in vapour strength at this stage either in the case of the mixture or in that of ether will almost certainly cause breath holding, struggling, and general excitement.

Other things being equal, patients to whom some narcotic such as morphine or scopolamine has previously been given are less likely than others to display excitement, but the avoidance of this state seems to be nearly as much dependent upon the use of an equable vapour as upon that of any preliminary drug. Even the most nervous subjects may often be anæsthetised without a struggle provided care be taken.

When the substitution of ether for the mixture is commenced the face-pad should be placed between the mask and the face. Directly the patient has become accustomed to this slight change ether may be more freely added to the mask. A few moments later the oval collar already described (p. 339) may be placed around the edges of the mask, thus securing the passage of the whole of the respiratory current through the etherised fabric. Occasional lip friction with a soft towel is advantageous. The anæsthetist must observe how respiration is being performed. In most cases it will be found to be nasal in type, and often inadequately nasal. Should the respiratory current be ample there will be no necessity, at all events, at this stage, for interference. If, however, the current be inadequately nasal—and this will be evident from the "sniffing" inspiration and laboured abdominal breathing—it may be necessary in order to obtain the best results to take steps to secure oral respiration. Delay in obtaining anæsthesia is nearly always dependent upon an inadequate respiratory current. It must be borne in mind, however, that any attempt at this stage to convert nasal into oral breathing, unless of momentary duration, is liable to be attended by symptoms of recovery owing to the necessary withdrawal of the mask. Sometimes briskly wiping out the mouth and pushing the lower jaw forwards will bring about the desired amplification of respiration. Sometimes the rapid insertion of a wooden mouth-prop between the teeth (Fig. 16) will be all that is needed to cause the respiratory current to travel by the oral route. Should jaw spasm co-exist with nasal inadequacy, considerable difficulty and delay may arise, and the anæsthetist will have to decide either to treat the *impasse* by crowding on ether, or to remove the mask and pads, open the mouth with a Mason's gag, rapidly sponge out the fauces, and insert the oral "airway" (Fig. 20) with the object of obtaining a free respiratory current. When the change to ether has been effected, when the stage in which unconscious excitement and struggling may possibly arise has been passed, and when the breathing has become perfectly free, ether may be liberally added to the mask, and the administration conducted as already described when dealing with the "perhalation" method of etherisation (p. 337).

The ether anæsthesia thus produced is of a highly satisfactory type, from the point of view of the surgeon, and particularly from the point of view of the abdominal surgeon. Recent clinical observations seem to indicate that although, by various devices and rapidly acting sequences, deep ether anæsthesia may safely be secured within two or three minutes from the commencement of inhalation, the eventual type of anæsthesia so produced is not nearly so satisfactory, either from the surgeon's or from the anæsthetist's point of view, as that which results after a gradual and slower induction as above described. For example, if we induce ether anæsthesia by the "gas and ether" sequence (p. 491), and then exchange the Clover's inhaler for the Skinner's mask and pads (p. 339), and thus proceed from closed to so-called "open" etherisation, we do not obtain quite the same degree of muscular relaxation and quietude of breathing which we should have secured by the gradual induction here advocated. Curiously enough, too, the patient whose nervous system has gradually been invaded will be found to be less liable to display inconvenient reflexes during surgical stimuli than the patient who has been subjected to some rapid induction method.

Should the anæsthetist desire to use the C.E. mixture as a preliminary to **closed etherisation** the same general principles as those mentioned must be followed. In such a case the Clover's or Ormsby's inhaler should be charged with ether either beforehand or soon after commencing the administration of the C.E. mixture upon a Skinner's mask; and the ether inhaler substituted for the mask when consciousness has become so dulled as to allow the substitution to be effected without the knowledge of the patient. If a Clover's inhaler be employed the indicator may either be placed at "0" or between "0" and "1" when the substitution takes place. Should an Ormsby's inhaler be used the administration of the C.E. mixture must be carried a little further than if a Clover's inhaler be employed, otherwise some resistance on the part of the patient may be expected. The introduction of the "open" method of etherisation, however, has dealt a great blow to these closed methods, and hence to sequences of this nature.

There is an interesting clinical fact regarding the use of this sequence. It is that when changing from the mixture to ether a very satisfactory result is obtainable when the C.E. mask is exchanged for an Ormsby's inhaler previously charged with ether. This fact may often be turned to good account when anæsthetising strong, plethoric, or alcoholic men for short operations, upon highly sensitive parts. Thus, simple rectal operations may often be conveniently performed under this sequence thus applied. The administration of the mixture is carried to the commencement of the stage of excitement. The point at which the change should be effected is generally to be recognised by the breathing becoming deeper and of an unconscious type, by muttering or phonated sounds, or by one or both hands slowly being raised towards the head. At this particular juncture, the Ormsby's inhaler, the sponge of which has been moistened with about half an ounce of ether, is loosely and gradually applied. In many cases the breath will be "held" for a second or two, but the breathing will quickly become deep, regular, and stertorous, and the muscular system will rapidly relax. The property possessed by an Ormsby's inhaler, charged with ether, of thus cutting short the excitement stage of the C.E. mixture is very remarkable and is not altogether easy of explanation.

2. The Chloroform-Ether Sequence

Whilst this succession of anæsthetics is advantageous in that it allows of the patient being slowly anæsthetised by the most pleasant of our anæsthetic vapours, it is disadvantageous in that the anæsthetist is liable, unless thoroughly experienced, to overstep the point to which chloroform may be given upon an open mask without incurring that risk which is inseparable from its use when thus administered. If, as is now generally admitted, the chief risk of non-graduated or purely open chloroformisation comes into play during the induction stage, it is clear that unless special care be taken, the use of chloroform as an induction agent may introduce into this sequence almost the same amount of risk as would obtain were chloroform used from first to last. A little reflection, however, will show that there is, during slow chloroformisation, a short interval in time between the point at which consciousness is so dulled that the odour of ether vapour would not be recognised, and the point at which unconscious excitement and struggling—the phenomena which sometimes culminate in danger—are liable to arise; there is a psychological moment, so to speak, at which the change from chloroform to ether should be effected.

The object to be aimed at, therefore, is to administer chloroform only up to that point at which consciousness is impaired, and then gradually to substitute ether so that any excitement which may occur will take place under the latter anæsthetic. Ether is particularly appropriate at this juncture, for not only does it remove risks that would otherwise be present, but it has the effect, often in a remarkable degree, of cutting short any excitement or struggling under chloroform.

The appliances needed for this sequence are identical with those necessary in the preceding sequence. The frequency with which the drops of chloroform should be added to the mask will depend upon the special circumstances present, but the anæsthetist should endeavour to administer a mild and equable atmosphere continuously. As in other similar methods conversation is to be encouraged at the outset, and, in the case of children, counting aloud is advantageous. Consciousness will more quickly become impaired than when the C.E. mixture is similarly employed as an induction agent. The advantage of conversing with the patient at the very outset of this type of administration is that the anæsthetist can easily judge when the proper moment has arrived for commencing the change of anæsthetic. When it is clear, at the end of from one to four minutes (according to the type of subject) that consciousness is waning, a few drops of ether may be added to the mask. A few moments later the face-pad may be adjusted between the mask and the face as a preliminary to the "perhalation" method of etherisation. Ether is now progressively sprinkled or poured in small streams, from time to time, upon the mask, and the administration is thenceforth conducted as in the preceding sequence.

3. The Chloroform-C.E.-Ether Sequence

This sequence has much to recommend it. Though somewhat more complex than those above described, it has the merit of meeting a large number of requirements, and particularly the requirements of fastidious anæsthetists. Whilst the initial factor of the sequence makes the administration as pleasant as possible to the patient, and the terminal factor secures safety, the intermediary factor, containing as it does the the other two factors in a state of mixture, permits the anæsthetist to proceed with remarkable smoothness from chloroform to ether. The sequence is seen to its best advantage perhaps in the case of powerfully-built men to whom morphine and atropine have previously been administered, and in whom it is necessary to obtain a maximum degree of abdominal relaxation for some intra-abdominal procedure.

A chloroform drop-bottle (adjusted so as to deliver drops only), a C.E. drop-bottle (adjusted so as to deliver a small stream of the mixture), and an ether bottle (also capable of delivering a small stream of this anæsthetic) are needed, together with the open mask, face-pad, and gauze collar, above described (p. 339). The chloroform is first dropped on the mask gradually and carefully during conversation or counting aloud. In from one to four minutes, according to circumstances, the C.E. mixture is substituted. After two or three minutes more the face-pad is inserted between the mask and the face, and ether, in its turn, is substituted for the mixture. Finally the oval gauze collar (Fig. 35) is placed around the mask and the administration of ether conducted as above described (p. 337). The remarks which have been made concerning the management of any excitement or struggling that may occur (p. 411), as well as those relating to the paramount importance of free oral respiration under ether (p. 342), must carefully be borne in mind in conducting this sequence.

The following are three cases which illustrate this chloroform - C.E. - ether sequence. The resemblance between the details of the cases arises simply from the fact that in all three the sequence is shown to great advantage; it is one of the chief merits of this method that untoward and unsatisfactory events during the induction and maintenance of anæsthesia are conspicuously rare.

Illustrative Case, No. 26.—Female, aged 45. Very stout, but not wheezy or breathless. Florid colour, heart sounds normal. Morphine ($\frac{1}{4}$ gr.) and atropine ($\frac{1}{120}$ gr.) half-an-hour beforehand. Slow induction with chloroform (3 minutes), C.E. (3 minutes), and then "open" ether. No excitement, no struggling. Appendix removed; then gall bladder also excised. No laryngeal sounds or stertor, no reflex rigidity, no cough. Corneal reflex absent for the greater part of the administration; towards the end it was allowed to return. Manipulations of the peritoneum excited no reflex whatever. The patient was wholly edentulous, and respiration was nasal; but in spite of this, the colour remained excellent. The operation lasted two hours. No after-effects at all.

Illustrative Case, No. 27.—Male, aged about 32. Tall, strong, florid man; moderate in both smoking and drinking. Slight nasal catarrh. Morphine ($\frac{1}{4}$ gr.) and atropine ($\frac{1}{120}$ gr.) half-an-hour beforehand. Induction with chloroform (2 minutes), C.E. (2 minutes), and then "open" ether. Induction took 13 minutes in all; no movement, no excitement. When incision for appendicectomy was made, the corneal reflex was very slightly present, and there was a slight twitch of one foot. There were, however, no abdominal rigidity, no cough, no laryngeal sounds, and no stertor throughout the administration. Except at the commencement, the corneal reflex was absent all the time. No after-effects; patient passed into a deep sleep when administration was suspended.

Illustrative Case, No. 28.—Female, aged 25. Big, healthy patient, not nervous. Appendicectomy; morphine and atropine three-quarters of an hour beforehand. Induction with chloroform (3 minutes) and C.E., then "open" ether. No movement, no excitement. Incision 10 minutes after induction began. Surgeon remarked upon slight rigidity once, but this was easily corrected by rather deeper anæsthesia. Never any sound of mucus, nor any tendency to cough or strain. Once, while appendix was being manipulated, the colour was not quite so good as before, and pulse very slightly less full; but certainly no definite shock worthy of the name. No after-effects.

4. The Nitrous Oxide-Ether ("Gas and Ether") Sequence

We are indebted to Clover for the valuable suggestion and practice of administering nitrous oxide before ether. The former agent is a particularly appropriate one for *inducing* anæsthesia. It is by no means unpleasant to inhale; it rapidly destroys consciousness; its administration is unattended by excitement or struggling; and its use is practically free from risk to life. Although ether, as we have already seen, is the best anæsthetic for ordinary surgical work, the sensations which attend its administration *ab initio* are generally disagreeable. Nitrous oxide therefore supplies the very qualities in which ether is deficient. From the point of view of some patients it is a great boon to be rendered unconscious quickly and to be spared the feelings which attend the initial stages of etherisation. Moreover, the exclusion of atmospheric air, which is essential in the case of nitrous oxide, is less disadvantageous with ether than with other anæsthetics. In other words, we may pass from deep nitrous oxide to deep ether anæsthesia without admitting that quantity of air which would be essential were we dealing with chloroform.

Clover's first plan[1] for the employment of this sequence was to render the patient unconscious with nitrous oxide, and then to change the inhaler for an ether apparatus. His next method was first to administer nitrous oxide by itself, and then to add ether gradually by causing the gas to pass over this anæsthetic. After working at the subject for many years, he perfected his combined "gas-and-ether" apparatus, which was conspicuous for its ingenuity. Experience has proved, however, that this appliance is not only too cumbrous and complicated for general use, but that it possesses other disadvantages. The principal of these is that the channels through which the patient has to breathe are so constricted that considerable

[1] *Brit. Med. Journ.*, 15th July 1876, p. 74.

stress is thrown upon respiration; whilst it is difficult if not impossible thoroughly to cleanse all parts of the inhaler.

Attempts have from time to time been made to administer nitrous oxide and ether by passing the gas through a Clover's portable ether inhaler. It is not proposed to describe in detail what has been done in this direction, as no useful purpose would be served. The chief difficulty which presented itself was, that whereas for the successful administration of nitrous oxide the escape of expired "gas" is essential, at all events at the commencement of the inhalation, no such escape of the expirations is necessary in administering ether. Some years ago the author devoted a considerable time to this particular matter. He found that by attaching a bag containing nitrous oxide to a Clover's inhaler, and by employing a stopcock which would allow of one-half of the nitrous oxide being breathed through valves, and of the remaining half being breathed backwards and forwards during the gradual admission of ether vapour, a very satisfactory result could be obtained. With the introduction of the wide bore modification of Clover's inhaler even greater success was achieved than was possible with the narrow bore models.

The **apparatus** necessary for obtaining the best results with this sequence consists of: (*a*) a face-piece of appropriate size: (*b*) the wide bore ether chamber and bag of Fig. 42, p. 349: (*c*) a nitrous oxide stopcock and bag similar to that shown in Fig. 27, p. 286, but with a stopcock of larger bore: and (*d*) a cylinder or cylinders for the supply of nitrous oxide. The face-piece is fitted to the ether reservoir which, except in hot weather, should have been previously immersed for a few moments in warm water. The nitrous oxide bag is partly filled with nitrous oxide (the quantity placed in the bag being a matter of importance), and the stopcock of the bag is fitted to the ether reservoir. For men with hair about the face the bag should be quite full; for very tall or strong men nearly full; for men of average height and for healthy women about three parts full; and for weakly women and children about half full. The face-piece should be so adjusted upon the ether reservoir that the open filling-tube of the latter is horizontal and ready for the reception of the ether; the ether indicator should point to "0"; and the valves of the stopcock should be dry and freely acting.

Administration is thus conducted. The apparatus having been accurately applied, the patient is requested to breathe backwards and forwards through the mouth. Air will enter and leave the stopcock. Nitrous oxide is then turned on, and one half of the quantity in the bag is breathed out at the expiratory valve. The valves are now thrown out of action, and to-and-fro breathing of the remainder of the gas results. After a few to-and-fro breaths, about half an ounce of ether is rapidly poured into the inhaler (Fig. 64); the plug of the

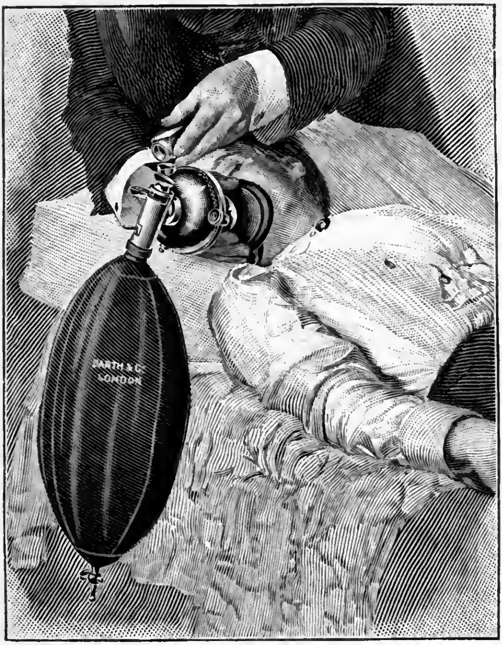

FIG. 64.—The Administration of Nitrous Oxide and Ether by means of the wide-bore modification of Clover's Ether Inhaler and the author's Nitrous Oxide Stopcock.

filling-tube is replaced; and the rotation of the indicating handle is commenced. The juncture at which the ether is introduced is a matter of importance. The ideal moment is that at which consciousness has just vanished. If it be poured in too soon, the patient may detect and remember the unpleasant odour of ether. If the introduction be unduly deferred, there is the chance that, just as the anæsthetist is engaged in pouring in the ether, the symptoms of the patient may indicate the need for the first breath of air, and as this need cannot at the moment be satisfied, the administration loses that absolute smoothness which should characterise it. If the patient be easily affected by nitrous oxide, the ether may be poured in after two or three to-and-fro breaths. If he be comparatively insusceptible, ten or twelve of such breaths may be necessary before a sufficient degree of insensibility is produced. The rotation of the indicating handle is effected more rapidly than in administering ether without nitrous oxide. It is exceptional for the slightest cough, breath-holding, or movement to occur. When snoring commences, one inspiration of air is allowed. Should any epileptiform twitching arise, this symptom must also be taken to indicate the need for air. The indicator is gradually made to pass towards "F," an occasional breath of air being permitted. It is often a good plan to expedite vaporisation by grasping the ether reservoir with the hand. At the end of about one or one and a half minutes the gas-bag should be exchanged for the smaller ether bag; and the handle moved to "2" or "3" according to the type of subject and the depth of anæsthesia required for the operation. The apparatus then presents the appearance of that shown in Fig. 42, p. 349, and the administration is conducted as already described when discussing ether anæsthesia (p. 350). If these details be carefully followed, the patient will not be conscious of the slightest odour of ether, and anæsthesia will be induced without excitement, struggling, or asphyxial complications. The advantage of having a large bore to the ether vessel has already been alluded to, and this advantage is very conspicuous in passing from nitrous oxide to ether anæsthesia.

This method of administering nitrous oxide and ether has numerous advantages. Firstly, it is precise; that is to say, with known quantities of the two anæsthetics, and with a perfectly fitting face-piece, one is able to obtain similar results in similar subjects. Secondly, if the quantity of nitrous oxide be carefully adjusted to the requirements of the particular case, it is possible to obtain all the advantages of this anæsthetic as an induction agent without the occurrence of asphyxial symptoms. Thirdly, only a limited quantity of nitrous oxide is needed, so that the bag may be filled before the patient enters the room. The patient is thus spared the noise, etc., connected with the supply of nitrous oxide to the bag, and the administrator is spared the trouble of keeping up a supply of the gas with the foot-key during the administration. One may have to give "gas and ether" to patients who are lying in bed, and in these circumstances it is a great convenience to have at hand a detached bag of nitrous oxide. As already mentioned (p. 152), the method is not very satisfactory for patients with much hair about the face, owing to the

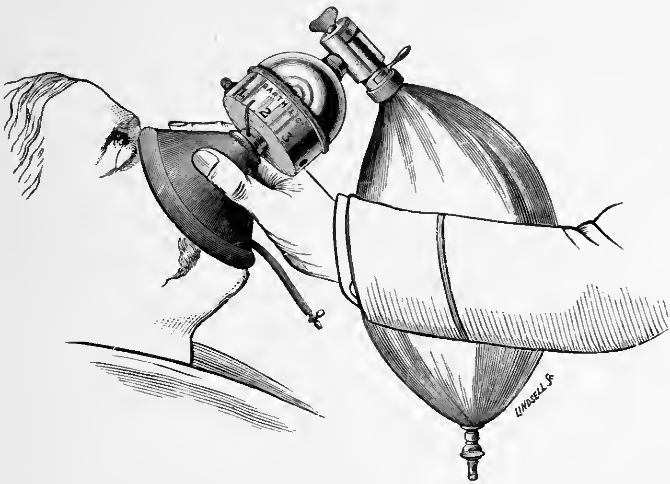

FIG. 65.—The Administration of Nitrous Oxide and Ether by means of Clover's Ether Inhaler and the author's Nitrous Oxide Stopcock.

impossibility of obtaining perfect coaptation of the face-piece. Other disadvantages are the free salivation and mucorrhœa which are often produced. It is the frequency of a slight asphyxial element during full etherisation which probably accounts for this; and the growing favour of open methods of administration of ether, with preliminary atropine medication, is due largely to this effect of Clover's inhaler.

The narrow-bore Clover's inhaler shown in Fig. 37, p. 345, with the corresponding stopcock and bag of Fig. 27, p. 286, will also answer well for this sequence, but not so well as the wide-bore apparatus. The administration with a narrow-bore inhaler is represented in Fig. 65. As it is necessary with the narrow-bore inhaler to charge the ether reservoir before applying the face-piece, there may be an odour of ether when the patient commences to inhale. As already mentioned, there is a greater liability to stertor and cyanosis with a narrow-bore than with a wide-bore apparatus. With the exception that the ether chamber is charged with ether before use, the administration is conducted in the way above described.

There is a simple way of administering nitrous oxide and ether which is employed by some anæsthetists. The metal angle-piece to which the bag of Clover's inhaler is attached is furnished with a small tap to which a tube from a nitrous oxide cylinder may be fitted. The administration is begun by allowing some nitrous oxide to pass into the bag, and the patient breathes this backwards and forwards whilst ether is gradually mixed with it by rotating the ether reservoir. This plan has the merit of simplicity; but considerable experience is required to avoid introducing an unduly asphyxial element into the administration.

5. The Ethyl Chloride-Ether Sequence

This sequence has been extensively employed, although the initial sensations are somewhat less pleasant to the patient than those of nitrous oxide. As already mentioned, it is necessary to administer a fairly strong ethyl chloride vapour in order to produce that rapid effect which is essential if we wish to eliminate excitement, and it is this strength of vapour which may constitute the disadvantage of the sequence. By a very slight error in the adjustment of the initial strength, suffocative sensations, culminating in breath-holding, struggling, and respiratory spasm, may occur. At the same time, there can be no doubt that this sequence constitutes a valuable addition to our resources.

One of the best ways of **administering** these anæsthetics in succession is the following. The apparatus required is that shown in Fig. 42, p. 349. Although not designed for this sequence, it happens to meet every requirement. About 3 c.c. of ethyl chloride are sprayed into the bag, which is then fitted to the ether reservoir. The ether indicator is *turned to "F,"* the plug of the filling-tube is removed, and the face-piece is applied. With this arrangement of apparatus the to-and-fro current will be found to pass chiefly through the wide and open filling-tube, the thick walls of the rubber bag offering so much resistance to the current that it takes the easier course. The result of this is that little or no ethyl chloride vapour is at first breathed. As the handle is gradually moved, however, *from "F" towards "0,"* the resistance to the current through the empty ether chamber increases, so that more of the current enters the bag. In this way the strength of the ethyl chloride vapour is gradually augmented, and when "0" is reached the breathing takes place entirely into and out of the bag. All that is now necessary is to pour in about an ounce of ether through the open filling-tube, to replace the plug, and to move the indicator gradually *from "0" towards "F."* Should the ethyl chloride produce an unexpectedly profound effect, and abolish corneal reflex, air must be admitted during the transition. In ordinary circumstances, however, air is unnecessary until ether stertor commences. The rotation of the indicating handle may be effected more rapidly than in the nitrous oxide-ether sequence. In this way ethyl chloride anæsthesia may be made to pass gradually into ether anæsthesia, and the latter condition may be maintained as already described.

If preferred, the wide-bore inhaler may be used somewhat differently. About 3 c.c. of ethyl chloride are placed in the ether reservoir itself, which in warm weather may require cooling before the introduction of the anæsthetic. The indicator of the inhaler is turned to "0," and the face-piece is applied so as to catch two or three expirations in the bag. After a few respirations, the indicator is gradually turned on to "1," "2," etc., as in administering ether, till deep breathing, stertor, or a dulled lid reflex indicates sufficient ethyl chloride anæsthesia. The indicator is then rapidly brought back to "0," the plug is removed, and about an ounce of ether quickly introduced. At this juncture a breath of air may be necessary. The indicator is now gradually turned on, and ether anæsthesia ensues in the ordinary course, an occasional breath of air being admitted.

Another convenient plan is to use the modified Ormsby's inhaler of Fig. 44, p. 353. The sponge having been removed and placed near at hand, about 3 c.c. of ethyl chloride are sprayed into the bag. The inhaler, with its air-slot open, is then applied during an expiration. About an ounce of ether is now poured upon the sponge, or the latter is made to absorb this quantity of ether from an open glass vessel. By gradually closing the air-slot as already described, ethyl chloride anæsthesia is rapidly induced. The etherised sponge is then passed into the inhaler, which is quickly replaced, and ether anæsthesia then supervenes.

All the three methods just described have the advantage that there is no ether in the inhaler when the ethyl chloride is being administered. Sometimes, however, it is convenient to charge the ether inhaler with ether before inducing anæsthesia. Thus McCardie [1] employs an ordinary Clover's inhaler, with the addition of a two-way stopcock in the angle piece of the bag. A few c.c. of ethyl chloride are placed in the bag, and the stopcock is turned off, so that the vapour is imprisoned. The ether chamber is charged with ether, and the indicator turned to " 0." The face-piece is applied during two deep expirations, which are caught in the bag by closing the two-way stopcock at the end of the second expiration. The patient is instructed to breathe very quietly, the air-hole of the stopcock being gradually closed, so that the way is opened to the bag containing the ethyl chloride. Anæsthesia takes place so rapidly that ether vapour may quickly be admitted to the current. It is important not to use more than 2 or 3 c.c. of ethyl chloride, and to admit air when stertor commences. In this way ether anæsthesia becomes quickly induced.

GROUP II

SEQUENCES TERMINATING WITH CHLOROFORM

6. The Ether-Chloroform Sequence

This sequence, like certain others, is generally one of expediency rather than one which has been predetermined;

[1] *Birmingham Medical Review*, November 1905.

a sequence, in fact, rendered necessary by the exigencies of the case. There is perhaps no sequence which more frequently gives rise to difficulties and dangers than this one, although when the nature of such difficulties is fully understood it is easy to avoid them. It occasionally happens in practice that ether is badly borne, and that the anæsthetist falls back upon chloroform. There are some patients who, as the expression goes, "take ether badly," even though it be administered carefully and by the most appropriate method. It is exceedingly important, therefore, to bear in mind that a change from ether to chloroform is a totally different thing to a change from chloroform to ether. When we change from chloroform to ether we pass from an agent which is bland, but depressing, to one which is, comparatively speaking, irritating and stimulating, and the result is, as a rule, highly satisfactory so far as the general well-being of the patient is concerned. But when we pass from ether to chloroform we must be on our guard, particularly if the patient be deeply etherised. If ether anæsthesia be only partly established, and the corneal and laryngeal reflexes be not annulled, there is little to be said against such a change. In fact, there are many anæsthetists who intentionally employ such simple sequences as the "gas and ether," the ethyl chloride-ether, or the C.E.-ether up to a certain point; and then change to chloroform with the object of eliminating all excitement and of thus passing smoothly to chloroform anæsthesia. The intentional use of chloroform after ether, as in such compound sequences, is, however, a different matter to changing from deep ether anæsthesia to chloroform in order to correct undesirable symptoms. When once we have fully anæsthetised a patient with ether, and have permitted that anæsthetic to excite the secretion of more or less mucus in the upper air passages and to stimulate the respiratory and circulatory systems to the utmost, we must be exceedingly careful in changing to chloroform. By such a change the anæsthetist lays down a comparatively blunt and takes up a comparatively sharp instrument. The free respiratory movements of ether will tend to cause a very rapid absorption of chloroform; the higher blood pressure of the more stimulant anæsthetic will quickly begin to fall; and the churned-up mucus in the larynx and trachea—which offers no appreciable resistance to the forcible air current under ether—will now begin to constitute a definite obstruction to the comparatively feeble respiratory current of chloroform. In other words, unless the anæsthetist be on his guard; unless he sponge out mucus and encourage its expulsion by permitting a few acts of coughing or swallowing, he may easily find that his patient is passing, or has suddenly passed, into a highly undesirable state (pp. 378 and 570). As a general rule the corneal, swallowing, and coughing reflexes should be allowed to return before the change is effected, and a careful and continuous watch must be kept till it is clear that the proper type of chloroform anæsthesia has become established.

7. The C.E.-Ether-Chloroform Sequence; 8. The Chloroform-Ether-Chloroform Sequence; and 9. The Ethyl Chloride-Ether-Chloroform Sequence

As just mentioned the sequences of Group I., namely, the C.E.-ether, the chloroform-ether, the nitrous oxide-ether, and the ethyl chloride-ether sequences may often advantageously be employed, to lead up to chloroform anæsthesia. The change from ether to chloroform should be made just before the full effects of ether have been secured. As we have already seen, each of these simple sequences has its special advantages during the induction period, and if it be desired to secure these particular advantages and to use chloroform subsequently, a change from ether to chloroform may readily be made.

The point at which the change should be made may generally be known by the coexistence of the corneal reflex with softly snoring breathing, or by the coexistence of this reflex with an occasional cough. At this point the ether inhaler is removed, the lips wiped out with a soft cloth, and a chloroform mask applied. The degree to which the mask should be moistened with chloroform will depend upon the circumstances present and the experience of the anæsthetist. Should the change be made somewhat prematurely, and the patient return to the excitement and struggling stage, it is better to reapply the ether inhaler for a few moments than to persist with chloroform. On the other hand, should the anæsthetist have produced rather too deep an ether narcosis, partial recovery attended by cough should be encouraged; and the chloroform mask, moistened with small quantities of the anæsthetic, may then be applied.

10. The Nitrous Oxide-Ether-Chloroform Sequence

A few special remarks may, perhaps, be made concerning the nitrous oxide-ether-chloroform sequence. By the employment of this sequence for the great majority of ordinary surgical cases, most requirements of the anæsthetist, patient, and surgeon may be fulfilled. As a general rule the patient loses consciousness in six or seven breaths; there is no odour of ether either beforehand or during the transition from nitrous oxide to that anæsthetic; and there is no struggling, excitement, coughing, retching, cyanosis, or respiratory embarrassment. In addition to these great advantages the parts under operation are less vascular than when ether is employed throughout; whilst the patient is saved the unpleasant taste and other after-effects incidental to close etherisation. It would, of course, be idle to assert that a smooth induction may be relied upon in every case; but provided the proper subjects be chosen, and the method be conducted with the closest attention to detail, difficulties rarely, if ever, arise. The author has now employed this succession of anæsthetics for several years, and whilst admitting that it is hardly suitable for those who have had but little experience, he can confidently recommend it to all others. By its use one is able to pass to deep chloroform anæsthesia in a comparatively short time—usually in from five to six minutes—and the somewhat disconcerting phenomenon of false chloroform anæsthesia is never witnessed.

In order that the reader may fully understand the practical details of this sequence, he should carefully study what has already been said concerning the nitrous oxide-ether and the ether-chloroform sequences (pp. 491 and 498). The nitrous oxide-ether sequence is carried to the point above indicated;

and at this point the change to chloroform is effected. As the success of the sequence under consideration largely depends upon the change to chloroform being made at the proper moment, it is particularly important that the remarks made in connection with the ether-chloroform sequence should carefully be studied.

11. The C.E.-Chloroform Sequence

On the assumption that the C.E. mixture is safer than chloroform for the induction of anæsthesia, some anæsthetists employ it for this purpose and then change to the latter anæsthetic. The substitution of chloroform for the mixture is also frequently made when it is clear that the latter is producing some respiratory distress, as it may in asthmatics or other patients suffering from some derangement of the respiratory system. The anæsthetist should proceed with caution and bear in mind the different values, so to speak, of the two agents he is employing. This sequence has its chief sphere of usefulness in operations on the tongue, larynx, neck, and brain.

GROUP III

SEQUENCES TERMINATING WITH THE C.E. MIXTURE

12. The Ether-C.E. Sequence

This sequence, for obvious reasons, is generally used from necessity rather than by design. We have already spoken of the precautions to be observed when changing from ether to chloroform (*vide supra*, p. 499), and the remarks that have been made apply with almost equal force to this particular succession of anæsthetics.

13. The C.E.-Ether-C.E. Sequence; 14. The Chloroform-Ether-C.E. Sequence; 15. The Nitrous Oxide-Ether ("gas and ether")-C.E. Sequence; and 16. The Ethyl Chloride-Ether-C.E. Sequence

The remarks already made concerning the compound sequences referred to in Group II. apply also with regard to these sequences.

17. The Chloroform-C.E. Sequence

The only appliances necessary for the application of this sequence are an open mask, a chloroform drop-bottle, and a C.E. drop-bottle. The chloroform drop-bottle should be adjusted so that it delivers its anæsthetic in drops only. The C.E. drop-bottle should be adjusted so as to deliver its contents in a small stream. After from one to three minutes of very gradual chloroformisation a small quantity of the mixture may be added, from time to time, to the mask by momentarily tilting the drop-bottle so that from five to ten drops of the mixture fall upon the fabric at each tilt.

The substitution of the terminal for the initial anæsthetic may be effected a trifle earlier in this sequence than in the chloroform-ether sequence, as the substitution of the C.E. mixture is less likely to be detected during waning consciousness than the substitution of ether. After one or two minutes' administration of the C.E. mixture the additions to the mask may be made more frequently. As already mentioned a slow and gradual induction is the key to the avoidance of excitement and struggling. Should such phenomena arise great care must be taken not to press the anæsthetic unduly. Should struggling commence it is best, as a general rule, to remove the mask for some seconds and briskly to wipe out the inside of the lips with a towel with the object of keeping up regular respiration. Should the excitement stage threaten to become pronounced, and ether be at hand, it is good practice to substitute this anæsthetic till struggling has begun to subside, when the mixture may be resumed. Excitement and struggling are, however, attended by less risk under the C.E. mixture than under chloroform similarly administered. Should the respiration become shallow under the C.E. mixture, either early in the administration or later, the addition of a little ether to the mask will generally quickly re-establish a proper type of breathing. In certain cases, indeed, and particularly in those in which some degree of surgical shock presents itself (p. 69), it is excellent practice to alternate the C.E. mixture and ether in obedience to the requirements of the case till it is obvious from the condition of the patient that the mixture may be resumed.

This sequence is useful when the patient particularly desires chloroform, at all events for the commencement of the administration, whilst other indications point to the use of the C.E. (or A.C.E.) mixture.

GROUP IV

SEQUENCE TERMINATING WITH ETHYL CHLORIDE

18. The Nitrous Oxide-Ethyl Chloride Sequence [1]

The advantages of this sequence which is only applicable for brief operations, such as those of dentistry, are as follows:—The induction period is invariably smooth; the patient detects no odour of ethyl chloride; and a deep anæsthesia with muscular relaxation is obtained. The theoretical advantages of the sequence from a physiological standpoint have lately been emphasised by Guy, Goodall, and Reid (see p. 127). A two-gallon bag is partly or completely filled with nitrous oxide according to the type of patient; a graduated tube containing about 3 c.c. of ethyl chloride is fitted to the vulcanite stopcock at the bottom of the bag; one half of the nitrous oxide is exhaled through valves; the other half is breathed backwards and forwards; the ethyl chloride is gradually tilted into the bag (Fig. 66); and a breath of air is admitted if required. The interesting point about this method is that patients are by its use plunged, in an extraordinarily short space of time, into the deepest anæsthesia with which we are acquainted, the pupils becoming dilated and the muscular system relaxed with almost alarming rapidity.

Dr. A. Moritz employed this method at the Royal Dental Hospital of London in over 3000 cases. He found that patients preferred the induction sensation to those of ethyl chloride alone; that coughing, cyanosis, excitement, and struggling never occurred during the induction stage; that marked vaso-dilatation was often produced; that deep anæsthesia came about with extraordinary rapidity; that the best results were

[1] This sequence was described by the author in the *Journal of the British Dental Association*. September 1903, vol. xxiv. p. 615.

obtained with fairly large doses (5 c.c.) of ethyl chloride without much rebreathing; that during the recovery stage there was often a long analgesia period free from movement, which could generally be utilised by the operator; that headache, vertigo, hysterical outbursts, and (in men) pugnacious demonstrations occasionally manifested themselves after the administration; that nausea or vomiting occurred afterwards in about one case in every seven; that in alcoholic and neurotic subjects a much

Fig. 66.—Apparatus for the administration of Nitrous Oxide in conjunction with Ethyl Chloride.

better result was often obtained than with nitrous oxide; that the average available anæsthesia was about 60 seconds; that the method could always be depended upon for providing an adequate anæsthesia; and that in no case were there any dangerous symptoms.

The author does not employ this method to any great extent on account of the undue frequency of unpleasant after-effects.

§ 2. Alternations of General Anæsthetics

Certain anæsthetics, and particularly ether and chloroform, are sometimes administered alternately either throughout or, more commonly, towards the conclusion of an administration. Thus, the so-called "two-bottle" method by which ether and chloroform are alternately dropped or sprinkled upon an open mask (the induction of anæsthesia having been accomplished by "gas and ether" or ethyl chloride and ether) has been in use for many years at the Bristol Royal Infirmary and is spoken of very highly by Mr. A. L. Flemming.[1] After full anæsthesia has been induced by one of the sequences just mentioned, and close etherisation has been in progress for some little time, a Murray's domit mask is substituted for the ether inhaler, and ether and chloroform are alternately added to the mask from time to time. Mr. Flemming advises that the fabric should be kept moist with ether and that chloroform should be added to it in very small quantities—one drop in every four, five, six, or even seven breaths being sufficient to maintain an even anæsthesia. By this method the total quantity of chloroform used is often as small as four or five drachms per hour.

A somewhat similar plan of alternating ether and chloroform was introduced some years ago by Dr. Walter Tyrrell who employed for the purpose a modification of Junker's inhaler (Fig. 49, p. 393) consisting of two bottles for the respective anæsthetics. By this arrangement he was able to alternate the two vapours as occasion required. He reported favourably upon the method, particularly as regards after-effects.

Whilst there can be no doubt that we have in ether on the one hand, and in chloroform or a chloroform mixture on the other, agents which, from many points of view, are particularly appropriate for this alternate plan of anæsthetisation, the ether counteracting any depression which the chloroform or chloroform mixture may have induced, and the chloroform or the chloroform mixture rendering it possible to

[1] *Brit. Med. Journal*, 17th Sept. 1910, p. 767.

reduce the quantity of ether used, we must not lose sight of the fact that there are certain inherent disadvantages and risks in thus alternating ether and chloroform. We have already seen (p. 499) that great care is needed in substituting chloroform for ether, particularly if the ether anæsthesia be deep, the breathing rapid, and the secretion of mucus excessive, and that unless the administrator be on his guard and employ exceedingly small quantities of chloroform, he may readily overstep the bounds of safety. There is, of course, less objection to alternating the C.E. mixture and ether than to alternating chloroform and ether, and it must be admitted that the C.E. mixture is often particularly useful for meeting certain contingencies in the course of an "open ether" administration. Thus, we have already seen (p. 339) that if during the induction of anæsthesia by "open ether" or by a sequence terminating in "open ether" there should be any great difficulty in obtaining the full ether effect, small quantities of the C.E. mixture may, with advantage, be added to the mask, and that full anæsthesia may thus be more rapidly induced. Moreover, there are many cases in which it is advantageous, in the later stages of an "open ether" administration, to alternate carefully ether and the C.E. mixture. The author has tried this plan in several cases and can speak well of it. It often happens, for example, in the course of an "open ether" administration that a favourable opportunity presents itself for a more or less regular alternation of ether and the mixture. Thus, if in the course of "open ether" the circumstances are such that the administrator can allow, or thinks it advisable to allow the corneal reflex to return he may, on the appearance of this reflex, temporarily substitute a few drops of the C.E. mixture for ether, and as the reflex vanishes resume the ether, repeating the alternation, with more or less regularity, throughout the administration. Such a course is often advisable when the surgeon is dealing with some comparatively insensitive structure or when there is some special reason, owing to the patient's condition, for maintaining as light a degree of anæsthesia as possible. By this alternation the total consumption of ether—always a matter of importance in certain subjects and in protracted operations—may be reduced. If, however, during such an administration a very profound effect should be desired, if the surgeon should be about to embark upon some stage of the operation likely to be attended by shock, or if shock should actually be developing, the alternation should at once be suspended in favour of continuous etherisation. As a general proposition it may be said that should a deeper anæsthesia be required and the corneal reflex be *present* the indication would be for the mixture, whereas should a deepening of the anæsthesia be needed and the corneal reflex be *absent* the indication would be for ether. Practised upon these lines and applied with a due appreciation of the different values, so to speak, of the two agents employed, the alternation of ether with the C.E. mixture will often be found to be advantageous to the patient and convenient to the anæsthetist.

CHAPTER XVII

LOCAL AND REGIONAL ANÆSTHESIA

A. THE PROPERTIES OF THE PRINCIPAL DRUGS USED FOR PROCURING LOCAL OR REGIONAL ANÆSTHESIA

For many centuries the inhabitants of Peru have been in the habit of chewing the leaves of the coca-plant for the purpose of obtaining mental calm and physical endurance. But it is only within the last half-century that any serious attention has been devoted in Europe to the investigation of the active principles contained in these leaves; and their use for the production of local and regional anæsthesia is of correspondingly recent date. Up to the end of the last century these were the only local anæsthetic drugs which had proved at all satisfactory; but in the last ten or twelve years several excellent synthetic substitutes have been discovered and placed upon the market.

The dried leaves of the coca-plant contain four alkaloids: cocaine, truxilline (isatropyl-cocaine), cinnamyl-cocaine, and tropacocaine. The first three are closely allied chemically to each other, but the fourth differs from them considerably in composition. Tropacocaine is present in much larger proportion in Javanese coca than in the South American varieties, and is in fact prepared commercially from the Asiatic product.

Cocaine and tropacocaine are thus seen to be vegetable alkaloids; whereas most of the synthetic local and regional anæsthetics are not true alkaloids at all, although many of them have been given names terminating in -ine.

Cocaine is methyl-benzoyl-ecgonine; its composition is represented by the formula $C_{17}H_{21}NO_4$. It occurs in colourless monoclinic prisms with a slightly bitter taste. It is almost insoluble in water; but one part of it is soluble in 10 parts of 90 per cent alcohol; in 4 parts of ether; in $\frac{1}{2}$ part of chloroform; in 4 parts of oleic acid; in 12 parts of olive oil.[1]

Cocaine hydrochloride occurs in colourless acicular crystals and as a crystalline powder. One part is soluble in 3 parts of 90 per cent alcohol; in $\frac{1}{2}$ part of water; in 3 parts of glycerin. The solutions have a bitter taste, and are said to keep better if half per cent of boric acid is added to them.

Cocaine itself and the hydrochloride are officinal in the *British Pharmacopœia.* There are also several other salts of this alkaloid which have been and are used to a certain extent. The carbolate has been favourably reported on in dental practice. The citrate, also used chiefly by dentists, is deliquescent and highly soluble. The formate is much less soluble than these. The lactate has been used especially for allaying vesical pain. The nitrate has the advantage of being compatible with silver nitrate, and has been useful for this reason in ophthalmic surgery. The salicylate has been given for asthma: it is soluble 5 parts in 1 of water, and $2\frac{1}{2}$ in 1 of 90 per cent alcohol. The hydrobromide and the sulphate are identical in action with the officinal salt (Whitla). The hydriodide is chiefly used in dental surgery, and is contained in Martindale's *Dental Anæsthetic.*

Tropacocaine is freely soluble in water. It is obtained from Javanese coca, but is also contained in the South American leaves (*vide supra,* p. 509). The constitution of tropacocaine is benzoyl-pseudotropeine-hydrochloride.

Alypin is the hydrochloride of benzoyl-tetramethyl-diamino-ethyl-dimethyl-carbinol. It is a white crystalline powder, soluble in an equal quantity of water (Squire) and almost to an equal degree in 90 per cent alcohol.

Anæsthesine is the ethyl ester of para-amido-benzoic acid, and is thus allied chemically to novocain. It is soluble only to the extent of 1 part in 1200 of water, and 1 in 6 of

[1] W. Hale White, *Materia Medica,* 11th ed. p. 399.

alcohol. The para-phenol sulphonate of anæsthesine is known as *subcutol*, and has been used in 0·8 per cent solution to produce local infiltration anæsthesia (Whitla).

β-eucaine is benzoyl-vinyl-diacetone-alkamine, soluble one part in one and a half of aniline oil. The hydrochloride is soluble in 30 parts of water;[1] in 4 parts of aniline oil; and in 11·5 parts of alcohol (90 per cent). The lactate is also much used, and is considerably more soluble than the hydrochloride (1 in 4 of water; 1 in 8 of alcohol).

Holocaine is the hydrochloride of para-diethoxyethenyl-diphenyl-amidine. It is soluble in 50 parts of water and in 6 of 90 per cent alcohol.

Nirvanine is the hydrochloride of diethyl-glycocoll-para-amido-orthohydrobenzoic methyl ester. It has marked antiseptic properties.

Novocain is para - amido - benzoyl - diethyl - amino - ethenol hydrochloride. It is soluble in equal parts of water. It melts at 155° C.

Orthoform is methyl-para-amino-meta-oxybenzoate. It is a white, bulky, odourless, crystalline powder, strongly antiseptic; it is only sparingly soluble in water (1 in 450, Squire), but soluble it alcohol (1 in 6). The hydrochloride is soluble in 8·4 parts of water, and in 17 parts of 90 per cent alcohol.

The Hydrochloride of Quinine and Urea has been used in America as a local anæsthetic. It is soluble in equal parts of water.

Stovaine is the hydrochloride of ethyl-dimethyl-amino-propinol benzoate. It is soluble in $1\frac{1}{4}$ parts of water and in 4 parts of alcohol.

Acoine is dipara-anisyl-monophenethyl-guanidine hydrochloride. It is but slightly soluble in water.

B. THE PHYSIOLOGICAL ACTIONS OF THE DRUGS COMMONLY USED FOR PRODUCING LOCAL OR REGIONAL ANÆSTHESIA

Cocaine has been in use for a very much longer period of time than any of the other drugs mentioned in the preceding

[1] One in 40 (Squire).

section; and it is natural that its physiological action on the various tissues and organs is better understood than that of some of its lately discovered synthetic rivals. Further, researches into the properties of the latter substances are often expressed in terms of cocaine as a standard; and it will therefore be convenient to consider briefly the action of cocaine as a local anæsthetic, before indicating the points in which the other drugs differ from it.

Cocaine has little action on the unbroken skin; but when a 5 to 10 per cent solution of the hydrochloride is applied to mucous membranes it produces complete local anæsthesia to pain and touch. When injected subcutaneously the same effects are produced at the site of inoculation. When stronger solutions are used the sensibility to heat and cold is abolished, and motor paralysis also results. Cocaine stimulates vaso-constrictor nerves, and hence produces contraction of the arteries.

When a solution of cocaine, or of a salt of cocaine, is dropped into the eye, local anæsthesia is produced—first of the conjunctiva and cornea, later of the iris also. This anæsthesia is developed in about seven minutes, and lasts about the same length of time. At first there may be a transitory contraction of the pupil; but this is soon replaced by wide dilatation, which lasts for twelve to twenty-four hours, or even longer. The dilated pupil responds little or not at all to light, and accommodation is also paralysed. The ocular tension is slightly lowered, and the palpebral fissure is widened. The vessels of the eye are constricted. These effects are due to irritation of the sympathetic.

When a solution of a cocaine salt is injected into the subdural space of the spine, sensation and motor power are abolished in all regions the nerves of which arise from the cord below the point of injection, or below the level to which the cocaine solution has been diffused.

When cocaine is absorbed into the circulation it is quickly converted into ecgonine. It is excreted by the kidneys.[1]

The use of cocaine as a local anæsthetic has many times

[1] The greater part of the foregoing paragraphs has been derived by kind permission from Dr. W. Hale-White's *Materia Medica.*

been attended also by constitutional symptoms, due to the toxic action of the drug when absorbed. The maximum official dose of cocaine hydrochloride is half a grain, and this should not be exceeded. Some few patients, however, possess an idiosyncrasy to cocaine, and exhibit symptoms of poisoning as a result of absorbing very small quantities of the drug. The symptoms develop rapidly, and may include vertigo, pallor, fainting, profound cardiac and respiratory depression with tremors and other nervous symptoms.

Tropacocaine is less toxic than cocaine, but more rapid in its action. These two are said to be without any marked action upon the red blood corpuscles, whereas the synthetic substitutes tend either to destroy them or to modify their powers of resistance. Tropacocaine is less irritating to the eye than cocaine, and does not dilate the pupil.

β-eucaine has a slower and less powerful action than cocaine; but anæsthesia is more prolonged, the heart and circulation are not markedly affected, and the pupil is not dilated. It can safely be given in very much larger dosage than cocaine.

Orthoform is so little soluble that it has practically no action upon unbroken skin or mucous membrane. But applied to sores or abraded surfaces it is a powerful local anæsthetic and antiseptic, and is much less toxic than cocaine. *Nirvanine,* like eucaine, has a more prolonged and less toxic action than cocaine. *Holocaine,* on the other hand, has effects somewhat resembling those of strychnine, and therefore cannot be used in strong solutions. It does not affect the pupil, accommodation, or circulation. *Alypin* also is without action upon the pupil, and is less toxic than cocaine on the human subject, although it seems to be highly toxic to certain animals (*vide infra*).

Braun's postulates—omitting one not generally accepted—with which a satisfactory **local anæsthetic drug must comply** are:

1. Low toxicity in proportion to anæsthetising power.

2. Solubility in water to 2 per cent at least; and stability of the solution, which should keep without deteriorating and be capable of sterilisation by boiling.

2 L

3. Non-irritability to the tissues, and freedom from after-effects when absorbed into the circulation.

4. Compatibility with suprarenal extract.

Cocaine, stovaine, novocain, tropacocaine, alypin, β-eucaine lactate, and nirvanine are sufficiently soluble to satisfy the second postulate. β-eucaine hydrochloride is near the 2 per cent limit. Acoine, holocaine hydrochloride, orthoform, and anæsthesine are all more or less insoluble. (It is to be noted that insolubility is not necessarily a disadvantage in all circumstances: thus orthoform has been much used in laryngeal work, insufflated in the dry state through the upper aperture of the glottis.) All the drugs mentioned above which are soluble will keep in solution without deteriorating; and all except cocaine can be sterilised in solution, if necessary, at a temperature of 115° C. Stovaine does not bear sterilising so well as the others do.

The most powerful anæsthetic action is that of stovaine; next stand cocaine, novocain, tropacocaine, alypin, and β-eucaine lactate, which are all about equal. The others have inferior actions in this respect. Experiments on mice and rabbits have resulted in the construction of a table of toxicity relative to cocaine:[1]

Alypin,	1·25	Stovaine,	0·625
Cocaine,	1·00	Novocain,	0·490
Nirvanine,	0·714	β-eucaine lactate,	0·414

The irritant action upon the tissues of stovaine, tropacocaine, and β-eucaine lactate is greater than that of cocaine; that of novocain is less. All these five are compatible with suprarenal extract, but the solutions should be used freshly mixed. Either sterile water or sterile normal salt solution may be used to dissolve the anæsthetic.

An important research into the properties of six local anæsthetics has been published by M. J. Chevalier.[2] This author finds cocaine more toxic than any other of those experimented with; alypin runs it close in this respect, but

[1] Le Brocq, *Pharm. Journ.*, 1909, p. 674.

[2] *Bulletin des Sciences Pharmacologiques*, abstracted in the *Lancet*, 29th Nov. 1909.

does not surpass it. He agrees with Le Brocq, however, in placing these two as easily the most toxic of the group. Chevalier points out that cocaine differs from the rest in causing a rise of blood-pressure, owing to its general and local vaso-constrictive power. Of the others, stovaine most nearly approaches cocaine in this respect, but it has no action on the vaso-motors. β-eucaine is an energetic cardiac depressor, and for this reason its toxicity is greatly increased when it is rapidly introduced into the circulation.

When local anæsthetics are combined with the active principle of the suprarenal glands, the intense vaso-constrictive action of the latter is said to lower the cellular vitality of the tissues, and so to increase the susceptibility of the cells to the action of the anæsthetic drug. Whether this is the case or not, the main advantage derived from the combination lies in the fact that thereby the circulation in the tissues is so much impeded that the anæsthetic remains much longer in contact with them, and is not carried off in the lymph stream. Thus a more intense, because more truly local, action is produced.

C. LOCAL ANÆSTHESIA

General Considerations.—It is seldom that the professional anæsthetist is called upon to produce local anæsthesia for surgical purposes, since surgeons usually prefer to regard this as part of the technique of the operation and to manage it themselves. Text-books of operative surgery, accordingly, contain information on the best methods of securing local anæsthesia; but it is essential that anæsthetists also should possess a working knowledge of the subject, especially in view of the multiplication of drugs, and methods of using them, of the extension of local with spinal or general anæsthesia, and of the widened sphere of usefulness which local anæsthesia now possesses.

The indications for local anæsthesia vary with the individual operator, with the confidence he has in his anæsthetist, and with the country in which his medical education has been conducted. Here in Britain local anæsthesia is favoured, broadly speaking, mainly for short and trivial operations. The freezing of whitlows, boils, and other superficial abscesses previous to incision has long been a common practice. The subsequent smarting and the imperfect analgesia obtained do not recommend the method when dealing with highly-strung, nervous patients; and the impossibility of dissection in the frozen tissues restricts the use of this method to those cases where a simple superficial incision is alone requisite. Infiltration anæsthesia, popular in certain clinics abroad, has not yet established itself amongst us. Local anæsthesia by drugs is steadily making headway; in many dental practices it has superseded general anæsthesia, and in the surgery of the nose and throat the same is also true, though to a lesser extent. For the snaring of nasal polypi, the incision of quinsies, the removal of laryngeal tumours, and numerous similar minor operations, local anæsthesia has deservedly won a position of favouritism from which no improvements in general anæsthesia are likely to oust it. In ophthalmic surgery general anæsthesia is now hardly ever required except for one or two operations, such as iridectomy for glaucoma, and excision of the globe.

In general surgery local anæsthesia is much used for the removal of sebaceous cysts, warts, or pieces of superficial tissues for examination, urethroscopy, cystoscopy, and other procedures. Its value is also universally admitted in operations, such as tracheotomy, exploratory lung puncture, etc., when owing to the patient's condition a general anæsthetic may be particularly dangerous:—

Illustrative Case, No. 29.—Male patient, aged 50. Very big powerful man, markedly obese; a free liver and great smoker. An epitheliomatous growth was obstructing the larynx, rendering breathing very difficult; for forty-eight hours swallowing had been impossible. To administer a general anæsthetic was to render disaster inevitable; so novocain and adrenalin were injected, first *into* the skin over the trachea, and then *under* the skin and into the deeper tissues. Although the analgesia produced was not quite everywhere complete, the patient, a very plucky man, allowed a tracheotomy to be performed without wincing. Owing to the thick neck and obesity of the patient, this operation took about twenty minutes. The result was infinitely better than could have been hoped for under a general anæsthetic. On a subsequent occasion chloroform was successfully administered through the tracheotomy tube.

Unfortunately local anæsthesia by drugs is of less value in inflammatory and suppurative conditions, as the introduction of the hypodermic needle is too painful to allow of the solution being injected near enough to the site of operation. The difficulty can sometimes be surmounted by anæsthetising the nerves which supply the affected part, a proceeding which has been recommended by some operators. This requires a careful study of anatomy (as, for example, in anæsthetising the nerves of a finger for the opening of a whitlow), and the method has not been adopted to any great extent in this country. It is, however, enthusiastically advocated by Leedham Green[1]; and it is quite possible that the near future may witness considerable progress along these lines. Venous injection of local anæsthetics has been suggested, and E. C. Ryall is experimenting with it in this country.[2] The risk of thrombosis is said to be slight, but more experience is needed before a definite pronouncement is possible.

On the Continent local anæsthesia is used in many operations for which British surgeons prefer general anæsthesia. One reason of this may be the much higher level of skill in general anæsthesia which undoubtedly exists in this country. In consequence of this our surgeons do not look with the distrust born of experience upon general anæsthesia for certain operations, and so they do not experiment with local anæsthetics so freely. Goitre, for instance, and especially the exophthalmic variety, is in some European surgical clinics removed under local anæsthesia only. Strangulated hernia, empyema, cervical glands, and many other operations which render general anæsthesia more difficult than usual, are held to be indications for local anæsthesia. For some of these spinal anæsthesia is now adopted, with results which are certainly more satisfactory than local anæsthesia pure and simple gives. But it is clear that the greater the perfection attained with the technique of general anæsthesia, the less likely is the surgeon to resort to local anæsthesia for these major operations. On the other hand, if local anæsthesia can be brought to such a pitch of perfection that a strangulated

[1] *Vide* a series of articles in the *Midland Medical Journal*, 1911; and the *Medical Annual*, 1912.

[2] *Practitioner*, Feb. 1911.

hernia can be relieved without pain to the patient and with less risk than when a general anæsthetic is employed, then for that case a general anæsthetic is certainly contra-indicated.

Local anæsthesia can be produced by three **methods**, namely, by *cold*, by *infiltration*, and by *drugs*.

Cold is best applied by spraying the part with ether or ethyl chloride, and so freezing it. Ethyl chloride is usually employed, and the best result is obtained when the tube is held some distance—three feet or so—from the tissues aimed at, so that a shower of many fine droplets reaches the skin, which rapidly turns white and hard. It is this hardness which prevents anything beyond a simple incision of the frozen tissues. The method is therefore suited only for small superficial abscesses, where a single incision is alone necessary. The freezing process produces a partial analgesia rather than a true anæsthesia; and the process of thawing, which soon begins, is distinctly uncomfortable. Ethyl chloride for this purpose is sold in tubes having a much smaller aperture than those designed for use in general anæsthesia. This results in economy of ethyl chloride and in a more efficient frigorific effect.

Infiltration, a process associated especially with the name of Schleich, consists of the distension and infiltration of the tissues around the operation area with normal salt solution, to which minute quantities of drugs, such as cocaine, morphine, suprarenal extract, and the like, are sometimes added. It is particularly important to inject the solution first of all *into* the skin, and not under it. It is claimed that by this method anæsthesia can be produced sufficient to admit of the performance of even prolonged operations; but the resulting œdema of the tissues is a drawback to dissection of them which has militated against the popularity of the method.

The **drugs** used for procuring local anæsthesia have already been enumerated above (p. 510). The favourites in this country are cocaine, eucaine, and novocain.

For **nasal, pharyngeal,** and **laryngeal** operations, a solution of one or other of these local anæsthetics is either painted or sprayed on to the surface of the mucous membrane about the site of operation. Eucaine (β-eucaine lactate) and novocain can be safely used in strengths up to 10 per cent for this purpose, and in quantities sufficient to produce full anæsthesia of the surface layers. Cocaine should not be used stronger than 5 per cent. Many instances of syncope and other distressing symptoms have attended the use of strong cocaine solutions; and fatal accidents due to cocaine poisoning from this source have occurred. Whatever strength is used not more than half a grain in all of cocaine should be given.

For **ophthalmic** surgery a 2 per cent solution of cocaine hydrochloride is a favourite strength. One or two minims should be dropped into the conjunctival sac ten minutes before the operation is begun; and three similar instillations after five minutes, just before operation, and just after the eye has been irrigated, respectively. In ophthalmic practice eucaine has been found to cause too much irritation[1] and novocain to be not powerful enough.[2]

For **subcutaneous injection** novocain and eucaine are to be recommended; and suprarenal extract increases the efficiency of both of them. A very useful formula[1] is the following:

Solution of suprarenal extract (1 in 1000) . .	♏ x
β-eucaine lactate	gr. iij
Sodium chloride	gr. xij
Water to	dr. iiiss

The whole of this quantity, which should be freshly prepared and sterile, can be used without fear of toxic symptoms. A sterilised syringe with a fine needle should be filled with solution, and about five to fifteen minims injected into, not under, the skin in three or four places round about the site of operation. After five minutes more anæsthetic can be injected under the skin, and later still into the deeper tissues, and into the site of operation itself (unless this is contra-indicated by the nature of the proposed operation). The deeper the dissection involved by the latter, the deeper should the injections be carried. If during the operation sensation begins to return, more solution can be dropped into the wound or injected round about it. A 2 per cent solution of novocain with three minims of 1 in 1000 adrenalin added to each drachm, is equally useful. According to

[1] Corner and Pinches, *Operations of General Practice*, p. 29.
[2] Jessop, *Ophthalmic Surgery and Medicine*, p. 492.

Bennett and Gamble, a solution of cocaine hydrochloride containing 0·594 gm. in every c.c. is isotonic with normal blood serum. Similar isotonic formulæ for eucaine and novocain are given as follows :—

β-eucaine lactate 0·2 gm.	Novocain	0·25 gm.	0·50 gm.	2·0 gm.
Sodium chloride 0·87 gm.	Sodium chloride	0·87 gm.	0·82 gm.	0·5 gm.
Distilled water to 100 c.c.	Distilled water to	100 c.c.	to 100 c.c.	to 100 c.c.

D. THE COMBINATION OF LOCAL WITH SPINAL OR GENERAL ANÆSTHETICS

The use of local anæsthesia to minimise the pain caused by a **spinal injection** is of value when dealing with children, women, or nervous men (see pp. 143 and 519).

The commonest combination of **local** with **general anæsthesia** is in the surgery of the throat and nose. A plug soaked in suprarenal extract and some local anæsthetic is frequently pushed into the nares some minutes before the time of operation. As a rule this is best removed by the anæsthetist, with the consent of the surgeon, before the administration is begun.

That the combination is not without danger when strong solutions are used is shown by the following case, which is not the only one of the sort we have encountered :—

Illustrative Case, No. 30.—F., 23. Not nervous; good colour; heart-sounds normal. Submucous resection of nasal septum. Some time before operation both nares were plugged with cotton wool soaked in 10 per cent cocaine and adrenalin. Chloroform administered in dorso-lateral posture. Whilst corneal reflex still present, operator passed in a small sponge with *solid cocaine* on it to a point which had been hyperæsthetic. There was a slight phonated sound, and the patient was noticed to be pale. Vomiting seemed imminent, and the fauces were accordingly sponged to expedite this act. The breathing was irregular and rather deep, with pauses, and there was slight stertor with inspiration. The pupils dilated, and the eyelids slightly separated, but not suddenly. The head was then lowered, and as matters did not improve the chest was compressed five or six times by the surgeon. The corneal reflex, which had vanished, now returned, and the pulse (not previously felt) was fair; but the hands were cold and the face pale. Respiration was still irregular, with deep sighs and pauses. Chloroform was again cautiously given, and the operation, which lasted an hour, was completed. During the whole of this time respiration remained sighing and irregular, and several times the fauces were stimulated to keep the breathing going. *The pupils remained dilated.* The breathing remained of a sighing type for two or three hours after recovery, but the patient suffered no other ill effect. It seems clear that this was a case of acute cocaine poisoning, possibly due to the rapid absorption of solid cocaine in a patient already fully cocainised.

Another manner in which local anæsthetics are sometimes useful is in dealing with patients whose throats are irritable or inflamed; as, for instance, by excessive smoking or voice-using. The vapour of ether or chloroform sometimes sets up such additional irritation in these patients as to lead to choking sensations, struggling, or coughing. A little dilute cocaine sprayed on to the fauces and larynx beforehand may circumvent this obstacle to a smooth induction.

E. SPINAL ANÆSTHESIA

The induction of anæsthesia for surgical purposes by the injection of drugs into the spinal theca was first suggested by Corning; but Bier in 1898 was the first to put the suggestion into practice. At that time cocaine was the local anæsthetic in general use; and Bier accordingly used it for inducing spinal anæsthesia. The results were far indeed from satisfactory; and Bier himself abandoned the method for the time being, recognising that the perils of cocaine thus used rendered the method much too dangerous. Notwithstanding this, Tuffier continued to use cocaine; but spinal anæsthesia was almost unanimously condemned until 1903 and 1904, when stovaine, novocain, and tropacocaine were introduced, and spinal anæsthesia took on a fresh lease of life. Since then the method has been tried by innumerable surgeons and anæsthetists both in Britain and in other countries, and many modifications of technique have been devised. In England Barker, McGavin, Gray, Canny Ryall, and others, have devoted special attention to the subject, on which they have published numerous papers. Notwithstanding the enthusiasm with which these authors speak of spinal anæsthesia, the consensus of opinion amongst British surgeons and anæsthetists absolutely condemns it *as a routine method*; and the authors share this feeling very strongly. This being the case, it will be convenient first to consider the indications and contra-indications for spinal anæsthesia, before discussing the physiology or the practical details of the administration. For a good account of the history and development of spinal anæsthesia, the reader is referred to a paper by A. Brownlee.[1]

Indications and Contra-indications for Spinal Anæsthesia

For normal healthy individuals there is not the slightest doubt that spinal anæsthesia by any method hitherto introduced is more dangerous than the most dangerous of general anæsthetics, chloroform. It's use is therefore quite unjustifiable in ordinary cases, when there is no particular danger attaching to general anæsthesia, and when a competent person can be procured to administer. In all ordinary surgical cases, therefore, spinal anæsthesia is contra-indicated. There are, however, certain patients to whom this contra-indication applies with special cogency; and on the other hand there are those in whom spinal anæsthesia is permissible or even actually indicated.

Contra-indications of more than ordinary cogency may be furnished by the state of the patient, the operation to be performed, or the extraneous circumstances of the case.

The State of the Patient.—Notwithstanding the advocacy of Gray[2] we remain unconvinced that spinal anæsthesia is desirable for children; save perhaps in infants so desperately ill that a general anæsthetic is impossible, as for instance in a case of enterectomy for intussusception published by Fairbank and Vickers.[3] But apart from exceptional cases of this kind, spinal anæsthesia should not be attempted under the age of seventeen. Old age, on the contrary, is not a special contra-indication. Nervous, excitable, and morbidly introspective patients should not be operated upon under spinal anæsthesia if it is possible to avoid it.

Spinal disease of any kind (locomotor-ataxy for instance)

[1] *Practitioner*, Feb. 1911, p. 214.

[2] *Lancet*, 25th Sept. 1909; 2nd Oct. 1909; and 11th June 1910.

[3] *Ibid.*, 5th Feb. 1910. This, it is fair to admit, is one of H. T. Gray's own cases.

is an absolute bar to the induction of spinal anæsthesia; and so is the existence of a cerebral tumour. So also is any local septic condition, such as a bed-sore or a pustular eruption, which prevents the injection being made with full aseptic precautions. Septic lesions well away from the lumbar spine need not of themselves be contra-indications; but conditions of general infective or septic disease should prohibit the employment of spinal anæsthesia.

The operations to be performed are limited to those upon regions below the diaphragm; indeed it is very seldom that anything above the level of the umbilicus can safely be attempted under spinal anæsthesia. Operations involving the Trendelenburg position should not be performed under spinal anæsthesia; nor any involving manipulation of the spinal cord (laminectomy, etc.).

Extraneous circumstances of the case may contra-indicate spinal anæsthesia. Thus conditions in which it is impossible to procure pure and sterile solutions of the drug selected, or to rely absolutely on the aseptic technique of the injection, or to have at command reliable instruments for the purpose; in all these conditions spinal anæsthesia is better avoided. Absolute rest in bed for 24 hours afterwards at the least is essential; and unless this can be obtained spinal anæsthetisation should be denied.

Indications for spinal anæsthesia may, like contra-indications, be classified into those connected with the patient, the operation to be performed, and the extraneous circumstances of the case.

The state of the patient which may indicate spinal anæsthesia includes, roughly speaking, just those conditions which make general anæsthesia highly dangerous. Pneumonia,[1] or other acute lung disease; advancing pulmonary tuberculosis; pleurisy with effusion; pericarditis; long-standing cystitis giving rise to ascending infection and pyelitis; morbus cordis, in the stage of broken compensation; diabetes, in the stage of acetonæmia and threatening coma; renal disease, in the stage of incipient uræmia: in all these conditions an anæsthetic may be necessary for some grave emergency, and if the site of

[1] Cf. *Brit. Med. Journ.*, 28th May 1910, p. 1282.

operation be below the diaphragm, spinal anæsthesia may be legitimate or even indispensable.

The advocates of spinal anæsthesia lay great stress on the lessened shock which is occasioned by drastic operative procedures. There is, probably, some validity in this contention; but this advantage is often neutralised by a condition of subsequent collapse which is directly due to the spinal anæsthetic. Further, in nervous patients, especially women, the alarm and mental disturbance caused by the circumstances of a surgical operation performed during consciousness tend to counterbalance the advantage gained by the diminution of actual surgical shock. So great may be the mental disquietude during the preliminaries of spinal analgesia that the patient may assume a distinctly cyanotic appearance. Taking everything into account, therefore, it can hardly be said that spinal anæsthesia possesses any marked advantages over general anæsthesia in this particular respect; and this is all the more true when the open ether method of inhalation anæsthesia is selected for the purposes of the comparison.

To show the usefulness of spinal anæsthesia in dealing with dangerous operations on exceptionally bad subjects, the following case is quoted.

Illustrative Case, No. 31.—Very feeble, emaciated man, aged 68. Dilated heart; aortic and mitral regurgitation; dyspnœa; irregular pulse. Abdominal exploration for epigastric tumour, which had caused much vomiting and cachexia. 0·12 gm. of novocain and 0·001 gm. of strychnine were injected into the theca through the 12th interspace. In ten minutes anæsthesia was complete up to the nipples. An epigastric incision showed that the mass was an inoperable cancer of the stomach, and the wound was sewn up again. The patient recovered sufficiently to proceed home a month later, where he soon afterwards died of his disease.

The operation contemplated must be, as has already been said, in a region below the diaphragm, and should be below the umbilicus. Acute intestinal obstruction of some days' standing, with fæcal vomiting, is a condition for which spinal anæsthesia may be appropriate; and especially so if the obstruction is due to a strangulated hernia. Prostatectomy in old men is another operation for which spinal anæsthesia has distinct advantages: an excellent relaxation can always be secured, and the patients are so often suffering from purulent cystitis or pyelonephrosis that they are bad subjects for the very deep narcosis under ether or chloroform which the surgeon requires for his manipulations. Ectopic gestation with profound collapse from hæmorrhage is another condition where spinal anæsthesia has proved valuable.

The extraneous circumstances of the case which may indicate spinal anæsthesia are multifarious. Thus, surgeons practising in remote countries where no one is available to act as anæsthetist, can perform many operations which formerly were impossible. In such cases the ordinary contra-indications of spinal anæsthesia do not apply, and much latitude may be allowed. Moreover, in tropical countries ether evaporates very rapidly and may be difficult to administer; so that chloroform is often the anæsthetic of routine, and when given by a nurse or even by an untrained native is probably more dangerous than spinal anæsthesia induced by the surgeon himself. On shipboard, too, spinal anæsthesia has a wide field of application; an outfit for the purpose might well be added to the Board of Trade list of surgical apparatus which owners are compelled to provide on board their vessels.

In military surgery spinal anæsthesia may also prove to be of value. Some medical officers do not think so, since modern military surgery is practised as little as possible on the battlefield, and almost entirely in stationary hospitals miles from the firing line. It seems possible, however, that the prejudice against field surgery might be lessened if it were shown by experience that better results can be obtained with spinal anæsthesia than with chloroform. It must not be forgotten that it is the terrific shock, entailed by an amputation or similar major operation on a man who is in a state of chronic starvation and chronic overwork, and has just passed through the exhausting horrors of a modern battle, that deters surgeons from primary operations on the field. The next great war will probably provide experience on this point; and it may be found that spinal anæsthesia lessens shock so much as to bring field surgery once more into favour.

Then again there are emergencies which arise suddenly soon after a full meal. A fracture or a dislocation of the lower limb, or a traumatic rupture of some internal organ may occur, and anæsthesia may be necessary without delay. For setting a broken leg or thigh, or for reducing a dislocation of the hip, in such circumstances, spinal anæsthesia may be most useful, especially as it provides full muscular relaxation of the part.

The Drugs used for inducing Spinal Anæsthesia

The drugs used for spinal anæsthesia have been numerous. In this country those now commonly used are novocain and stovaine; tropacocaine is also used by some administrators, though it is not so popular with us as with certain of the Continental clinicians. For comparisons of the toxicity and other properties of these drugs, the reader is referred to the information given earlier in the chapter (p. 511 *et seq.*).

Of drugs used in combination with the foregoing, the most important are suprarenal extract and strychnine. The former has been used with novocain and stovaine, but has no particular advantage, and has now been abandoned by most anæsthetists. The latter is highly praised by Jonnesco and by his disciple in this country, E. C. Ryall. It is given for the purpose of preventing any inhibition of the respiratory centre by the direct action of the anæsthetic; and it is claimed that by its use it is safe to make the injection in any part of the vertebral column, and to anæsthetise patients for operations on the head, neck, and arms. It will be sufficient here to express the author's profound dissent from this latter proposition (see p. 523). At the same time it may be said that the use of strychnine in spinal anæsthesia is of advantage as a prophylactic against respiratory failure; but the doses used must be very minute. In one recorded fatality caused by spinal anæsthesia, it is believed that the symptoms were due to overdosage of strychnine rather than of novocain.[1]

Other ingredients of a spinal injection have been used because of their physical characteristics. Thus Barker employs glucose to secure viscosity, and to make the injected solution so much heavier than the cerebrospinal fluid that its destina-

[1] *Brit. Med. Journ.*, 19th March 1910, p. 690.

tion can be controlled by appropriate postures after it is injected. Gum arabic has been used on the Continent for the purpose; and mannitol has also proved useful in the same way.

The Technique of Lumbar Anæsthetisation

Though the question of technique has received the most painstaking consideration from very many surgeons and anæsthetists, there are still many points on which opinion is not unanimous. In what follows reference is made to novocain and stovaine, but this implies no censure of tropacocaine, which has been repeatedly spoken of highly by those who have used it. Since improvements and changes in technique are frequent and rapid, we shall indicate here only in a general way the methods of which our personal experience justifies us in speaking. It will therefore be understood that there are other methods, and that it is necessary at present to preserve a perfectly open mind as to the relative merits of different methods.

First and foremost *asepsis* is the one essential foundation on which everything else depends. No one should think of inducing spinal anæsthesia unless his antiseptic and aseptic technique is beyond reproach. At present there has been in this country but little shortcoming in this respect; for the method has been in the hands almost exclusively of experienced surgeons and of highly-trained anæsthetists. But since others may have occasion to use spinal anæsthesia in the future, it is necessary to emphasise in the strongest possible way the imperative necessity of the most stringent and careful asepsis.

The skin may be disinfected by any recognised efficient routine; and should then finally be washed over with sterilised water. If the lately fashionable iodine method be used, the sterilised water will not be necessary. Into the skin over the proposed site of injection may with advantage be injected fifteen or twenty drops of some local anæsthetic, such as the solution of eucaine recommended on p. 519. The local anæsthetic must be sterile, and must be injected with disinfected and gloved hands from a sterilised syringe.

The novocain or stovaine for intrathecal injection is best procured in ampoules containing definite quantities of drug in a definite volume of water, and with dextrose or any other inert ingredient already added. Such ampoules are now manufactured by many firms. If strychnine is to be given as well, it is best made up separately and mixed with the anæsthetic in the barrel of the syringe. The maximum dose of stovaine for a fully adult patient in good condition is 0·1 gm.; that of novocain slightly more, up to 0·15 gm. As a rule, it is advisable not to exceed half or two-thirds of these doses—with 0·0005 to 0·001 gm. of strychnine if thought advisable—and to wait a few minutes until the anæsthesia produced can be determined. If anæsthesia is not sufficiently complete, the remainder of the dose may be injected.

There are numerous instruments for the purpose on the market. An ordinary Pravaz syringe does well; and Barker's instruments have also proved very satisfactory in our experience.[1] The Record syringe is also a useful instrument. The apparatus must be carefully sterilised by boiling; and if stovaine is used, care must be taken that no soda is present in the steriliser. The quantity of solution for a single injection is from 1 to 5 c.c. Barker now uses a solution consisting of stovaine 5 parts, glucose 5 parts, and distilled water 90 parts, all by weight. This fluid is as nearly as possible isotonic with the blood; it has a specific gravity of 1023, as against that of the cerebro-spinal fluid, which is 1007. The ordinary dose of stovaine which he now uses is 0·05 gm., which is contained in 1 c.c. of this solution: he finds it very rarely necessary to exceed this amount.[2]

The patient sits with the head and shoulders bent well forward, and the spine arched. If he is not in a fit state to sit up, the injection may be given in the lateral posture; but the knees should be well drawn up and the back fully rounded. The administrator then defines the interspace selected for the spinal puncture. As a rule the third lumbar interspace gives the best results; but for high abdominal operations the 12th dorsal, or the 1st or 2nd lumbar space

[1] A. E. Barker, *Brit. Med. Journ.*, 23rd March 1907, 1st Feb. 1908, and 22nd Aug. 1908.

[2] *Ibid.*, 16th March 1912.

may be chosen. With hands carefully disinfected, then rinsed in sterile water or sterile salt solution, and finally gloved, the administrator enters the trocar in the middle line, midway between two consecutive vertebral spines. The trocar is kept exactly in the sagittal plane of the body; but is directed slightly upwards rather than quite vertically at right angles to the skin surface. Occasionally this manœuvre will fail to enter the theca, in which case a lateral puncture about half an inch to one side of the mid-line may be tried; in this case the trocar is pushed slightly inwards towards the mid-line, as well as slightly upwards.

When the theca is successfully entered—at a depth, in adults, of 8 or 9 cm.—clear cerebro-spinal fluid issues from the trocar. If blood alone issues, or if no fluid issues, the injection should not be made, but another puncture performed. If cerebro-spinal fluid tinged with blood appears, the injection can, as a rule, be successfully proceeded with. The amount of fluid thus allowed to run out should not greatly exceed in bulk the quantity of solution which it is proposed to administer. The barrel of the already filled syringe should be rapidly connected, and the desired dose introduced through the trocar into the spinal theca. The trocar is then withdrawn, and the puncture sealed with sterile gauze and collodion.

The next care of the administrator is the subsequent posture of the patient. If the proposed operation is on the lower limb, the patient should remain sitting for half to one minute, and should then be laid supine with a pillow under the shoulders and head. If the injection be made in the lateral posture, the limb to be operated on should correspond with the under side of the patient; and the patient should be left in that position for one and a half minutes before he is placed supine. If the lower abdomen is to be opened, the supine position may be assumed twenty to thirty seconds after the injection has been given, care being taken to keep the head and shoulders distinctly raised above the level of the abdomen by pillows. If the upper abdomen is the site of operation, the patient should be laid supine at once with the pelvis raised on a pillow, and the head and shoulders also raised; the dorso-lumbar spine is then the lowest part of the trunk.

The Phenomena of Spinal Anæsthesia

The objective phenomena exhibited when a spinal anæsthetic injection has been properly given are, in chronological order:—

(*a*) Loss of knee-jerks.

(*b*) Loss of plantar and cremasteric reflexes.

(*c*) Gradually increasing analgesia of the feet, legs, thighs, perineum, abdomen.

(*d*) Loss of motor-power in the same regions, coming on after the analgesia.

In about six or seven minutes anæsthesia is complete up to the umbilicus, and in three or four minutes more up to the epigastrium. Sometimes the level of anæsthesia reaches the nipples, or even the clavicles; and when Jonnesco's method of cervical injection is followed, there is no limit to the resulting anæsthesia.

The subjective sensations are: Sensations of warmth and glowing of the feet, soon extending to the legs and thighs. Then follows a feeling of swelling as if there were an increased flow of blood to the lower limbs; also a feeling of heaviness, probably due to early muscular paralysis. The upper limit of anæsthesia is usually quite abrupt. One medical man who has personal experience of a hernia operation under spinal anæsthesia says that when he coughed he felt as if his abdominal contents were being forced down on to a solid mass in the pelvis; when his (right) Poupart's ligament was stitched, he felt as if heat were being applied to the skin over the splenic region, and had to satisfy himself by inspection before he could believe that this was not the case.

Certain effects other than those enumerated above are also sometimes met with. Pallor, nausea, vomiting, sweating, and feeble pulse are occasionally produced by the injection. Relaxation of the sphincter ani is not uncommon. Air hunger and other signs of respiratory disturbance are also sometimes exhibited.

The resulting anæsthesia lasts for a variable time. Sometimes it begins to pass off in half an hour, sometimes it remains complete for an hour and a half or two hours. Usually after an hour there is some return of sensation, and if this happens before the operation is finished, it is best to administer a very little chloroform or ether. As sensation returns, there is often severe pain in the wound, and small doses of morphia sometimes quite fail to control this. Complete failure to produce anæsthesia is not very rare; it is probably due to some error of technique whereby the trocar fails to enter or becomes disengaged from the interior of the spinal theca.

After-Effects

The most frequent sequelæ are headache and pyrexia. The former may be very severe and persistent; the latter does not usually exceed 102° F. Vomiting is not uncommon, but is seldom prolonged or troublesome. Respiratory failure has been reported many times from the Continent, but does not seem to have troubled British administrators much. Post-operative pneumonia is said to follow spinal just as frequently as it does general anæsthesia.

Paralyses of various muscles have been reported in a small percentage of cases, and are often both serious and prolonged. Paralysis of the sphincters sometimes occurs; and the resulting incontinence of urine or fæces is very annoying to the patient, though it generally passes off in course of time. Ophthalmoplegias are the next commonest sequelæ, and are sometimes far from transient; paralysis of the external rectus has been the most frequently reported, and may be permanent. Paraplegia has been reported a good many times. Meningitis has also, rarely, been a sequela of spinal anæsthesia; defective asepsis in technique is probably the usual explanation of this extremely serious complication. Persistent insomnia is also sometimes set up.

As regards the effect of spinal anæsthetics upon the urinary system, the evidence is slightly conflicting. Cystitis and paralysis of the bladder causing retention and incontinence are sequelæ which undoubtedly occur. Albuminuria and casts or blood are said by recent investigators to be quite common; indeed, it is affirmed that in three cases out of four renal changes of more or less consequence can be detected. This is denied by the more enthusiastic advocates of spinal anæsthesia. For detailed information on this point reference should be made to a paper by E. C. Ryall,[1] in which comparisons are given of the effects upon renal secretion of the different drugs in use for inducing spinal anæsthesia. Riche and Chauvin[2] report that stovaine produces a lasting and severe albuminuria in practically every case. After novocain albuminuria is usually more transient; but they have found glycosuria once and urobilinuria twice after the use of this drug.

The most important research into the effect of spinal anæsthesia upon the actual tissues of the cord is that of Spielmayer,[3] who took the opportunity to examine thirteen cases *post mortem*. In some cases no change was found; but in others lesions which are deemed to be characteristic of, and attributable to, the anæsthetisation, were made out in the cells of the anterior cornua. This author has also done experimental work upon animals, an account of which is given in the same paper.

The fate of the drugs injected to procure spinal anæsthesia has been investigated by Klose and Vogt, and in this country by Barker.[4] The latter confines himself to stovaine, traces of which he can detect in the cerebró-spinal fluid up to forty-eight hours after injection, though most of it is eliminated therefrom within half that time. He also finds that stovaine appears in the urine from the forty-fifth to seventy-fifth hour. Only once in twelve cases could it be found earlier than this. The maximum excretion is from the fiftieth to sixtieth hour.

The Mortality Rate of Spinal Anæsthesia

The list of complications and sequelæ already given is enough to show that these powerful drugs are capable of exerting injurious influences on the central nervous system. This capacity has, unfortunately, many times been the direct

[1] *Practitioner*, Feb. 1911, pp. 235-240.
[2] *Comptes rendus de la Soc. de Biol.* No. 71, 1911.
[3] *Münch. med. Woch.*, Aug. 1908, p. 1629.
[4] *Brit. Med. Journ.*, 18th Sept. 1909, p. 789.

cause of death. Numerous lists of consecutive spinal anæsthetisations, often running into thousands, have been published, with death-rates from nothing up to one per cent. Without going into any great detail, it may be said with certainty that spinal anæsthesia, by whatever technique induced, has a direct mortality greatly in excess of that due to general anæsthetics administered by expert anæsthetists. When the principles here laid down for the choice of spinal anæsthesia are observed, it is inevitable that a comparatively high death-rate should be encountered; because the cases thus treated will be largely those for which any operation and any anæsthetic are dangerous. But quite apart from this, the authors hold the firmest conviction that the method has dangers of its own, much too serious to enable it to replace general anæsthesia as a routine method for unselected cases. Hitherto spinal anæsthesia has been in none but highly expert hands. Even then it has proved much more fatal than ether and chloroform are in the hands of the inexperienced; methods and results will have to be vastly improved before it can displace general anæsthesia for the general practitioner's purposes, and we regard its use at present as unjustifiable for any but exceptional cases of the kinds indicated on pp. 523 to 525. The relative merits of spinal and general anæsthesia are discussed in a very fair and broad-minded paper by Richards,[1] of Cairo, who gives the results of his first 500 cases. This summary is especially valuable inasmuch as the administrators were for the most part house-surgeons and others who had had no special experience of the technique; and the results may be taken as representative of the average likely to follow the general adoption of spinal anæsthesia.

[1] *Brit. Med. Journ.*, 23rd Dec. 1911.

CHAPTER XVIII

MINOR DIFFICULTIES IN ANÆSTHETISATION

In preceding parts of this work frequent reference has been made to the various difficulties and dangerous conditions with which the anæsthetist may have to deal. It has been pointed out that certain subjects are more liable to give trouble than others (Chap. VI.); that when some operations are in progress there is a special tendency to the supervention of threatening symptoms (Chap. VII.); and that each anæsthetic is capable of producing its own special states of difficulty and danger. But whilst the circumstances which may contribute to the establishment of the abnormalities and accidents of anæsthesia are of the most varied description, the abnormalities and accidents themselves fortunately admit of comparatively simple classification. For purposes of description it is proposed first to consider, in the present chapter, the minor difficulties in anæsthetisation, reserving the consideration of the more grave respiratory and circulatory derangements for Chaps. XIX. and XX. respectively.

Whilst it would perhaps be misleading to emphasise the frequency with which troublesome cases present themselves in actual practice, it would be equally misleading were we to regard these minor difficulties as unimportant. By the careful observation of the patient's symptoms; by watching with an attentive eye for the slightest deviation from what may be called the normal course; and by correcting or relieving symptoms which are in themselves but trifling, it is often possible to avert altogether the dangers and difficulties which may properly be described as major.

Hesitating Breathing.—Patients sometimes give trouble by breathing in a hesitating and imperfect manner. Others hold their breath and refuse to breathe at all. Difficulties of this kind are not infrequently dependent upon respiration taking place, perhaps inadequately, through the nose. Patients should be instructed to breath through the mouth. With nitrous oxide, restricted breathing may come about from faultiness in the inhaling apparatus, *e.g.* badly working valves, from tight-lacing, from the patient being ignorant of the manner in which he should inhale, or from sheer nervousness and apprehension. The remedy in each case is sufficiently obvious. With other anæsthetics restricted breathing is often due to too strong a vapour; but even though a very dilute vapour be used, some patients will absolutely refuse to breathe freely. In such cases encouragement and reassurance should be brought to bear; and, above all things, the administrator should never lose patience.

In some patients the breathing may remain hesitating and restricted after consciousness has been completely abolished. As a general rule brisk friction of the lips with a towel, or sponging out the pharynx, will restore respiratory rhythm. The author has notes of two cases in which hesitating breathing seemed to culminate in respiratory arrest. In one of these the patient was a hysterical young woman to whom nitrous oxide was being given; in the other A.C.E. was the anæsthetic, and the patient, a middle-aged man, who had obstinately refused to breathe, became so much asphyxiated that it was necessary to open his mouth and separate his tongue from the pharyngeal wall.

When morphine, or a combination of alkaloids of which morphine is one, has been given beforehand, slow and shallow breathing is sometimes met with during the induction: no attempt should be made to rush these patients into anæsthesia by crowding on the vapour.

Crying: Sobbing.—The management of crying children has already been considered (p. 146). Crying must be carefully treated because of the liability to the intake of large quantities of anæsthetic. In administering pure nitrous oxide to a crying child it is very easy to induce an undesirable degree of asphyxia.

Early Coughing, Retching, and Vomiting.—Sometimes the contact of an anæsthetic, gas or vapour, with the mucous membrane of the upper air-passages will immediately excite coughing, retching, or vomiting.[1] This is not uncommon in heavy smokers with irritable throats. When using chloroform, or a chloroform mixture, the retching will usually subside if the patient be engaged in conversation during the first minute or so of induction. Should this not succeed, a change from the dorsal to the lateral posture may prove successful. Some anæsthetists take the precaution to spray the fauces with a little dilute cocaine solution in these subjects. Similar difficulties may occur in dental practice when the mouth-prop is inserted; but they may generally be overcome by requesting the patient to count his respirations. Should this not answer, a gargle of weak carbolic lotion (about 1 in 100) will probably subdue the irritability. Should retching be excited by chloroform or a chloroform mixture, the substitution of nitrous oxide as part of a sequence will sometimes prove advantageous.

Mental and Muscular Excitement: Struggling.—Amongst the common causes of excitement and struggling may be mentioned: the presence of inadequate nasal breathing; the employment of an inhaler whose air-way is or has become restricted; undue vapour concentration; too rapid an administration; and handling or unnecessarily interfering with the patient whilst semi-conscious.

The excitement and intoxication phenomena which occasionally occur during incipient anæsthesia are important for two reasons. In the first place, the deep and irregular breathing which is often associated with them may lead to the intake of dangerous quantities of the anæsthetic. In the second place, the muscular spasm which is so prominent a feature of these phenomena may introduce an asphyxial factor into the anæsthesia. When suitable methods are chosen and properly applied, excitement and struggling are exceptional. There are, however, certain subjects in whom difficulties from this

[1] The author has known a perfectly healthy individual, who had just taken food, and who wished to try the effects of the A.C.E. mixture experimentally, to be suddenly seized with emesis after one or two inhalations.

quarter will arise, even though every care be taken. Shouting, gesticulation, pugilistic movements, and muscular spasm of various parts are most common in vigorous men, and particularly in those who have become addicted to alcohol, tobacco, and sedative drugs. When anæsthetising such patients the administrator must be on his guard, and have assistance within easy call in case the patient becomes unmanageable. It is very common for middle-aged or elderly men who are being anæsthetised by chloroform, or a chloroform mixture, to raise the hands slowly and grasp the inhaler; and if this movement, which generally subsides of itself, be roughly suppressed, violent struggling may ensue. Should the patient's movements be such that he may possibly do himself damage, or greatly interfere with the administration, they must, of course, be gently restrained by an assistant, care being taken not to lean heavily upon the chest or abdomen. As a general rule, the cautious but continuous application of the anæsthetic quickly causes mental and muscular excitement to subside. With chloroform, the air-supply should be as free as possible during so-called struggling; whereas with ether moderate air-limitation is advantageous and free from risk in patients whose general condition is satisfactory. It is not uncommon when chloroform or a chloroform mixture is being administered to a muscular or obese man for the head and shoulders to become gradually raised from the bed or table as the result of muscular spasm. With this upward and forward movement, which should not be altogether prevented, there is nearly always some temporary suspension of breathing, which, by passing the fingers through the lips, or rubbing the latter briskly with a towel, generally quickly subsides. This difficulty is much less frequently encountered in those to whom preliminary injections of morphine and atropine have been administered.

There are certain highly exceptional subjects in whom anæsthetics produce a delirious or maniacal state, either during incipient anæsthesia or during the recovery period. When such a state arises in connection with the induction stages it may, in the absence of sufficient assistance, render a satisfactory anæsthesia impracticable. The author has met with a few cases of this kind in dental practice,[1] whilst employing nitrous oxide and oxygen; but they also occur under other anæsthetics. In the following illustrative case, which is unique in the author's experience, the violent excitement came on under nitrous oxide preparatory to ether.

Illustrative Case, No. 32.—M., about 30. Dark complexion. Strongly built. Good teeth. Said to be "neurotic" and very sensitive. No visceral disease detected. No history of alcohol or drug-habit. Has a dislocated ulnar nerve. Occasional attacks of mental disturbance from acute pain, the hand becoming blue and cold. He is said to be a courageous and business-like man. The family history is "neurotic." Has had anæsthetics before, and has broken two dental chairs and one window. Four men were necessary to hold him down. I anæsthetised him twice. On first occasion, for suturing ulnar nerve; on second, for passive movement of elbow. At first operation he became very violent after a few breaths of nitrous oxide—at a point when most patients are able to control movements on being requested. On second occasion, $\frac{1}{4}$ gr. of morphine was given before nitrous oxide-ether sequence. Mouth-prop inserted. After a few inhalations he began violent kicking. Surgeon and four nurses required to restrain movements. Large quantities of ether needed to obtain relaxation. In 8–10 minutes relaxed. Administration about 25 minutes. Whilst coming round, side to side movements of head began, with rigidity, shouting, and kicking. Restraint again needed. Very violent. He bit himself whilst trying to bite me. $\frac{1}{4}$ gr. more morphine given. A few weeks later he was anæsthetised by some one else. A dose of bromide of potassium and chloral was given beforehand. A rather better result was obtained, but still with great difficulty.

So far as the author is aware there is no adequate explanation of such cases as the above. Sometimes one may find peculiarities of this kind displayed by patients closely related to one another. This was the case in the patients to whom the author administered nitrous oxide and oxygen (*vide supra*). On other occasions the recalcitrant patient has had a family history of insanity.

The author has fortunately only once failed to induce anæsthesia in general surgery. The patient, a thick-set man of 46, was a great smoker, moderate drinker, and gave a history of having damaged furniture to the extent of £40 when a dentist endeavoured to anæsthetise him with nitrous oxide. A gradual administration of the A.C.E. mixture was tried, but without success. The "gas and ether" sequence was next attempted,

[1] See *The Administration of Nitrous Oxide and Oxygen for Dental Operations*, 3rd ed. p. 81.

but this rapidly induced so much maniacal excitement that no operation could be performed. There was a history of insanity in the family.

Quite recently the author failed to obtain anæsthesia for a dental operation. The symptoms somewhat resembled those in the above-mentioned Illustrative Case. The patient was a florid, wiry man about 30, who led an outdoor life and smoked and inhaled about thirty cigarettes a day. There was a history of his having broken the chair of a former dentist and of his having been conscious of the tooth extraction. His unfortunate experiences had somewhat unnerved him, but he was quite amenable. "Gas and ether" were attempted with a wide-bore inhaler. Whilst ether was being gradually turned on he began to struggle, straightened his body, and then rose from the chair and stood up breathing deeply and looking dazed. He was obviously unconscious of his surroundings. After an interval an attempt was made to obtain anæsthesia by the gradual administration of the C.E. mixture, the patient counting aloud. He counted to forty-four when he became excited, got up, breathing deeply, and assumed a threatening attitude. No further attempt was made to anæsthetise him.

In highly exceptional cases of this kind it would seem to be necessary, if anæsthesia is to be secured, either to have adequate assistance at hand in order to restrain the patient's movements, or to employ some preliminary narcotic such as morphine or scopolamine before the administration (*vide* Chap. IX.).

Jaw Spasm or Trismus: Spasm of Thoracic and Abdominal Muscles leading to Embarrassment of Breathing.—These conditions, which may culminate in respiratory arrest, will be considered in the following chapter.

Obstructive Stertor.—The various forms of stertor have already been discussed (p. 53). As the conditions capable of causing this sound may, under certain circumstances, culminate in respiratory arrest, the management and treatment of stertor will also be considered in the following chapter.

Stridor.—For similar reasons the treatment of laryngeal stridor will also be dealt with in the following chapter.

Early Shallow Breathing: False Chloroform Anæsthesia.—When this condition, which has already been fully described (pp. 66, 79, 411), becomes established, it must either be treated (1) by administering a few breaths of ether vapour, (2) by peripheral stimulation, *e.g.* lip friction, face friction, pinching, or otherwise stimulating the patient in the hypochondriac region.

Illustrative Case, No. 33.—F., æt. 45. Hysterectomy for large tumour. Heart-sounds normal. Induction by nitrous oxide and ether; then changed to chloroform, and then to C.E. The patient passed into the condition of false anæsthesia. The cornea was insensitive, but when the abdominal wall was scrubbed with a nail-brush the corneal reflex reappeared. Ether was then substituted to promote deep breathing, which was soon established. The corneal reflex disappeared, and permission was given to the surgeon to make an incision. But instantly, on this being done, both legs were raised and nearly upset the tray of instruments. After this difficulty was surmounted, the administration went smoothly.

Illustrative Case, No. 34.—F., æt. 20. Says she has a slight cold in the nose. Heart-sounds normal. Morphine and atropine half an hour before induction. Nitrous oxide and ether to begin with. In two or two and a half minutes changed to C.E. on open mask. No struggling. When apparently anæsthetised, the patient was turned on her side, and carried in that posture into the operating room. C.E. was then continued as before. When the corneal reflex, which was very slightly present when she was moved, had disappeared, the fauces were sponged out twice; the first time there was a single cough and expulsion of a little mucus, the second time there was no reflex effect. The patient was slightly pale, and she was thought to be ready for operation (appendicectomy). In about eight minutes from the time the patient was brought into the operating room, the operation was begun. The incision caused brisk movements of the legs, and the corneal reflex at once returned. The abdomen also remained rigid. A change was then made to "open" ether, and in two minutes respiration was deep, corneal reflex was absent, and the operator proceeded without any further difficulty. There was a great deal of vomiting afterwards. In this case it is possible that owing to the "cold in the head" there was an excessive collection of mucus in the stomach. Possibly also the interruption of administration rendered necessary by the transference of the patient from one room to another had some influence in causing the marked condition of false anæsthesia.

Late Coughing, Retching, and Vomiting.—Speaking generally, coughing should be kept in abeyance, for it is likely to inconvenience the operator in most operations, and more especially in abdominal, ophthalmic, rectal, and vesical cases. If it be difficult to abolish cough when using ether, chloroform should be substituted; but care must be exercised in effecting the change owing to the free intake of chloroform vapour during the deep inspirations between the coughs. As already explained, there are some cases in which an occasional cough is a positive advantage, in that it keeps the air-passages free. In persons with much bronchitis, or with any affection accompanied by pulmonary or bronchial secretion, an occasional cough is to be encouraged. Coughing is nearly always preceded by deglutition movements, so that should the administrator desire to keep his patient free from cough, he should narrowly watch the behaviour of the larynx. The possibility of epistaxis or hæmoptysis taking place during anæsthesia and giving rise to cough must not be forgotten.

Retching and vomiting, like coughing, never occur during very profound anæsthesia. They are met with either before true surgical anæsthesia has become established, or whilst the patient is emerging from the effects of the anæsthetic. It is the duty of the anæsthetist to do all in his power to prevent their occurrence whilst the patient is under his charge. Retching and vomiting are objectionable as complications of surgical anæsthesia for at least three reasons. In the first place, the movements of the patient's abdominal and thoracic parietes may embarrass the operator, or actually render the operation hazardous or impossible; in the next place, should there be food present in the stomach, its discharge may interfere with the administration, or endanger the life of the patient; and lastly, with certain subjects under chloroform, there is a liability to syncope during the act of vomiting. To avoid the *contretemps* in question, the anæsthetist should give the anæsthetic as smoothly as possible, and not permit the anæsthesia to become light enough to allow of any vomiting or straining. An intermittent inhalation will be very liable to lead to swallowing, retching, and possibly actual vomiting.

Some patients are much more liable than others to retching and vomiting during anæsthesia. The most liable appear to be children and adults of both sexes who are the subjects of nasal or naso-pharyngeal catarrh, the stomach showing a tendency to eject swallowed mucus and muco-pus even when anæsthesia is comparatively deep. The afferent impulse which starts the vomiting in these cases is sometimes furnished by an intra-abdominal or uterine manipulation. Flabby young men and women with muddy complexions, and persons who are, as it is said, of "bilious temperament" or liable to "sick headaches," may also give trouble by unexpectedly vomiting during an operation. Children who have eaten a heavy meal the night before an operation, and those to whom milk has been given even six or seven hours beforehand, will be specially liable to vomit during anæsthetisation. Persons of spare build, as well as the aged, are not nearly so liable to this condition as those of opposite types.

When once the patient has been placed fairly under the influence of the anæsthetic, the administrator may usually avert vomiting. He must watch for the early indications of its approach, and at once increase the depth of anæsthesia. Amongst these indications swallowing is perhaps the best. Sometimes a high-pitched inspiratory sound may indicate a tendency to vomit. Or a shallow form of breathing, with some pallor but with good conjunctival reflex, may be equally suggestive. Or, lastly, an increase in the size of the pupil may help as a guide, though, if the administrator has been on the alert, he will probably have received earlier warning from other signs. It is easier to avert vomiting under ether or the C.E. mixture than under chloroform, for the simple reason that a more profound narcosis may be safely maintained with the two former than with the last-named agent.

When the symptoms seem to indicate that vomiting is approaching, it may frequently be averted by suddenly rubbing and vigorously wiping away mucus from inside the lips, pulling the chin away from the sternum, and quickly re-applying the mask or inhaler. When it is obvious that emesis cannot be prevented, the administrator should at once turn the patient's head to one side (if it be not already so placed) and raise the opposite shoulder. The teeth usually become clenched at this stage, and little or no air enters the chest, as the larynx is, of course, closed. The lower jaw should be pushed forwards from behind, and in a few moments the duskiness will pass off without difficulty. The mouth-opener shown in Fig. 17 (p. 258) may be very useful in separating clenched jaws during the act of vomiting. Should the patient be feeble, it is not desirable to allow the breathing to become even temporarily suspended, so that an endeavour should be made to expedite matters as much as possible.

Hiccough.—Hiccough seems to be most liable to occur when the intestines are being manipulated or operated upon. It is, however, very rarely met with. It is chiefly inconvenient during abdominal operations, and in cases requiring regularity and tranquillity of breathing. Unfortunately hiccough is difficult to relieve. It occurs with ether as well as with chloroform, and is little if at all influenced by modifying the depth of anæsthesia.

The author has notes of a case of gastro-enterostomy in which hiccough occurred and lasted half an hour. Chloroform was the anæsthetic. Directly a Murphy's button was inserted and the stomach distension relieved, the hiccough disappeared. When hiccough appears early in an administration, it sometimes ceases when the skin incision is made.

Hiccough during anæsthesia is usually a sign of some reflex irritation, as, for instance, an accumulation of mucus in the stomach or fauces; in such an event it will often be found that hiccough ceases as soon as vomiting has occurred or the faucial mucus has been removed by sponging.

Illustrative Case, No. 35.—M., æt. 37. Thin, nervous man. Appendicectomy at 9.45 A.M.; no food since previous night. Morphine and atropine beforehand. Induction with chloroform - C.E. - ether sequence. For last twenty minutes of operation the patient hiccoughed continuously. Sponging out the fauces failed to arrest it; but the hiccough stopped at once after the patient retched and brought up some stomach mucus.

In another case, also an appendicectomy, hiccough seemed to be caused by irritation of the inflamed peritoneum; for it ceased as soon as the peritoneal cavity was closed, having resisted all other treatment for twenty minutes.

Sneezing.—Sneezing occasionally, though rarely, occurs during anæsthesia. The author has met with it chiefly in connection with intra-nasal operations. Should it fail to subside when the anæsthetic is pushed, it is best to spray the nasal passages with a dilute solution of cocaine. Sneezing may be so violent as to constitute a distinct difficulty, especially in delicate operations about the face.[1]

Inconvenient Muscular Rigidity.—As indicated in preceding pages, the plan which is most likely to secure complete muscular relaxation is (1) to administer some preliminary narcotic, (2) to induce anæsthesia slowly by chloroform or the

[1] See *Lancet*, 2nd and 16th Dec. 1893.

C.E. mixture, (3) to proceed to full ether anæsthesia by the perhalation system, and (4) to maintain free oral breathing.

As has been pointed out, muscular flaccidity can never be relied upon either with nitrous oxide or with ethyl chloride. Excessive smokers sometimes become so rigid under nitrous oxide that it is difficult to obtain satisfactory anæsthesia.

Illustrative Case, No. 36.—M., about 48. Thick-set and powerful, smokes 6 ounces of dark Virginian tobacco weekly. Says that the particular tobacco "affects the head" of those not used to it. Nitrous oxide and oxygen for the removal of four teeth. When partly anæsthetised "hesitating breathing" appeared. Whole body became rigid and tended to turn to the (patient's) left side. Cyanosis from suspension of breathing. Operation difficult owing to posture. Only possible to remove one tooth. Allowed patient to regain consciousness. After two or three minutes again administered nitrous oxide and oxygen, giving more oxygen than before. Much better result, but patient again rigid. Three teeth removed.

Sometimes it is difficult to secure thorough and complete muscular relaxation with any anæsthetic, certain parts of the body remaining inconveniently rigid. Athletic patients, alcoholics of both sexes, excessive smokers, and tall muscular men of nervous temperament are particularly liable to give trouble in this direction. Patients with a retracted abdomen, such as is common in certain affections of the stomach, may also prove to be difficult subjects so far as the attainment of abdominal relaxation is concerned.

The most persistent and board-like rigidity the author ever witnessed was in the case of a lady who was very wasted from malignant disease. Oöphorectomy was being performed for recurrent carcinoma of the breast. There was hardly any thoracic respiration, from secondary lung affection. Although chloroform was given to the fullest degree compatible with safety, the abdominal rigidity persisted and rendered the operation exceedingly difficult.

Similarly, should long-standing abdominal pain have led to the muscles of a particular area remaining perpetually "on guard," it may be practically impossible to relax that area. In one very pronounced example of this condition the muscles of the right hypochondriac region had become so hypertrophied in the course of some gall-bladder affection as to constitute a distinct visible projection, and in attempting to relax the spasm the author pushed the anæsthetic (chloroform) to such a degree that considerable traction-shock took place during the operation.

Reference has already been made[1] to the interesting case of an excessive smoker who remained so rigid under chloroform that it was practically impossible to perform an abdominal operation. See also Illustrative Case, No. 36.

Speaking quite generally, muscular rigidity during general anæsthesia is in the great majority of cases dependent upon sub-oxygenation arising either from an inadequate supply of oxygen in the gaseous or vaporous atmosphere presented to the patient, or from some mechanical impediment to the entry and exit of a sufficiently oxygenated atmosphere. Thus we meet with general muscular spasm when pure nitrous oxide is freely pushed, and with abdominal rigidity when the air-way is obstructed by laryngeal spasm. With ether by closed methods there may be considerable rigidity during the first five or ten minutes of anæsthetisation, particularly in patients such as those just referred to. The difficulty is often referable to such causes as the use of a narrow-bore inhaler, the presence of a restricted air-way, an insufficient allowance of air, or the premature commencement of an operation. In some patients, for example, rigidity will disappear when a Clover's narrow-bore inhaler is replaced by a wide-bore model, or by an Ormsby's inhaler. In others, the substitution of oral for nasal breathing will bring about the desired result. In others again, an increase in the strength of ether vapour and in the air-supply will prove successful. One interesting and frequently efficient line of treatment is the temporary replacement of ether by a small quantity of chloroform. As already pointed out, it is necessary to be careful in substituting chloroform for ether; but if this temporary replacement be cautiously effected, it is quite permissible. For example, it will be found very useful, almost as a routine measure, when employing the nitrous oxide-ether sequence for very muscular men; the ether may be withdrawn for a minute or so in favour of chloroform just before the corneal reflex vanishes, *i.e.* whilst stertor and masseteric spasm are present.

[1] See p. 151.

Such a sequence is in reality a nitrous oxide-ether-chloroform-ether sequence, and is specially useful for quickly obtaining muscular relaxation in strong men.

It is generally supposed that complete muscular relaxation can always be safely secured by chloroform, but this is by no means the case. It is true that when no operative stimulus is at work, the muscular system is generally flaccid, even though the anæsthesia is not profound. When, however, certain operations are being performed, reflex rigidity is frequently very marked under chloroform; and it may be dangerous to administer this anæsthetic progressively with the object of overcoming it. We have already seen that numerous deaths have occurred during the administration of chloroform for the reduction of dislocations. When there is difficulty in obtaining complete flaccidity under chloroform, it is far better to substitute ether than to persist with the first-named anæsthetic. The substitution of ether for chloroform produces, as we have seen, a remarkably powerful effect.

In one case, that of a publican æt. 56, of heavy build, and with a large abdomen, this treatment answered admirably. The nitrous oxide-ether-chloroform sequence had been employed, but it was impossible to obtain complete abdominal relaxation. The operation was for appendicitis. Recourse was again had to ether, which was administered freely from an Ormsby's inhaler, and the abdomen quickly relaxed. With the object of ascertaining whether the effect had been purely accidental, a change was again made to chloroform; but the rigidity at once returned, so that it became necessary to finish the case with ether.

Should it be found impossible to obtain abdominal relaxation by any of the means above suggested, a device employed by Mr. Mayo Robson will sometimes answer well. He slightly raises the patient's head and shoulders at one end of the table and his pelvis at the other, thereby overcoming to a great extent the difficulties dependent upon muscular rigidity.

Reflex and other Movements.—In certain subjects and in certain operations, it may be impossible to abolish all reflex movements without running the risk of administering an overdose. Neurotic and alcoholic patients are most liable to display exaggerated reflexes. Cutaneous incisions about the feet and legs; rectal, urethral, and vesical operations; manipulations within the peritoneal cavity, particularly about the liver;

and the dilatation of any of the natural orifices of the body, are liable to elicit reflex phenomena, even during deep anæsthesia. Owing to the comparatively wide margin of safety with ether, this anæsthetic is specially indicated when it is desired to secure absolute immobility. It sometimes happens that the resources of the anæsthetist are sorely taxed in attempting to abolish a particular reflex. The following case, which has many points of interest, will make this clear:—

Illustrative Case, No. 37.—M., about 38. Fat. Very large thick neck. Full chin; much fat round angles of jaws. A heavily built man. A perfect set of teeth. Suffers from pharyngitis. Slight cough. Nasal passages not very free. Drinks a bottle of brandy a day. Fairly good heart-sounds. Not nervous. Administration begun 10.10 A.M. No food since previous night. Varicose veins, both legs. Administration lasted 2 hours 20 minutes. A.C.E.-ether sequence (see p. 483). No excitement to speak of. Soon stertorous with ether, but muscles rigid, and breathing rather embarrassed, so changed to chloroform (Skinner's mask). Found it necessary to keep Mason's gag in mouth, and tongue-forceps applied. Very narrow workable area. On the one hand (*a*) inconvenient reflex movement; slight phonation; breathing fairly free or only slightly obstructed by spasmodic retraction of tongue; slight or no corneal reflex; pupils variable. On the other, with more chloroform (*b*) slight reflex movement; greatly obstructed breathing—the tongue requiring forcible traction to overcome spasm; no phonation; no corneal reflex; slight duskiness; larger pupils. Difficulties augmented by presence of laryngeal mucus. Quick recovery from anæsthetic followed by heavy sleep.

In this case, which was an exceedingly difficult one, the choice lay between permitting reflex movements of the legs and bringing about a dangerous degree of obstructed breathing. A better result might, perhaps, have been obtained had a preliminary narcotic been given.

Clonic muscular phenomena and the curious movements referred to on p. 416 must be regarded with suspicion when they arise under chloroform. They are liable to mislead the anæsthetist, who may mistake them for reflex movements and increase the anæsthetic; they call, however, for less anæsthetic and more air.

Fine rhythmic tremor may be met with under all anæsthetics, but it is most common under ether. It chiefly affects the lower extremities, but it may be general. Muscular, nervous men, whose legs are exposed during the course of an operation, seem particularly liable to tremor. As a rule it may be stopped either by altering the position of the legs and feet, or by increasing the depth of anæsthesia. It is rare under chloroform.

Insusceptibility.—Two interesting cases of insusceptibility to nitrous oxide and other anæsthetics have already been narrated (see Illustrative Cases, Nos. 10 and 11, p. 332). Insusceptibility to anæsthetics may be more apparent than real; that is to say, there may be circumstances in the case which prevent the free access of the vapour to the pulmonary alveoli. Obstruction anywhere in the respiratory tract may have this effect; inadequate nasal respiration in patients suffering from adenoids or having high and narrow palates may be quoted as an example. Alcoholism, again, is well known to be a cause of actual insusceptibility. But there are cases in which it seems possible to exclude all these factors; and since the reaction of different individuals to many familiar drugs is known to be variable, there seems no reason why the same should not hold good of ether and chloroform.

Illustrative Case, No. 38.—F., æt. 15. Very tall and big for her age. Her father was a very peculiar man, subject to furious fits of temper, after which he would weep; he died of cerebral hæmorrhage. The daughter is said strongly to resemble her father in appearance. She has a high narrow palate, and has had adenoids removed; probably has some recurrence of this trouble. Several enlarged glands, but no enlargement of the spleen or other evidence of *status lymphaticus.*

The induction was begun with nitrous oxide and ether (the inhaler had not been warmed). The patient seemed to be extraordinarily insusceptible, and prolonged struggling ensued; the legs were suddenly raised and thumped heavily on the table. Twice the patient twisted herself almost on to her face, having to be held down by two surgeons. A change was made to chloroform, but the patient began to come round so quickly that the ether inhaler was reapplied. After 10 minutes C.E. was given, and in 5 minutes more the corneal reflex disappeared. The surgeon then seized the toe (where a contraction was to be remedied) and movements of the leg and body at once occurred; the limb had to be held while the incision was made.

In this case there may possibly have been imperfect access of vapour to the lungs, owing to defective nasal breathing. An abnormal nervous system may also have been a contributory factor. But the patient was certainly the most insusceptible girl of her age whom the author has anæsthetised. In another distinctly insusceptible patient, a better result was secured :—

Illustrative Case, No. 39.—F., æt. 39. Tall, well-developed ; very nervous ; pulse very rapid, but heart-sounds normal. Some time previously an attempt had been made to give this patient ether by the "open" system, but abdominal relaxation could not be secured, and the operation had to be abandoned. Apparently no morphine was given on that occasion. For the postponed operation $\frac{1}{4}$ gr. of morphine and $\frac{1}{100}$ gr. of atropine were given three-quarters of an hour before the induction. The patient was drowsy, but still rather nervous. Chloroform was given on an open mask for 3 minutes ; then C.E. for 2 minutes, then pure ether for 2 minutes. Some moaning and sighing occurred, and a return to C.E. was made for 3 minutes, after which ether was given for the remainder of the operation. The induction period lasted 11 minutes. There was no reflex movement or rigidity when the incision was made ; but loud crowing breathing at once set in, so loud that it excited the interest and imitation of a boy out in the street ! There was no abdominal rigidity, and the operation was satisfactorily completed. There was one subsequent act of vomiting, which expelled mucus only.

CHAPTER XIX

THE CAUSATION AND TREATMENT (PREVENTIVE AND IMMEDIATE) OF RESPIRATORY ARREST[1]

In order that the reader may possess a clear idea of the various ways in which respiration may become arrested it is necessary that he should study what has already been said in Chap. III. (**C.** II. (*a*)) concerning the respiratory phenomena of general surgical anæsthesia and the numerous factors which may influence the character of the respiration. He is also referred to the remarks in Chap. VI. (**C.**, **D.** and **E.**) as to the subjects most liable to respiratory embarrassment, and the various conditions, local and general, which may predispose to respiratory arrest.

For our present purposes—that is to say, in order that the rational treatment of arrested breathing may be thoroughly understood—respiration may be regarded as a function whose efficient performance is dependent upon the proper working of (*a*) the respiratory pump, and (*b*) the respiratory centre. It is clear that each of these factors is as important as the other. An inexhaustible store of nervous energy will, for example, be absolutely useless should the air-way be occluded or lung expansion prevented; whilst the most patent air-tract and the most vigorous muscles will be equally useless in the absence of motive force.

We may thus say that there are two fundamentally distinct forms of suspended breathing. The first of these (I.) is due to some mechanical interference with the action of the respiratory pump, and, for the sake of brevity, will be termed *obstructive* or *mechanical arrest of breathing*. The second (II.) is due to

[1] See footnote (p. 55) on the term "apnœa."

depression of the respiratory centre, and may conveniently be termed *central* or *paralytic arrest of breathing.*

Obstructive or mechanical arrest of breathing may be an incident of such triviality as hardly to merit description, or one of such difficulty and danger as to tax to the utmost the resources of the anæsthetist. Paralytic respiratory arrest is generally a more serious condition.

There are three distinct ways in which obstructive arrest of breathing may take place. It may result (1) from occlusion of the upper air-passages, produced either by (i.) spasm, (ii.) swelling, or (iii.) altered position of parts within or about the upper air-tract; (2) from the presence of some adventitious substance within the upper air-passages; or (3) from some condition which directly prevents lung expansion.

On the other hand, in paralytic cessation of breathing respiration simply comes to a standstill as the result of failure of nervous energy. This failure may be (1) toxic, *i.e.* from an overdose of the anæsthetic acting upon the respiratory centre; (2) anæmic, *i.e.* from cerebral anæmia due to fall of blood-pressure; or (3) reflex, *i.e.* from surgical or other stimuli inhibiting the action of the respiratory centre. Toxic arrest of breathing is usually wholly referable to the action of the anæsthetic upon the respiratory centre, but it may be partly due to other agents, such as morphine. Amongst the causes of anæmic arrest of breathing may be mentioned (i) cardio-vascular paralysis brought about by overdosage; (ii.) surgical shock of the circulatory type; and (iii.) other causes, such as the sitting posture, loss of blood, and the entry of air into veins. Patients with an abnormally slow pulse are liable to this form of arrested breathing during deep chloroform anæsthesia.

Broadly speaking, the embarrassments in breathing which are dependent upon some mechanical interference with the free entry and exit of air take place during light or moderately deep anæsthesia, and are to be corrected by removing the obstruction or impediment which has led to the embarrassment; whilst those respiratory derangements which are dependent upon central as opposed to peripheral causes arise during deep anæsthesia, and are to be treated by artificially supplying the motive force which has become temporarily paralysed.

There is an interesting and important point which must be referred to in connection with occlusion of the air-tract. Given that, at the moment when occlusion occurs, the nervous mechanism of breathing is intact, and that there is no condition present which will directly interfere with lung expansion, futile and deceptive respiratory movements will for a time continue, and unless the anæsthetist is on his guard, they will be very liable to mislead him. As a general rule these movements are diaphragmatic rather than thoracic in type. The teaching of the Hyderabad Commission, viz. that the respiratory movements should be watched and taken as an indication of air-entry, is highly erroneous. In order to be certain that respiration is proceeding, the anæsthetist must either *hear* or *feel* each breath, except, of course, when he is employing a bag-inhaler, in which case the movements of the bag may be safely taken as a guide. Should breathing cease from some direct interference with lung expansion, this spurious and deceptive movement of the chest and abdomen will, as a rule, be completely absent, and the same is, of course, true of respiratory failure of central origin.

The accompanying table has been drawn up with the object of showing in a condensed form the various ways in which breathing may come to a standstill during the use of an anæsthetic for a surgical operation.

TABULAR SUMMARY OF CAUSES OF RESPIRATORY ARREST DURING GENERAL SURGICAL ANÆSTHESIA; WITH EXAMPLES

Form of Respiratory Arrest.	Causation.	Examples.
I. Obstructive or Mechanical.	1. From occlusion of upper air-passage due to (i.) Spasm of parts within or about the upper air-tract.	As when masseters and other jaw muscles are spasmodically contracted; when the tongue is spasmodically retracted causing stertor; or when laryngeal spasm takes place causing stridor. See Illust. Cases, Nos. 42 and 43. When some surgical procedure reflexly causes respiratory arrest the condition may be termed "respiratory shock" (see pp. 67 and 253).
	(ii.) Swelling of parts within or about the upper air-tract; or	As when anæsthesia is being induced, particularly by pure nitrous oxide or by close etherisation, in plethoric, short-necked men with naturally narrow air-way. More common in Trendelenburg than horizontal posture (see Illust. Cases, Nos. 41*a* and 45).
	(iii.) Altered position of parts within or about the upper air-tract.	As when a flaccid tongue falls over larynx owing to altered posture, or when an epiglottic tumour causes sudden obstruction.
	2. From adventitious substances within upper air-passages.	Blood; vomited matter; mucus; pus; portions of morbid growths; extracted teeth, fragments of teeth or stoppings; artificial dentures; mouth-props; portions of instruments; pieces of sponge.
	3. From conditions directly preventing lung expansion.	As trunk weight in prone posture; extreme abdominal distension; and spasm of thoracic and abdominal muscles. When some surgical procedure reflexly causes general respiratory spasm the condition may be termed "respiratory shock" (pp. 67 and 253).
II. Central or Paralytic.	1. Chiefly toxic, *i.e.* from overdose of anæsthetic acting upon respiratory centre.	As when ether is administered in an overdose to a healthy subject.
	2. Chiefly anæmic, *i.e.* from cerebral anæmia due to fall of blood-pressure. (i.) From cardio-vascular paralysis produced by overdosage.	As in chloroform overdosage.
	(ii.) From surgical shock; or	Illust. Cases, Nos. 55 to 70.
	(iii.) From other causes, such as the sitting posture, hæmorrhage, and the entry of air into veins.	Illust. Case, No. 76.
	3. Reflex (?), *i.e.* from surgical or other stimuli inhibiting the action of the respiratory centre.	Illust. Case, No. 50.

I. TREATMENT OF OBSTRUCTIVE OR MECHANICAL RESPIRATORY ARREST

1. OBSTRUCTION DUE TO SPASM, SWELLING, OR ALTERED POSITION OF PARTS WITHIN OR ABOUT THE UPPER AIR-TRACT

The treatment of threatened or complete occlusion of the upper air-passages dependent upon spasm, swelling, or altered position of parts within or about those passages is to remove the cause of the obstruction.

As has been frequently pointed out in preceding pages, muscular spasm is a fruitful cause of occlusion, for it may

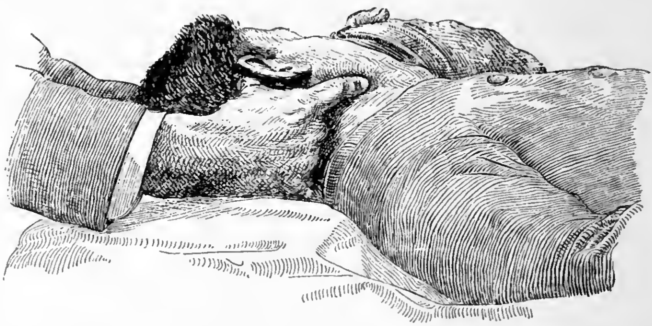

FIG. 67.—The Finger of the Administrator pushing the Lower Jaw forwards.

come into play at several points within the upper air-tract. In a large percentage of surgical cases it is necessary to counteract this tendency to spasmodic closure of the air-way by keeping the lower jaw pressed forwards from behind (Fig. 67). This procedure has the effect of bringing the base of the tongue and the epiglottis away from the pharyngeal wall, in which situation they are often held by muscular spasm. By means of the laryngoscope it is not difficult to demonstrate this recession of the epiglottis from the pharynx when the lower jaw is pressed forwards. Should there be much masseteric spasm, and stertor, it is often necessary to push the lower jaw forwards from both sides before breathing will freely take place. In some cases, moreover, the front teeth, by overlapping the lower, prevent the lower jaw from coming forwards, so that the teeth must be disengaged before breathing can be re-established. Under such circumstances as these the insertion of a small mouth-prop may be advantageous; but it is important to adjust it in such a way that the lower jaw may ride forwards upon the upper. The best plan is to place the prop of Fig. 16 (p. 257) between the *back* teeth so that it acts as a roller (Fig. 68). If it be inserted as in Fig. 69, between the *front* teeth, it may be impossible to move the lower jaw forwards, and respiratory embarrassment may increase rather than diminish. This is particularly likely to

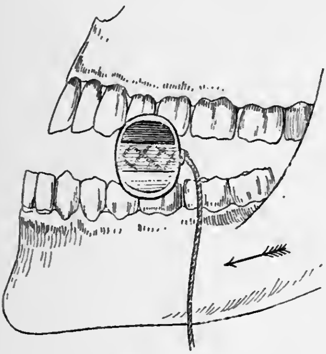

FIG. 68.—Mouth-prop between Back Teeth.

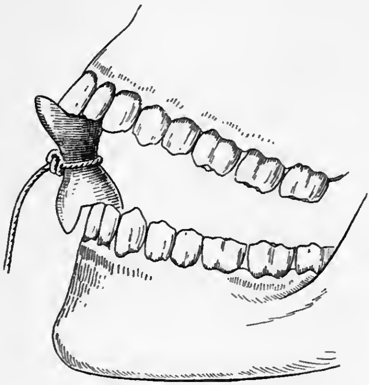

FIG. 69.—Mouth-prop between Front Teeth.

be the case in patients with high palates, projecting front teeth and laterally compressed jaws. There are certain cases in which breathing will not proceed when the mouth is widely opened, the explanation being, as Dr. Bowles has pointed out,[1] that the base of the tongue is thrown against the pharyngeal wall; and in such it will be necessary either to use a very small prop or to dispense with one altogether. In separating clenched jaws the mouth-opener of Fig. 16 (p. 257) will be useful. If no such appliance be at hand, the forefinger, or the closed blades of a Mason's gag, should be passed into the mouth through the space immediately behind the last molar teeth.

[1] *Stertor and Apoplexy.*

Pulling the chin away from the sternum,[1] or completely extending the head over the end of the operating-table, is often of use in the treatment of obstructed breathing, the beneficial effects being due to recession of the epiglottis from the laryngeal orifice. The author has in more than one case heard a distinct sound such as might be made by the sudden opening of the larynx, at the moment of extension, and respiration has at once recommenced. The extension is most likely to be of use in patients with free nasal passages and thin necks. In thick-necked, muscular subjects with nasal obstruction, extension of the head will of itself be useless as a remedial measure. In conjunction, however, with disengaging the teeth and pushing the lower jaw forwards, as above described, the extension is often distinctly valuable.

In cases of this kind the use of the "artificial air-way," described on p. 258, is often immediately successful in relieving respiratory embarrassment, especially when the patient is in the Trendelenburg position. If at the conclusion of the induction period, when the patient should be settling down into smooth and deep anæsthesia, the breathing be laboured and noisy, with sniffing or snorting sounds—if, in other words, the patient be "taking the anæsthetic badly" or "breathing badly"—the jaws should be separated and the whistle-shaped end of the "air-way" passed backwards into the pharynx, so that the oblique opening of the rubber tube faces the laryngeal orifice, and the metal ring should be adjusted so that it is grasped by the teeth or gums. The substitution of free oral for imperfect nasal or oral respiration will, in the great majority of cases, immediately be followed by slower and quieter breathing, an improvement in colour, and greater muscular relaxation; in fact, by an altogether better type of anæsthesia. Should there be much jaw spasm at the moment when it is desired to introduce the "air-way" it may be

[1] This was recommended by Clover, as a useful procedure, as far back as 1874. See *Brit. Med. Journ.*, 14th February 1874, p. 201. He made the following important remarks :—"The act of swallowing is usually performed well enough; but, if the anæsthetic have produced sufficient effect upon the patient to interfere with reflex movements, then the deglutition may be delayed at the moment when the epiglottis covers the larynx. Raising the chin, and pulling it as far as possible away from the sternum, is usually sufficient to obviate this source of obstruction.

necessary to separate the teeth by means of a Mason's gag. It is advisable to secure a fairly deep anæsthesia before the instrument is placed *in situ*, otherwise inconvenient reflex retching and coughing may be excited. The appliance is, in fact, only suitable for cases in which it is desired to maintain a deep anæsthesia.

In the event of the foregoing treatment proving unsuccessful, the mouth must be opened, a Mason's gag inserted, and the finger passed to the back of the throat to separate the tongue and epiglottis from the pharynx. The approximation of the base of the tongue to the pharynx is a common cause of respiratory arrest, especially in edentulous patients and in the subjects of deformities of the palate and jaws consequent upon long-standing nasal obstruction. In some of these cases it may be necessary to keep the base of the tongue hooked forwards by the finger, to use Longhurst's tongue lever (Fig. 21), or to apply the tongue forceps or tongue clip throughout an administration. The two former procedures should, if possible, be chosen in preference to the two latter. Should this treatment not succeed, the chest must be forcibly compressed with the object of overcoming the occlusion by increased intrathoracic pressure; and should this not answer, formal artificial respiration must be tried.

We have seen (p. 54) that the larynx itself may become obstructed in two ways, viz. from collapse of the arytæno-epiglottidean folds, or from spasm of its sphincter muscles. In all forms of laryngeal occlusion the treatment is practically the same. Minor degrees should be treated by suspending the anæsthetic, briskly rubbing the lips, and pushing the lower jaw forwards. When the spasm is dependent upon the local irritation of mucus, it is usually best to allow the patient to regain his swallowing and coughing reflexes, and the spasm will quickly subside. As a general rule, laryngeal spasm is met with during moderately deep anæsthesia. Generally it is best to lessen rather than to increase the depth of narcosis. In obstinate cases, when the stridor becomes more and more intense, and increasing cyanosis testifies to the deficient air-entry, it may be necessary to open the mouth and vigorously apply the tongue-forceps. Lord

Lister urged the importance of this prompt treatment and believed that tongue-traction acted reflexly in opening the larynx. Should it not succeed, artificial respiration may be tried, but it is not likely to be successful. The author has never known true laryngeal spasm to arrest respiration completely under ether. In fact, he has notes of several cases in which a change from chloroform to ether caused the spasm at once to subside. The condition is most common under chloroform.

The measures above described will generally succeed in opening an occluded air-tract, but in certain cases (which are fortunately highly exceptional) they will fail; and under such circumstances laryngotomy must be performed. To those who have had but little experience it might seem that this treatment could only be justifiable for the relief of obstruction dependent upon the presence either of adventitious substances or of morbid states; but such a view is erroneous. When certain factors combine, it may be impossible to overcome the occlusion by any other mechanical means. When, for example, the neck and throat muscles of a powerful and obese subject are thrown into a state of intense spasm, and when the tongue, fauces, laryngeal folds, and other adjacent structures become so engorged and swollen that the air-way is completely closed, nothing short of laryngotomy may be of any avail. (See Illust. Cases, Nos. 42 and 44). In such subjects deep stertor is, as we have seen, very common; it readily passes into occlusion; general asphyxial spasm results; and the last straw is furnished by swelling from general venous engorgement.

In the event of laryngotomy failing to re-establish breathing, artificial respiration by Silvester's or Schäfer's method (*vide infra*) must be immediately commenced, and in the vast majority of cases in which remedial measures have been carried to this point recovery will take place. But in certain cases the asphyxial condition present — a condition originally brought about by an occluded air-tract—gradually or rapidly becomes characterised by so much *general* respiratory spasm that even though an opening has been made into the occluded passages it may be impossible to set the respiratory pump going by the usual means. As we shall see when discussing respiratory spasm as one of the conditions capable of directly preventing lung expansion (*vide infra*, p. 578), the remedy to be adopted in such cases is lung inflation through the laryngotomy tube. The immediate cause of death in these cases would appear to be cardiac failure due to over-distension of the right cavities,[1] and venesection is hence indicated.

It is probable that lowering the feet, by bringing the patient's body across the bed or table, is advantageous; but such treatment must not be allowed to interfere with artificial respiration.

Respiratory arrest from alteration in the position of parts within the upper air-passages may sometimes be seen during deep anæsthesia, as when a patient is turned from the lateral into the supine posture, the flaccid tongue at once falling over the glottis. Similarly, pedunculated growths of the epiglottis or naso-pharynx may, in certain postures of the body, bring breathing to a standstill. In each case the treatment is simple and self-evident. In the Trendelenburg position there is a special liability to this form of obstruction. A mouth-prop or a Mason's gag is so often necessary to avoid this effect that the use of one or other may be recommended as a routine measure. The "oral air-way" is also useful.

When intercurrent asphyxia is not properly treated it may quickly assume grave proportions and culminate in the condition to which the term respiratory shock has been applied (pp. 67 and 253).

Illustrative Case, No. 40.—M., about 50. Thick-set. Large features. Receding chin. Glazed and red face. Very nervous. Nitrous oxide and oxygen for dental extraction. Mouth-prop inserted. Rather more oxygen than usual given—otherwise method as described on p. 318. Although breathing was at first freely oral, it soon became inadequately nasal. In 30 seconds from commencement, *i.e.* when consciousness barely lost, the patient held his breath. Brisk lid reflex present. Pressure of jaw forwards and pulling up chin did not succeed in starting breathing. Kept face-piece applied for 15 seconds, when cyanosis from suspended

[1] Venesection was practised by Dr. John Reid in the treatment of asphyxia (see Johnson's *Essay on Asphyxia*). See also an interesting case of drowning reported by Mr. J. F. Briscoe (*Brit. Med. Journ.*, 23rd September 1899), in which venesection apparently saved the patient. The venous engorgement was so intense that retinal hæmorrhage and temporary blindness occurred.

breathing becoming marked, face-piece removed and finger passed between tongue and palate, which were in close apposition. Immediate reflex retching excited. As anæsthesia judged to be insufficient (only about one-half or one-third the usual quantity of nitrous oxide having been inhaled), face-piece again applied. Breathing still refused to proceed. After about 10 seconds, face-piece again removed, and tongue again separated from palate and pharynx. One act of retching. Anæsthesia now judged to be sufficient for short operation owing to intercurrent asphyxial factor. Patient believes he was conscious of second extraction. Some uneasiness and rapidity of pulse afterwards.

In this case the reader should note (1) the type of subject; (2) the early arrest of breathing; (3) the presence of a mouth-prop—sometimes favouring obstruction; (4) the very simple nature of the arrest; (5) the correspondingly simple treatment; and (6) the dependence of the anæsthesia upon intercurrent asphyxia.

Illustrative Case, No. 41.—M., æt. about 40. Bloated, flabby, and very alcoholic. Short stature, short neck, large abdomen. Extremely nervous and tremulous. The lower jaw embedded, as it were, in thick flabby tissues, the patient having a "double chin." Good teeth. Operation, removal of small tumour in mammary region. A.C.E.-ether sequence (p. 483). A.C.E. given gradually. Respiration good. No struggling. Some rigidity coming on, Ormsby's inhaler was applied gradually. Respiration at first fairly free, but in a short time some spasm about the jaws came on, and he rather suddenly drew his head somewhat forwards so that the chin approached the sternum. This at once stopped breathing. Could not press jaw forwards from behind owing to thick neck; and forcible extension of the head and neck equally impossible because of extreme muscular rigidity. Mouth opened: Mason's gag introduced, and tongue-traction made. Respiration at once became re-established, and normal colour of face returned. No further difficulty beyond that great care had to be exercised to keep an air-way open.

The above case illustrates the difficulties which may arise in anæsthetising a patient of the type described by means of a "close" method. Had the C.E. mixture been gradually given throughout, on an open mask—the more appropriate procedure for such a case—respiratory arrest would probably either not have occurred or would have been much less pronounced.

Illustrative Case, No. 41a.—The patient a middle-aged man. 6 ft. 7 in. Florid. Hunts a good deal. Clean-shaved. Very good teeth. Smokes 200 cigarettes in a week. Has a "smoker's throat." Audible nasal obstruction on testing. Slow regular heart sounds.

? Alcoholic. A nervous man. Operation on feet. Induction with "gas and ether." No prop. Breathed gas well at first. The 2 gall. bag had to be slightly supplemented from cylinder. No struggling. Ether at first well borne. Then increasing difficulty from nasal obstruction and clenching of teeth. Could not get anæsthetic past the obstruction. After 2 or 3 minutes struggling commenced. Teeth separated by wooden wedge. Patient became almost or completely conscious. C.E. mixture then administered on a Skinner's mask. Mason's gag between teeth. Anæsthesia soon induced owing to the now free air-way. Oral "air-way" inserted. No further difficulty throughout. During the recovery period there was a good deal of mucus in the throat, and on sponging this from the fauces, vomiting took place—a large quantity of bilious mucus being ejected. *On inserting the finger to examine the throat it was observed that with each expiratory effort a soft mass about the size of half a walnut protruded forwards from behind the palate and then receded with inspiration.* It seemed to be central on examining the patient's throat during convalescence; no evidence was discovered of the swelling felt at the time of the operation. The fauces were much thickened, and the posterior wall was granular. It was observed when the mouth was open and the patient drew in a breath, that the faucial aperture was very small, and that the pillars of the fauces seemed to be in relief on the posterior pharyngeal wall.

On a subsequent occasion when a second anæsthetic was needed the chloroform-C.E. sequence was used. Administration began with chloroform on a Skinner's mask (2 mins.). Then C.E. mixture (about 5 mins.). The patient moved restlessly once or twice but there was no struggling. He complained of the slow action of the anæsthetic. At the end of 5 minutes, whilst inhaling the mixture, he began to shout and use bad language, but there was no struggling. An Ormsby's ether inhaler was therefore applied which at once stopped the shouting but caused suspension of respiration. After two breaths of ether, C.E. mixture was resumed. Respiration recommenced when wedge placed between front teeth. Induction lasted 12 minutes. Some reflex rigidity during operation on foot. As it was difficult to obtain full anæsthesia with the C.E. mixture, chloroform was substituted, and the artificial air-way inserted with good results. The administration lasted about 65 or 70 minutes. The patient recovered as on a previous occasion with explosive vomiting of swallowed mucus and much jaw spasm. On examining the fauces it was again found that the pharyngeal wall bulged with expiration, though not nearly so markedly as on a previous occasion.

This case was an exceedingly difficult one It is quoted at some length as it has many points of interest. The patient was one of the worst subjects for a general anæsthetic. He had a very obstructed air-way, an irritable throat, and by reason of his huge frame and tobacco-poisoned nervous system, he was very insusceptible to the anæsthetic. The case is specially interesting in the present connection because of the remarkable "bulging pharynx" which was observed with each expiration. It is probable that a better result would have been obtained had preliminary narcotisation been adopted and ether altogether avoided.

Illustrative Case, No. 42.—M., about 63. Tall, powerful build. Rather stout, with tendency to double chin. Rather receding lower jaw. Good heart-sounds, except for slight bruit probably due to excited action. Complexion naturally florid, but rather pale from nervousness. Temperate as regards alcohol, but smokes a good deal. Operation, excision of rectum. "Gas and ether" administered some weeks previously for a rectal examination: patient reported to have almost died: four teeth were knocked out during attempts at resuscitation: much cyanosis: tracheotomy nearly performed, but artificial respiration succeeded. Dorsal posture. A.C.E. first on Skinner's mask for 3 minutes: no difficulty. Soon began to snore. Just as slight rigidity commencing, *i.e.* in 4 or 5 minutes from beginning, changed to ether (Ormsby's inhaler). Slight cough and movement of arms. Gradually breathing stertorous, but corneal reflex still present. Patient placed in lateral posture. Operation (rectal) begun. *Slight reflex movement.* Stertor more pronounced. Some difficulty in pushing jaw forwards. Much spasm about jaws and neck. Operator was asked to suspend operation. Mouth opened with difficulty, and tongue separated from palate. Operation resumed. Changed to chloroform (Skinner), but almost immediately had to ask operator to stop operation again. Wooden wedge inserted, and finger passed to back of fauces, and for a few moments some air entered larynx, but breathing quickly ceased completely with intense cyanosis. Corneal reflex present. Mason's gag inserted. Tongue-forceps applied, but air would not enter. *Tongue, soft palate, fauces, and adjacent parts enormously swollen*, so that it was practically impossible to pass finger to epiglottis. Patient put back into dorsal posture. Head extended over end of table. Artificial respiration by Silvester's method attempted, but no effect produced. Tracheotomy rapidly performed by operator. *Artificial respiration still unsuccessful.* Air now blown through the tracheal tube,[1] and with immediate success. Artificial respiration was now possible. Recovery quickly ensued. The operation, which was successfully completed under chloroform administered through the tracheotomy tube, lasted 70 minutes. The tube was removed during the recovery period.

This remarkable case is one to which the term respiratory shock may be appropriately applied (pp. 67 and 253). It is probably to be explained as follows. *Predisposing causes*

[1] The credit for this prompt action belongs to Mr. H. R. Wadd of Richmond, who assisted at the operation.

of arrested breathing: excessive use of tobacco; naturally narrow air-way; receding lower jaw; flabby tissues; obstructive stertor, possibly favoured by close method of anæsthetisation. *Exciting causes of arrested breathing:* rectal manipulation during moderate anæsthesia, causing additional (reflex) stertor, and possibly some general (reflex) muscular spasm; rapidly resulting venous engorgement and swelling of tongue, palate, fauces, and adjacent parts. The author has never seen a more remarkable phenomenon than this rapidly supervening and intense swelling. According to this view of the case the first point of interest is the increase which took place in the already existing stertor. Reflex stertor has already been considered (p. 54). The next interesting point is that, in consequence of the intense asphyxial spasm by which the chest was fixed, it was impossible, by the ordinary method of artificial respiration, to obtain an entry of air through the tracheotomy tube. The third, and perhaps the most important point of all, is that lung inflation at once re-established breathing.

Illustrative Case, No. 43.—F., æt. about 35. Healthy in appearance. Good chest expansion. Quick but good heart's action. Operation for ruptured perineum. Chloroform on Skinner's mask. In 7 to 9 minutes from commencement of administration pupils moderately contracted (about $2\frac{1}{2}$ mm.), breathing quiet and non-stertorous, pulse and colour good. Operation commenced. On several occasions high-pitched crowing inspiration was noted, even though corneæ insensitive and patient apparently well under. The difficulty was overcome by giving more chloroform and pushing the lower jaw well forwards. On one occasion, however, this plan failed, and an asphyxial condition supervened. The mouth had to be opened and tongue-forceps applied. This restored breathing, but the colour remained pale and dusky afterwards. Ether now given on an open mask. Pulse and colour gradually improved, and satisfactory anæsthesia was maintained without any difficulty for half an hour. The operator found, however, that the parts were far more vascular under ether than under chloroform, so the latter anæsthetic was again tried. Precisely the same respiratory difficulty as before appeared. The operation, however, was by this time just finished. The crowing breathing subsided altogether directly the manipulations about the perineum were discontinued.

The above case is of considerable importance as illustrating the occurrence of what may be termed reflex laryngeal obstruction during the use of chloroform. The state which supervened was one to which the term respiratory shock may be applied (pp. 67 and 253). Florid, young, and middle-aged patients seem particularly liable to this condition under chloroform during such operations as that mentioned, and the only treatment which is of any avail in obstinate cases is forcible tongue-traction.

Illustrative Case, No. 44.[1]—M., æt. 35. Middle height, well nourished, rather florid. Present general condition good, but has had many rheumatic attacks, which have left him with articular disease and stiffness in many parts of the body. Neck rigid. Can only open mouth about one-quarter of normal extent owing to chronic rheumatoid disease of articulations of jaw. Pure nitrous oxide administered for tooth-extraction. Usual method adopted. Small mouth-prop inserted before face-piece applied. The usual phenomena of nitrous oxide narcosis presented themselves. Tooth extracted. The nitrous oxide had been pushed till respiration underwent the characteristic change in rhythm; but the admission of air which followed the removal of the face-piece failed to restore the rhythm of breathing. Instead of respiration becoming re-established and the normal colour returning, breathing became more difficult and quickly ceased, as if from some obstruction. It was impossible to push the lower jaw forwards because of its fixity, or to extend the head and neck owing to the rigid and ankylosed spine. The finger could not be passed to the back of the throat by reason of the small aperture between the teeth. Tongue-traction was at once made, but failed to restore breathing. Compression of the thoracic walls was equally unsuccessful. The patient was placed upon the floor and forcible pressure was brought to bear on the sternum, but the thorax was immovable. The face was cyanosed and bloated, the lips purple, the whole body rigid, the chest motionless and fixed. Breathing had been suspended for about 2 or 2½ minutes, according to my reckoning; but it is difficult to speak positively on this point. It was obvious that the only remedy left was laryngotomy. Having my tracheotomy instruments with me, I rapidly opened the crico-thyroid membrane with a pocket-knife and inserted a tube. Breathing at once recommenced. The patient made an uninterrupted recovery.

There are many points of similarity between this and Illustrative Case, No. 42. As has been shown, when nitrous oxide is administered to its full extent, the larynx is often drawn up, as in deglutition, to meet the epiglottis. Should the temporary obstruction thus brought about not pass off spontaneously, as it usually does, all that is necessary in ordinary cases is to push the lower jaw well forwards from behind, or to pass the finger to the back of the throat. But

[1] The author published this case in detail in *Journ. Brit. Dent. Association* for 1888, vol. ix. p. 222.

in this case these manœuvres were impossible, owing to the almost complete fixity of the jaw. It is probable that, as in Illustrative Case, No. 42, secondary venous engorgement and swelling contributed to the occlusion.

An exactly parallel case has been recorded lately.[1] A male, aged 24, suffering from multiple osteoarthritis, had a mouth full of septic roots. It was thought advisable to remedy this as part of the treatment of his condition, and gas was given by the nasal route for a first instalment of the clearance of the mouth. The jaw could be opened only $\frac{1}{3}$ of an inch, owing to changes in both mandibular joints; but nasal respiration was perfectly free. The course of events was exactly the same as in the case just described; and it is interesting to note that as soon as the asphyxial symptoms were relieved by tracheotomy, the congestion and swelling of the epiglottis, tongue, and neighbouring soft parts, which had been the cause of complete laryngeal obstruction, rapidly subsided, and the patient could breathe through the natural passages. The removal of the teeth was accomplished on the following day under chloroform administered through the tracheotomy tube.

The next case illustrates the impossibility, in some instances, of pushing or dragging the lower jaw forwards. The difficulty of breathing was due to this cause, for the base of the tongue was in contact with the pharynx and could not be brought away by the usual means.

Illustrative Case, No. 45.—M., æt. about 22. Pale: neck much enlarged both sides by sub-maxillary glands: no nasal respiration, probably from presence of adenoid growths. Operation for removal of cervical glands. Teeth kept apart by preliminary insertion of small piece of cork. Ether administered by Clover's inhaler. Respiration difficult. Unable to keep lower jaw pressed forwards by reason of its being deeply embedded in the glandular swelling. Tongue much engorged. A.C.E. mixture tried: no better result. The difficult respiration obviously depended upon the tongue obstructing the oral air-way. Had to keep base of tongue hooked forwards by finger. Eventually had to keep tongue pulled continuously forwards by means of tongue-forceps, and to administer chloroform from one end of a Skinner's mask. By this means respiration became free and all difficulty vanished. Administration lasted one hour.

Viewed in the light of more recent experience this patient was certainly not a suitable subject for close etherisation. Had the C.E. mixture been gradually administered from a Skinner's mask there would probably have been little or no difficulty.

[1] Relph and Rood, *Brit. Med. Journ.*, 28th May 1910, p. 1287.

2. OBSTRUCTION DUE TO THE PRESENCE OF ADVENTITIOUS SUBSTANCES WITHIN THE UPPER AIR-PASSAGES.

Blood may enter the larynx, trachea, or bronchi, either as the result of some surgical procedure about the air-passages or as a consequence of hæmoptysis or epistaxis.[1] The two last-named conditions are very rare, but it is nevertheless necessary to bear in mind the possibility of their occurrence. With regard to the entry of blood into the larynx, trachea, or bronchi, as the immediate result of some surgical operation, it is clear that the invasion may take place either from above or from below, and the symptoms displayed by the anæsthetised patient will naturally vary with his general state, the posture, the depth of anæsthesia, the quantity of blood present, and the natural degree of sensitiveness of the air-tract.

In operations within and about the mouth, nose, and throat, small quantities of blood frequently gain access to the larynx and trachea; but, as a general rule, such quantities do not give rise to any serious symptoms either at the time or subsequently; for when the anæsthetic is withdrawn, swallowing and coughing return and the breathing and colour quickly become normal in type. But if, during such operations, the rules to which reference has already been made (p. 184) be disregarded, and if hæmorrhage be free, obstructive symptoms may come about either gradually or with remarkable suddenness, and the anæsthetist may find himself face to face with an alarming state. Should it be necessary to keep up a fairly deep anæsthesia, and should the posture be such that blood cannot flow freely from the mouth, frequent sponging as already described (p. 184) must be practised. The sponges employed should be, when moist and expanded, about half the

[1] The author has met with one case of epistaxis under ether, in a young man of about 24, and with one case under nitrous oxide and oxygen in a girl of about 16. In Dr. Sheppard's notes he finds another case recorded in which epistaxis occurred under chloroform. In the latter case the patient was a man of 62, and the epistaxis came on after struggling. A moist râle in the trachea was the first indication of the bleeding. On looking into the mouth a good deal of clotted blood was discovered. Hæmoptysis is very rare. The author has never met with it, though he knows of one case in which it occurred, to a slight extent, under ether.

size of the patient's fist, and it is important that they should be coarse and free from loose pieces. New sponges which have been allowed to soak in 1 : 20 carbolic lotion and then washed in water should be used, and it is best to have half a dozen of such sponges at hand. The author was once able, by using a sponge of this kind, to entangle in its coarse meshes, and so remove from the larynx and trachea, a clot which measured over four inches in length. In cases of this class a careful watch must be kept for any moist expiratory râle—the first sign that the larynx and trachea are becoming invaded by an undesirable quantity of blood. Should this râle become audible the anæsthetic must be at once withheld until coughing takes place, whilst repeated sponging should be practised. The application of ice-cold water to the face will sometimes help to re-establish the coughing reflex. In some cases the breathing comes to a standstill so quietly that the true nature of the arrest may not be recognised. In gradually increasing obstruction, however, a râle is audible, and progressive cyanosis usually occurs.

In the following interesting case the entry of blood into the trachea and large bronchi during a throat operation necessitated the discontinuance of the anæsthetic before the final stage of the operation was reached.

Illustrative Case, No. 45a.—The patient was a healthy, wiry boy of 10. Anæsthesia was induced by "gas and ether" without the smallest difficulty. After two or three minutes' etherisation the C.E. mixture was administered upon a Skinner's mask for about four minutes. The patient was in the dorsal posture. The tonsils, which were large, were removed by a guillotine. The operation excited no reflex movement though the corneal reflex was just present. Anæsthesia was then kept up by chloroform for the removal of adenoids—Junker's inhaler being employed. During the removal of the adenoids frequent sponging was practised and the head was occasionally turned to one side. A coarse expiratory râle became audible (? laryngeal or tracheal). *The corneæ were insensitive to touch.* Notwithstanding this, there was no cough such as is usual when blood is present in the larynx during light anæsthesia. Frequent sponging and the application of iced water to the face were tried, and the patient was turned upon his side in order to keep one lung free. Still no cough occurred and the colour was distinctly dusky. Although the patient had so far recovered from the anæsthetic that sponging the fauces caused general movement and loud phonation, no cough could be elicited. It was obvious on putting one's ear to the chest that a considerable quantity of blood had gained access to the large bronchi. There still remained a slight operation to be performed upon the turbinate bones, but it was deemed advisable to defer this. *It was not until the patient became sufficiently conscious to obey a request to cough that he cleared his air-passages.* He then expelled, by coughing and vomiting, considerable quantities of blood, and the bronchial sounds rapidly began to clear up. There were no after-effects.

It is difficult to say whether, in the above case, the larynx and trachea were abnormally insensitive, or whether the asphyxial state brought about by the entry of blood into the larynx and trachea during a rather too deep anæsthesia produced the laryngeal insensibility. Reference has already been made to patients whose upper air-passages are insensitive to stimuli, and to the need for great caution in anæsthetising such patients for throat operations (p. 185).

Should the larynx be naturally insensitive, the hæmorrhage free, and the anæsthesia deep, blood may suddenly invade the air-passages and breathing cease with little or no alteration in colour. Should the withdrawal of the anæsthetic, assiduous sponging, and attention to posture prove unsuccessful in removing blood from the larynx, the chest and the abdomen must be forcibly compressed. As a general rule, this will succeed in expelling blood, but should it not do so, the patient must be partially or completely inverted and systematic artificial respiration performed, care being taken to keep the teeth apart, the tongue pulled forwards, and the throat frequently sponged out. If these measures fail, laryngotomy must be performed, artificial respiration renewed, and, if necessary, a catheter introduced into the trachea with the object of sucking out the obstructing fluid. Lung inflation through the laryngotomy wound may also be tried should artificial respiration fail to effect an entry of air.[1]

During operations upon lung cavities blood may enter the bronchi, and under certain circumstances obstruct breathing. The following interesting case may be quoted :—

Illustrative Case, No. 46.—M., about 45. Has been very ill for several weeks. Thin. Orthopnœa. Dusky. Prominent eyes. Anxious

[1] For illustrative cases see *Brit. Med. Journ.*, 24th Feb. 1883, p. 352 (two fatal cases recorded). Also *Lancet*, 7th Aug. 1881, p. 386. Also *Brit. Med. Journ.*, 16th Sept. 1882, p. 531 ; and *Lancet*, 30th Sept. 1882, p. 540.

and nervous expression. Quick respiration. Pulse feeble and quick—about 160. Air enters right lung fairly freely. Left side dull and immobile, with amphoric breathing at base. Operation, resection of rib and draining lung cavity. Lies more easily on right than on left side; but sitting posture most comfortable. Placed partly on right side and partly sitting. A.C.E. mixture given slowly, and then a little ether added. Breathing quick and somewhat more laboured. Deep anæsthesia impossible. Offensive pus evacuated. Some hæmorrhage. Rib excised. Drain inserted. During operation a coarse râle became audible, and though anæsthesia light, colour became more dusky. Placed patient on *left* side in order to keep better lung free from blood and pus. A coarse râle palpable over right lung. Dusky. Pulse very quick and weak. Strychnine injected. Enema of brandy. Brisk corneal reflex, but asphyxial state persisted. Patient still unconscious, though no anæsthetic had been given for a considerable time. As condition did not improve, I inserted gag and tickled epiglottis and fauces with finger. This induced cough, and a sponge in fauces now extracted a clot which had probably been coughed up from right bronchus. Immediate improvement and quick return of consciousness.

The above case is a very good example of intercurrent asphyxia. Symptoms such as these are often erroneously ascribed to the anæsthetic or to "shock."

Numerous cases are on record in which, during anæsthesia, **vomited matter** has been drawn into the larynx and trachea, and has thus caused fatal asphyxia. As we have already seen, vomiting is of not unusual occurrence with most anæsthetics, and should the stomach contain undigested solids or liquids there is always some risk connected with the expulsion of its contents. A proper regulation of the diet is not always possible, and there are, moreover, certain cases, *e.g.* those of intestinal obstruction, in which vomiting is a feature of the malady for which an operation is needed. In such cases every care must be exercised by the administrator. The advisability of washing out the stomach has already been discussed (pp. 170 and 205). When this precaution has not been taken, and it is known that the stomach contains semi-solid or fluid matter, the head should be kept upon its side throughout, and in the case of heavily built or obese subjects the opposite shoulder should be raised by a pillow, and a Mason's gag inserted in order to allow of the fauces being rapidly cleared, should occasion require. Unless these precautions be taken, the administrator may suddenly be confronted by an alarming condition

—the mouth and nose being full of vomited matter, the jaws tightly clenched, the neck rigid, the breathing completely arrested, and the patient cyanosed. In such circumstances as these it may be difficult to re-establish breathing in time to avert asphyxial syncope, especially when chloroform has been used and the patient's heart is dilated or feeble. In less urgent cases the larynx, trachea, and bronchi gradually become invaded by vomited fluid, and a state of increasing asphyxia results.[1]

The treatment to be adopted in all cases in which the vomiting of solid or fluid substances takes place is to clear and re-establish the air-way as speedily as possible. The mouth must be opened—if necessary with the mouth-opener—a Mason's gag inserted, the head and shoulders turned well to one side, and the fauces cleared with the finger or sponge. Should obstruction appear to be due to some undigested solid food which cannot be thoroughly reached and removed by the finger, a pair of curved forceps may be used with advantage. If the breathing become seriously impeded, and if the above measures fail to restore it, an attempt must be made, by compressing the sides and front of the chest, to force air past the obstruction. If, however, artificial respiration fail, laryngotomy must be resorted to.

Children, adolescents, and patients suffering from affections of the nose, throat, and adjacent parts may secrete considerable quantities of **mucus**, particularly during ether anæsthesia. In some cases an inadequate nasal air-way seems to be the principal factor in the causation of the excessive secretion, a comparatively small quantity of mucus within the naso-pharynx becoming churned up and aerated to such an extent that a copious frothy fluid results. In other cases it is not so much the *quantity* of mucus which constitutes the danger as its extraordinarily viscid and "stringy" *quality*. The difficulties referable to the presence of mucus and saliva are of two kinds. They either (*a*) depend upon the local irritant

[1] This would appear to be the most probable explanation of a case reported by Mr. Carter Braine (*Trans. Soc. Anæsth.* vol. vii. p. 12). The patient was a fat woman of 65, a bronchitic subject with intestinal obstruction. She had recently had champagne. There was frequent vomiting. A light chloroform anæsthesia was skilfully maintained, the patient being in the lateral posture. The ears became dusky, the breathing moist, and gradual asphyxia supervened.

action of these secretions; or (*b*) they come about from the secretions themselves actually blocking, to a greater or less degree, some portion or portions of the air-tract. (*a*) Coughing, repeated swallowing, laryngeal spasm, retching and vomiting, all of which phenomena have already been discussed, may be excited by the presence of mucus within or about the upper air-passages. With such anæsthetics as ether and chloroform it is possible that the secretion in question acquires an irritant character by reason of the absorption of the vapour which is being administered. Respiratory difficulties dependent upon this local action of mucus rarely give cause for anxiety; although they may, if persistent, culminate in a more or less pronounced degree of asphyxia, the true nature of which is liable to be overlooked. Thus, the association of constantly recurring deglutition movements, with more or less continuous laryngeal spasm, may in certain unsatisfactory subjects lead to laboured breathing, cyanosis, pulse-feebleness, or even pallor —phenomena which may erroneously be ascribed to "surgical shock" or "chloroform syncope." (*b*) When the breathing is vigorous, as is usually the case during ether anæsthesia, the obstruction caused by mucus is rarely sufficient to lead to respiratory arrest. It may produce some embarrassment in breathing, with duskiness or even cyanosis, but unless the anæsthesia be exceedingly profound no further trouble usually arises from this quarter. At the same time moist bubbling or rattling respiration associated with deep ether anæsthesia generally indicates some want of skill on the part of the anæsthetist; it is most likely to constitute a danger when certain other conditions predisposing to respiratory arrest are present. Thus, if deep chloroform anæsthesia be induced whilst the larynx and trachea contain viscid mucus, respiratory arrest may readily take place, the mucus acting as the "last straw." We have already seen (p. 500) that this is the reason why great caution is necessary in passing from ether to chloroform anæsthesia, and that the change from the first to the second anæsthetic should not be made when laryngeal mucus is known to be present without first allowing the patient to clear his air-passages by a cough. If this rule be not followed, the anæsthetisation of the patient to the usual degree may be unexpectedly attended by stoppage of breathing. Some years ago, before the author clearly appreciated this fact, he met with one or two cases in which breathing ceased in this way. The patients in whom such a cessation of breathing is most likely to prove dangerous are the very young and those whose air-passages have become narrowed as the result of some pathological state. If, in anæsthetising an infant, chloroform be substituted for ether, and breathing cease from the presence of viscid laryngeal mucus, there may be difficulty in restoring it. The author once met with such a case. When the breathing ceased he applied chest compression several times, but though he was able to force air *out* of the chest the elastic recoil was apparently not sufficiently powerful to overcome the obstruction caused by the viscid mucus and to draw air *in*. Fortunately breathing recommenced spontaneously; but the case showed how dangerous it may be to change from ether to chloroform during deep anæsthesia. The respiratory arrest which sometimes takes place during the anæsthetisation of patients whose air-passages have become narrowed by disease, may also have as its immediate cause the presence of mucus within the narrowed tract. For example, a case of enlarged thyroid may be complicated by the presence of tracheal or bronchial catarrh, and if anything more than a light chloroform anæsthesia be secured breathing may cease in the manner indicated. Lastly, respiratory arrest may be brought about by mucus entering the larynx as the result of suddenly changing the patient's posture.

Illustrative Case, No. 47.—F., about 18 years. Healthy looking. Good condition. Removal of small thyroid tumour. C.E. for 3 minutes. Chloroform for remainder of administration. When the patient was ready the neck was completely extended, with a pillow under the shoulders. Deep anæsthesia. No difficulty during operation. One slight attempt to cough out small amount of mucus. Cough soon subsided. When operation was nearly finished, the patient being well and properly under, with no sound of mucus in air-passages, the pillow under the shoulders was gradually moved towards the head, so as to lessen extension of the neck. The breathing immediately ceased and the pupils dilated.[1] The chest was compressed a few times and at each compression there was an audible

[1] This sudden dilatation of the pupil, the result of sudden and complete obstruction to the passage of air during deep chloroform anæsthesia, is a striking phenomenon. The author has observed it in several cases.

sound of air passing through fluid (mucus). No further difficulty ensued.

In the above case mucus had been accumulating in the naso-pharynx, and was thrown into the insensitive larynx by raising the head.

When mucus tends to accumulate, an attempt should be made to ascertain the cause. Some inadequacy in the air-entry is often present; and the substitution of free oral for inadequate nasal breathing may quickly have the desired effect. The head should be kept well upon its side, the dependent cheek frequently wiped out and the fauces cleared by means of coarse sponges. Should these simple measures fail and the mucus be causing an undesirable degree of respiratory embarrassment, the anæsthetic must be withheld and one or two coughs encouraged, after which a change to chloroform may be cautiously effected. If breathing tend to become or actually become arrested, and if it cannot be reflexly restored by throat sponging or other stimuli, chest compression and other measures which have been advocated in dealing with respiratory arrest from the presence of blood must be applied.[1]

There is nothing worthy of special notice regarding the presence of **pus** within the upper air-passages. It may gain access in various ways; and any difficulties connected with its presence must be treated as described above.

Portions of morbid growths, pieces of necrosed bone, etc., may become dislodged during certain operations within the nose, mouth, naso-pharynx, and larynx, and may possibly obstruct breathing. The author has good reason to believe that during operations within and about the nasal cavities, adenoid growths, portions of turbinated bodies, etc., frequently gain access with blood to the trachea and bronchi. But it is exceedingly rare, if the depth of anæsthesia be properly regulated and such operations be conducted with aseptic precautions, for any dangerous condition to arise either during or after anæsthesia.

Extracted teeth, fragments of teeth, and amalgam or other

[1] In the *Brit. Med. Journ.*, 18th Nov. 1882, p. 994, a case is reported in which a child of 17 months died under chloroform. At the autopsy large quantities of mucus were found at and below the bifurcation of the trachea.

stoppings are liable, during dental extractions, to fall or fly from the forceps of the operator. Bicuspid teeth have a special tendency to shoot from the forceps whilst being extracted. In most cases, no harm results from the escape of such bodies either into the mouth or throat. But there is, nevertheless, need for the greatest caution during the use of anæsthetics in dental surgery, seeing that several cases are on record in which alarming and even fatal symptoms have arisen from the entrance of foreign bodies of this class into the larynx or trachea. The accident seems to have taken place, in most cases, during a deep inspiration. When anæsthetising patients for these operations the head should be arranged as vertically as the requirements of the operator may permit; for when the head is thus placed, all substances which may escape from the forceps will tend to fall upon the tongue or floor of the mouth, from which situations they may be immediately removed. The head, moreover, should be adjusted so that it is in a line with the body; for if it be extended, the act of swallowing—nature's safeguard against the accidents under consideration—will be difficult or impossible. If a tooth, stump, or fragment should escape into the pharynx, and if it should not be immediately swallowed, it may remain for a considerable time in the epiglottic region, and may ultimately pass into the œsophagus or be forced away by coughing. Shell-like fragments of teeth are more liable than weightier bodies to enter the larynx, owing to their being more easily swept along by the inspiratory current. Should any of the foreign substances under consideration gain access to the larynx or trachea during anæsthesia, certain symptoms may occur at the moment of their entry. Coughing of a spasmodic character may thus be excited; and this may at once dislodge the substance. Sometimes the coughing is so slight as to escape notice. In other cases the foreign body lodges in the larynx and sets up urgent symptoms, such as stridor, cyanosis, and complete cessation of breathing.

In a case reported by Mr. Claremont in 1858 (*Lancet*, 15th May 1858, p. 477), some fragments of teeth entered the larynx during chloroform anæsthesia. When the patient became conscious, after the operation was over, coughing occurred, and a complaint was made of some soreness about the chest. There were, however, at the time, no distinct symptoms of the presence of the fragments. General bronchitis followed. Subsequently the fragments were coughed up from the lungs and the patient made a good recovery.

In the *Brit. Journ. Dent. Science*, vol. xxii., Jan. 1879, p. 7, a case is related in which a large amalgam stopping shot from a tooth during extraction under nitrous oxide, and presumably entered the larynx. Fortunately the patient coughed it out immediately after the effects of the anæsthetic had passed off.

See also *New York Med. Record*, 4th November 1882, p. 517. Also *Trans. Odont. Soc.* vol. iii., new series, p. 36.

In a case referred to in the *Brit Med. Journ.*, 18th Feb. 1899, p. 401, an extracted tooth entered the larynx during nitrous oxide anæsthesia, causing extreme cyanosis. Subsequently there was a feeling of tightness in the throat, aggravated by speaking or by change of posture. No breath sounds were audible over the left lung. Death took place in twelve days. At the necropsy the tooth was found in the left bronchus.

A case has been reported to the author in which a medical man, whilst sponging out the throat during a dental operation under ether, inadvertently pushed an extracted tooth backwards. It was hoped that the patient had swallowed the tooth. For three weeks she suffered from certain chest symptoms, which she ascribed to the anæsthetic. At the end of this time the tooth was coughed up and no further trouble followed.

Recently during an administration for dental extraction a tooth flew from the forceps just as it was extracted. It was thought to have fallen on the floor; but as it could not be found there, the mouth and pharynx were searched visually and digitally. There were no signs of the tooth, and just as a renewed search of the floor was instituted the patient, who was by this time coming round from the anæsthetic, suddenly coughed violently and expelled the missing tooth.

During the extraction of teeth under anæsthetics the operator should be most careful to leave nothing whatever loose in the mouth. He should remove each tooth or stump as it is extracted, and see that there is nothing hanging to the forceps when that instrument is reintroduced. When several upper roots have to be extracted, the back of the throat may be protected by the corner of a cloth or by an open-meshed sponge, too large to be gripped by the pharynx. Although the avoidance of accidents of this kind should rest with the operator, the administrator may often assist the latter. Thus it is possible for the administrator to place a finger across the back of the mouth between the tongue and palate; or to press the tongue against the palate and so shut off the oral cavity from the pharynx.

Should symptoms pointing to the entrance of a foreign body into the larynx manifest themselves, the patient should be bent forwards in the operating-chair and narrowly watched. The spasmodic cough and other symptoms may now quickly subside, the foreign body having either been coughed into the mouth and swallowed, or having become so placed in the air-passages that for a while it sets up very few symptoms. Should coughing, duskiness, and difficulty of breathing continue, the back may be smartly slapped whilst the patient is bending forwards. Should this not succeed, the patient may be turned on his side with the object of facilitating the exit of the substance. If this fail, inversion should be adopted. This last-named procedure, although open to the objection that it may cause the foreign body to be coughed into the larynx, where it may induce spasm, has answered in several cases, and may certainly be tried if the symptoms are of sufficient urgency. Should signs of laryngeal spasm (high-pitched stridulous breathing, cyanosis, embarrassed and ultimately suspended breathing) supervene, no time must be lost in opening the larynx at the crico-thyroid space, and, if necessary, performing artificial respiration through the opening thus made.

Other substances, such as artificial dentures, pivoted teeth, portions of or entire mouth-props or corks, portions of instruments[1] used in laryngeal, dental, or similar operations, pieces of sponge, etc., may gain access to the larynx, and set up symptoms of an asphyxial character requiring very prompt measures. An interesting, though unfortunately a fatal case,[2] in which an artificial denture became impacted in the larynx, occurred in 1872, and is well worthy of notice. An unattached cork has been known to slip from between the

[1] A very interesting and instructive case, in which the broken blade of a pair of extraction forceps entered the larynx, was reported by the late Sir William MacCormac (see *Lancet*, 2nd Jan. 1886). The patient was lying in the semi-recumbent posture on a couch with the head raised by pillows. Chloroform was given. The broken blade entered the larynx during two or three deep inspirations. A violent fit of spasmodic coughing immediately took place. The patient became livid and much distressed. Subsequently dyspnœa, cough, and pain were complained of, and Sir William MacCormac, by a skilfully planned operation, removed the foreign body, through a tracheal opening, from the right bronchus.

[2] See *Brit. Med. Journ.* vol. i., 1872, p. 419.

teeth and asphyxiate a patient under nitrous oxide.[1] The spring of a Buck's gag has also been known to enter the larynx and eventually lead to a fatal result. These facts should teach us how necessary it is to see that all dental mouth-gags are firmly secured by string or whip-cord, and also that all spring-gags should be avoided in dental surgery. A case has been recorded in which a sponge, used in the course of a dental operation, caused the death of a patient by becoming impacted in the upper air-passages.[2] A "quid" of tobacco has been known to cause asphyxial symptoms during anæsthesia.[3]

3. OBSTRUCTION DUE TO CONDITIONS DIRECTLY PREVENTING LUNG EXPANSION

We have already studied (p. 51) the respiratory phenomena of anæsthesia, and have seen that, as a general rule, most of the inspiratory work is done by the diaphragm. It is therefore very important that the descent of this muscle should be unimpeded, particularly in those cases in which the thorax would be unable to take on the additional work which would naturally fall to its lot in the event of the diaphragm being unable to act. Similarly, it is important to provide for free thoracic expansion, more particularly in cases in which, for some reason or another, abdominal movements are in abeyance. In more than one of the recorded nitrous oxide fatalities tightly-fitting corsets undoubtedly contributed to the accident. Should the precaution of removing all constricting clothing or bandages have been omitted, and the breathing become embarrassed or cease, no time must be lost in removing all impediments to lung expansion, and in performing artificial respiration should this be necessary.

There are certain **postures**, *e.g.* the prone and semi-prone, in which the trunk weight may tell directly upon chest expansion (see p. 241). Should breathing become much embarrassed or cease, the patient must at once be placed in

[1] See *Med. and Surg. Reporter*, 1867 ; and also Agnew's *Prin. and Prac. of Surgery*, vol. iii. p. 44.
[2] See *Lancet*, 5th Jan. 1901, p. 73.
[3] Fischer, *Deutsche Zeitsch. f. Chir.* Bd. xv. 188.

the dorsal posture and the ordinary means adopted for restoring breathing.

In certain subjects, and particularly in those who are elderly, obese, and emphysematous, the lithotomy posture may involve a dangerous degree of respiratory embarrassment, and it may be necessary to place the patient in some other position. The author has, for example, met with one case in which excision of the rectum had to be performed with the patient in the lateral posture.

Illustrative Case, No. 48.—F., thin, nervous, and somewhat anæmic from hæmorrhage. Operation for piles. Heart-sounds normal. Induction with "gas and ether"; then C.E. mixture. With the fifth or sixth breath of nitrous oxide she got clonus. Operation started under C.E. with corneal reflex present. No movement. The patient was put into the lithotomy position, and soon developed obstructive stertor. In the course of this she got a distinct epileptiform attack lasting six or seven seconds; no opening of eyes. The air deprivation or limitation probably caused this attack, though respiration never entirely ceased. There was no subsequent difficulty.

In this case it is clear that the patient was very susceptible to air limitation, since she developed clonus so early in the administration of nitrous oxide. The previous loss of blood may possibly have contributed to this susceptibility. The lithotomy position added another element to respiratory embarrassment, and the consequent anoxæmia culminated in the epileptiform spasms.

There are numerous **morbid states** which, whilst they may be compatible with blood oxygenation so long as the patient is conscious, will cease to be thus compatible directly anæsthesia has been produced. This may be the case, for example, in patients with excessive abdominal distension from ascites (see pp. 164 and 479), or in those with hydrothorax or other pleural or pulmonary diseases. As a general rule, a comparatively light anæsthesia is here indicated, particularly during the period of greatest respiratory distress; and should occasion require, artificial means must be used for maintaining breathing.

One of the most important conditions capable of directly preventing lung expansion is **general respiratory spasm.** This spasm, as we have already seen, may either arise (1) during the stage of rigidity and excitement (pp. 364 and 423); (2) as the reflex result of some surgical procedure (respiratory shock) (pp. 40, 67, 253, 562, and 563); or (3) as a sequel to occlusion of the air-tract (p. 559). Minor degrees of respiratory spasm are very common during the induction stage of anæsthesia, but the temporary respiratory embarrassment to which this spasm gives rise usually subsides spontaneously, *i.e.* without treatment. In certain types of subjects, however, complete arrest of breathing may take place, and unless remedial measures be promptly adopted this arrest may persist till the heart fails. It is in this way that strong men die in the early stage of chloroformisation. It is in this way, too, that certain cases are to be explained in which patients have died as the result of some surgical stimulus during light or moderate anæsthesia. The supervention of general respiratory spasm in those cases in which breathing has come to a standstill from some obstruction *within* the air-tract constitutes, as we have seen in Illustrative Case, No. 42, p. 562, a most formidable complication; for even when laryngotomy has been performed for the relief of the obstruction, we may find that we have to reckon with an even greater difficulty, viz. fixity and immobility of the thorax. Lord Lister has described one fatal case of this sort, and it is probable that a large number of others have taken place whose true nature has been overlooked.

Many years ago the author met with a somewhat remarkable case of respiratory spasm. The patient was a man of sixty-nine years of age, whose usual pulse-rate was 30 per minute. He was only slightly emphysematous, and not bronchitic at the time. Under the influence of ether his expiration was rather strained. During properly established anæsthesia, breathing suddenly ceased; and though there was no occlusion of the air-way, it was absolutely impossible to move the chest-walls one way or the other by artificial means. The pupils were at the time moderately contracted. Fortunately, breathing spontaneously reappeared after about half or three-quarters of a minute. The close etherisation employed was probably accountable for the symptoms. It is highly probable that the use of forced artificial respiration (p. 580) offers the best chances of resuscitation when breathing thus ceases.

For reasons already given, respiratory spasm under nitrous oxide or ether is not nearly so dangerous as under chloroform. The combination of this spasm with the continued absorption of incarcerated chloroform vapour will, in fact, rapidly destroy life; and this is the explanation of that form of syncope which has so often been described as having occurred early in chloroformisation. If, at the moment when respiration becomes suspended, there is comparatively little chloroform in the lungs and circulation, the wrist-pulse may remain palpable for some time, the heart holding out against the asphyxial strain with a resistance proportionate to its original vigour. If, however, anæsthesia be deep at the moment breathing ceases, the strongest heart may become so rapidly poisoned that the respiratory spasm may be attended or immediately followed by pulselessness.

When general respiratory spasm arises and does not spontaneously subside, the mouth should be opened by means of a Mason's gag, the tongue-forceps applied, the fauces stimulated by the finger and cleared of any mucus that may be present, and artificial respiration attempted. In the event of these measures failing to restore breathing, it is probably best to perform laryngotomy at once, partly because there may still be laryngeal obstruction present, and partly because, when once a laryngotomy tube has been inserted, it is comparatively easy to inflate the lungs. Immediately laryngotomy has been performed artificial respiration should be again tried. Should this fail an attempt should at once be made to inflate the lungs by means of a catheter or by applying the mouth to the tracheal tube, care being taken to close the lips and anterior nares of the patient. As already explained when dealing with occlusion of the air-tract (p. 563), there are certain exceptional cases in which the chest walls cannot be moved by the usual means, even though laryngotomy has been properly performed; and it is in such cases as these that lung inflation holds out the only chance of success. In Illustrative Case, No. 42 (p. 562), direct lung inflation undoubtedly saved the patient's life. Inversion should not be employed, for such a measure would only increase the distension of the right cardiac cavities.

Inflation of the lungs, by means of bellows, was the recognised method of performing artificial respiration before the plans now in use were known to the profession. Amongst those who have invented and used specially constructed bellows for lung inflation may be mentioned John Hunter,[1] Sibson,[2] Plouviez,[3] Marcet,[4] Richardson, and Fell.[5] When the simpler and handier methods began to find favour, inflation of the lungs fell into disuse; and at the present time it is rarely, if ever, employed. There can be no doubt, however, that in the circumstances above narrated lung inflation is the proper treatment. It is highly probable that more lives would be saved in asphyxial conditions generally were greater attention to be paid to lung inflation as a restorative measure.

Lastly, there are **certain operations** about the thorax and abdomen which may themselves mechanically interfere with breathing. Thus, during the removal of a renal tumour adherent to the diaphragm, complete suspension of breathing may take place each time traction is made.

II. TREATMENT OF CENTRAL OR PARALYTIC RESPIRATORY ARREST

1. PARALYTIC RESPIRATORY FAILURE DUE CHIEFLY TO THE TOXIC ACTION OF THE ANÆSTHETIC

This form of arrested breathing is typically seen when an overdose of ether is administered to a healthy patient (p. 367), With the C.E. mixture and *a fortiori* with chloroform, over-dosage is generally associated with such a fall of blood-pressure that the respiratory arrest may be quite as much due to cerebral anæmia as to the toxic action of the anæsthetic upon the respiratory centre. In the case of pure nitrous oxide, overdosage almost invariably induces muscular spasm within or about the air-passages, so that the respiratory failure is of a somewhat different type to that now under consideration.

In most cases respiratory failure of this kind comes about more or less gradually. The breathing grows shallower and shallower till it ceases altogether; or the standstill is preceded by irregular jerks and inspiratory "catches." In rare cases the arrest takes place with unexpected suddenness. As we have seen, shallow and almost imperceptible respiration does not of itself necessarily imply that danger is present. Other

[1] *Asclepiad*, 1890, p. 201 *et seq.* [2] Silvester, *op. cit.* [3] Kappeler, *op. cit.*
[4] *Proc. Roy. Med. Chir. Soc.* vol. iv., 1861-64, p. 45.
[5] *Brit. Med. Journ.*, 1st March 1890, p. 495; *Ibid.*, 16th August 1890, p. 884.

signs must be consulted. So long as the normal colour of the face and ears is not materially altered, the pulse not markedly affected, and the conjunctiva sensitive to touch, feebleness of breathing means little or nothing. But should feeble respiration coexist with a pallid, dusky, or cyanotic complexion, a small, slow, or irregular pulse, and a totally insensitive cornea, the anæsthetic must be withheld, for these signs collectively indicate that complete cessation of breathing is imminent.

When respiration threatens to come to a standstill, without actually ceasing, and the administrator feels certain that the air-passages are not occluded, the anæsthetic should at once be removed, and the lips lightly but briskly rubbed from side to side with a dry towel. Halting and feeble breathing under chloroform may usually be re-established by lip-rubbing, the immediate effect of which is often very remarkable. The author has frequently known respiration, colour, and pulse immediately to improve on briskly rubbing the lips. Sometimes breathing can only be kept satisfactorily proceeding by this little manœuvre. Should these measures not succeed, respiration must be assisted by pressing, with each feeble expiratory movement, upon the chest walls. Gentle rhythmic pressure upon the sternum with one hand, or similar pressure upon the sides of the chest with both hands, may be made. Should the feeble or irregular breathing seem to be dependent upon feeble cerebral circulation, the head should be lowered whilst the measures here advocated are being applied. In one or other of these ways actual cessation of breathing may often be averted.

Should the respiration cease—and this will be known by the absence of all thoracic and abdominal movements, the increasing duskiness of the face, and cessation of all breath sounds—systematic artificial respiration must be resorted to without a moment's delay.

Silvester's Method of Artificial Respiration.[1]—If the patient be lying lengthwise upon a bed, he should be rapidly placed transversely, and his head allowed to hang over the side. Should he be lying upon

[1] See *The Discovery of the Physiological Method of Inducing Respiration in Cases of Apparent Death from Drowning, Chloroform, Still-Birth, Noxious Gases, etc.*, by Henry R. Silvester, 1863.

an operating-table, similar extension of the head may be effected over the end of the table. If he be in the sitting posture at the time of the respiratory failure, he should be at once placed on the ground with his shoulders slightly raised and his head extended. Although it is here assumed that the air-passages are patent, it is best, as a routine practice, to insert a gag, apply the tongue-forceps, and make traction upon this organ in order to be quite sure that it is not obstructing breathing. This will of itself often re-establish respiration, without the necessity for

Fig. 70.—Artificial Respiration by Silvester's Method (Expiration). From a photograph.

further manœuvres; such tongue traction is often known as **Laborde's** method of artificial respiration. As is well known, the respiration may become obstructed so inaudibly that an error in the diagnosis of the kind of respiratory failure may easily be committed. Full extension of the head and neck, as pointed out by Dr. Howard,[1] tends to keep open a free air-way. The administrator should stand behind his patient, and, grasping the arms at the elbows, should press them firmly and steadily against the sides of the chest (Fig. 70). In the vast majority of cases this

[1] See *Lancet*, 27th October 1888, and *Brit. Med. Journ.*, 7th November 1888, "On Raising the Epiglottis."

pressure will cause an expiration; but should it not do so at once, forcible pressure below the costal margins, and directly towards the diaphragm, may be brought to bear. After the arms have been steadily pressed against the sides for about a couple of seconds, they should be brought deliberately towards the administrator, so that they come into the long axis of the patient's body, on either side of his head. This procedure usually has the effect of enlarging the capacity of the chest by

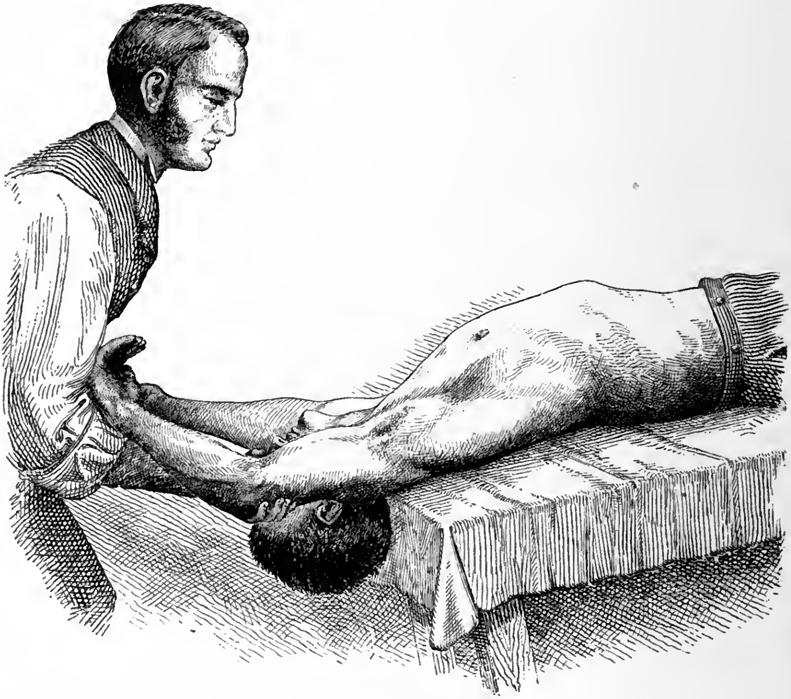

FIG. 71.—Artificial Respiration by Silvester's Method (Inspiration). From a photograph.

causing the pectoral muscles to raise the upper ribs. In this way (Fig. 71) inspiration is effected. The arms should be kept extended for about a couple of seconds, after which they may be again brought to the side as in Fig. 70. These expiratory and inspiratory movements should be repeated regularly and steadily about fifteen times per minute, careful watch being kept for any spontaneous respiration. If any signs of the latter appear, the natural movements should be supplemented by the artificial till the breathing has become thoroughly re-established. Care must be taken throughout to maintain a free air-way, and not to exert undue and unnecessary force during expiration. Ribs have been fractured, and rupture of the liver has actually occurred, from too roughly handling the patient.

Schäfer's Method[1] **of Artificial Respiration**, though superior to all others for cases of asphyxia by drowning, etc., is not so well adapted for respiratory failure in the operating theatre as it is for other forms of suspended breathing. This is because it necessitates turning the patient on his face, and because the operator must kneel astride the body. This would in most cases necessitate placing the patient face downwards on the floor, which would be nearly always impracticable during the performance of an operation. While simple chest compression, or Silvester's method is being practised, it is easy enough to cover the wound with a sterile towel; but obviously there would be dangerous delay before the wound could be adequately secured if the patient were to be put prone on the floor.

The method itself is extremely simple. The patient is placed face downwards on the floor with the head turned to one side and the arms extended. The operator kneels astride the loins, or on one side of the patient, facing towards the head, and places the inner sides of his wrists on the lumbar regions, in such a way that the thumbs are parallel to each other and to the spine, about three inches apart, while the fingers spread outwards over the lower ribs of each side. Leaning forward, the operator throws the whole of the weight of his body, head, and arms on to his hands, thus compressing the patient's chest and causing expiration. After a second or two he leans back, taking all his weight off his hands, but without removing them from their position; the elasticity of the patient's ribs then causes expansion of the thorax and inspiration ensues. This complete process is repeated twelve or fourteen times a minute.

Chest Compression.—Rhythmic compression of the chest walls, each compression being followed by a removal of the pressure, has already been alluded to as of service in threatened respiratory arrest. As Richardson pointed out,[2] this plan is particularly useful in young subjects, *i.e.* in those with elastic thoracic parietes. Indeed, in the treatment of suspended breathing in children, this simple chest compression usually answers as well as any other method of resuscitation, although, as pointed out above, the presence of mucus within the larynx may prevent the inspiratory recoil which is essential.

The Administration of Oxygen in conjunction with artificial respiration is recommended by some authorities, but it is of questionable value in the class of case now under consideration. If lung ventilation can be secured by artificial means the oxygen of atmospheric air will generally be found sufficient for restorative purposes. Many observers, indeed, consider atmospheric air preferable to oxygen. Moreover, the necessary manipulations for administering oxygen are very likely to

[1] See Report of a Committee of the Royal Society of Medicine on the best method to be adopted in employing artificial respiration in the case of the apparently drowned.

[2] "Artificial Respiration: The Theory and the Practice" (*Asclepiad*, 1890, p. 201).

interfere with the all-important duty of the anæsthetist—that of securing lung ventilation as quickly as possible. Lastly, it is obvious that even were oxygen valuable in these cases it would only be possible to employ it, as a restorative, in hospitals and similar institutions.

Should the arrested breathing be associated with a feeble or imperceptible pulse, the artificial respiration may with advantage be combined with partial **inversion.**

Experience leads the author to believe that **drugs** are of little or no value in the treatment of respiratory arrest.

Digital dilatation of the anus has been recommended as a means of stimulating respiration when other measures have failed. Three successful cases have been recorded by Keyworth.[1]

As already mentioned, patients under the influence of opium, morphine, or other sedatives, are more liable to this variety of arrested breathing than other subjects; and as in Illustrative Case, No. 2, p. 268, delay in the re-establishment of respiration may be quite as much dependent upon the action of the sedative as upon the action of the anæsthetic.

With regard to **prognosis**, we may say that, if a pulse can be detected at the wrist when respiration ceases, and if air can be made to enter and leave the chest, recovery may almost certainly be looked for. Even though the pulse cannot be felt, the administrator should by no means despair, but promptly commence and perseveringly continue artificial respiration. It is almost unnecessary to say that artificial respiration must be kept up so long as there is the slightest chance of restoring the patient. Recovery has been known to take place some considerable time after all signs of natural respiration and circulation have been in abeyance. The most formidable cases are those in which respiration and circulation almost simultaneously cease, apart from surgical shock as a factor.

As special descriptions have been given of the symptoms which characterise an overdose of each agent, it is unnecessary to append any illustrative cases of this variety of respiratory failure.

[1] *Indian Medical Gazette*, 1st May 1911, p. 178.

2. PARALYTIC RESPIRATORY FAILURE DUE CHIEFLY TO CEREBRAL ANÆMIA

Paralytic respiratory failure during anæsthesia is undoubtedly sometimes due, either wholly or in part, to cerebral anæmia. Leonard Hill has particularly insisted upon this fact in chloroform toxæmia (p. 111), and the author can corroborate his views from a clinical stand-point. In the case of ether the administration of an overdose leads to a paralytic cessation of breathing, which is not as a rule dependent, at all events to any great extent, upon lowered blood-pressure. In chloroform toxæmia, however, the arterial tension is often so reduced that the blood-supply to the respiratory centre is greatly diminished, and the breathing fails quite as much from this cause as from the sedative action of the anæsthetic. Patients with an abnormally slow pulse may display this form of arrested breathing under chloroform, even though the anæsthesia be not pushed to the point at which the corneal reflex vanishes. In one case of this kind the author found it necessary to replace chloroform by ether in order to preserve efficient respiration. Numerous cases of chloroform syncope have been recorded in which the breathing reappeared and disappeared as the trunk was alternately inverted and brought to the horizontal plane, clearly showing the intimate dependence of respiration upon blood-pressure. Other things being equal, patients in the sitting posture are more liable than others to display indications of anæmic arrest of breathing. On the other hand, the respiration of those placed in the Trendelenburg posture is generally conspicuously satisfactory, provided that all obstruction be prevented. In surgical practice anæmic arrest of respiration not unfrequently comes about from surgical shock. In the opinion of the author, indeed, surgical shock of the circulatory type is a far more common incident of chloroform anæsthesia than is generally believed; and when this shock is acute, respiratory depression or arrest from cerebral anæmia so rapidly follows the circulatory depression, that unless the most careful observations be made a wrong interpretation may be put upon the case.

The **treatment** of anæmic respiratory arrest is **artificial**

respiration, combined with **partial or complete inversion.** It is, in fact, the same treatment as that described in the following chapter as appropriate in primary circulatory failure of such intensity as to involve respiration. Oxygen is often advocated in these cases, but as in toxic respiratory failure it is of questionable value. Whilst in obstructive arrest of breathing our first duty, as we have seen, is to remove the obstruction and to secure free lung ventilation, and whilst in respiratory arrest of toxic origin our energies must be primarily devoted to flushing the alveoli with atmospheric air, with the object of quickly reducing the tension of the anæsthetic gas or vapour within the pulmonary blood-stream, the main indication in respiratory failure from the causes now under consideration is to promote the action of the nervous mechanism of breathing. This is not necessarily accomplished by oxygen although, of course, a sufficiency of this gas must be available. Attention must rather be directed to the maintenance of an efficient cerebral circulation and to stimulation of the respiratory centre by central or peripheral agencies. By tilting the body to the necessary degree, by face and lip friction, by intravenous or rectal saline infusion, and by similar means, anæmic respiratory failure is most likely to be corrected. It is in such cases as these that a mixture of **oxygen and carbonic acid gas** would appear to have been used with good results upon the Continent, the latter constituent of the mixture acting as a strong respiratory stimulant.

Dr. Ettori Levi of Florence employs a mixture of oxygen and carbonic acid gas containing from 10 to 30 per cent of the latter, and speaks very highly of it as a restorative in chloroform collapse or surgical shock. He states that the effects are often brilliant, especially when respiration is feeble or of the Cheyne-Stokes type. His best results were obtained with a 15 per cent mixture. Dr. Levi states that several hundred cases have thus been treated in the surgical clinic of the Florentine University. A gasometer containing the two gases is kept ready for use in the operating theatre. Dr. Levi refers to papers by Drs. Machetti and Cresenzi.

With regard to other remedial measures these must be looked upon as of secondary importance; but should opportunities be favourable, the drugs recommended for the treatment of circulatory failure (p. 619) may be employed whilst artificial respiration is proceeding. Of these strychnine is most likely to be of service, and may be subcutaneously given in doses of about $\frac{1}{40}$th gr.[1]

Several cases illustrating this form of respiratory arrest will be found in the following chapter. The following case differs from them only in that the effects were displayed before the operation began, and can therefore hardly be attributed to surgical shock:—

Illustrative Case, No. 49.—F., æt. 44. Anæmic from loss of blood; thought probably due to carcinoma ventriculi. Heart sounds normal; not nervous. Induction with C.E. mixture, six minutes. Corneal reflex not present; pupils $2\frac{1}{2}$ mm. Gag in position, mouth well open, no respiratory obstruction of any kind. The dressings were then removed by a nurse, and the abdomen exposed for preparation. Before anything else had been done, the patient gave three unusually deep gasping respirations, the last of which was the deepest. The abdomen was being watched at the moment, and it remained in full expiration; no further attempt at natural breathing was made. The pupils were found to be widely dilated. The colour was excellent. The pulse was very slow and feeble at the wrist; in the temporals it could not be felt at all. The tongue was pulled out with the fingers, and the chest was squeezed five or six times; breathing then returned, and anæsthesia was continued with "open" ether. When the incision was made there was practically no bleeding; and the wrist pulse was still slow and feeble, though better than before. At the conclusion of the visceral manipulations the pulse had become normal in volume, though still rather slow. When the abdominal walls came to be sutured, the surgeon complained of some rigidity. The corneal reflex was still absent, as the patient had been kept well under ether; so C.E. was resorted to in order to get relaxation. In two minutes this was satisfactorily attained, but the pulse once more became very weak, and respiration shallow, though it never actually ceased.

3. PARALYTIC RESPIRATORY FAILURE DUE TO REFLEX INHIBITION OF THE RESPIRATORY CENTRE (?)

The author has notes of one or two interesting cases in which breathing has apparently ceased from what may be

[1] Dr. H. C. Wood has kindly sent the author a pamphlet entitled *Strychnine as a Respiratory Stimulant,* which gives his experiments with this drug. In one case of opium poisoning, seven injections, each of $\frac{1}{16}$th gr. of sulphate of strychnine (=about 6 min. of Liq. Strychninæ Hydrochloratis), were given. See also a case of chloroform poisoning (2 oz. swallowed) in which strychnine was apparently of use (*Brit. Med. Journ.*, 20th November 1897, p. 1498).

termed reflex respiratory inhibition. The following case will illustrate this point:—

Illustrative Case, No. 50.—M., æt. 51. ? A malingerer. Abdominal incision. Ether. Clover's inhaler for induction, then Ormsby's. Well under. Abdomen relaxed. No corneal reflex. Respiration deep and stertorous. Then less full. Good colour. Sudden cessation of breathing at moment of incision. Recommenced very feebly and with long pauses. For the first half-minute of feeble breathing colour good, but soon became dusky. Chest compression soon restored respiration.

In another case of which the author has notes, breathing also suddenly ceased at the moment of an abdominal incision during deep anæsthesia, but as there was some rigidity of the abdomen and chest, the case may possibly have been one of reflex respiratory *spasm* rather than inhibition.

The treatment of this condition is artificial respiration.

CHAPTER XX

THE CAUSATION AND TREATMENT (PREVENTIVE AND IMMEDIATE) OF CIRCULATORY FAILURE

Disturbances of the peripheral circulation are exceedingly common during general surgical anæsthesia, and in a considerable proportion of the cases in which these disturbances occur there is no necessity for anxiety. It by no means follows, because the pulse has ceased at the wrist, that the heart has ceased also. Nor does it follow, because the pulse has become impalpable in one artery, that it has vanished from another.[1] Just as many of the respiratory phenomena displayed by anæsthetised patients may be misinterpreted, so may many of the circulatory phenomena be misunderstood and ascribed to causes which are not at the moment in operation. There is, perhaps, a greater liability for errors of this kind to creep in when studying the pulse than when observing the respiration; and this probably explains the existence of a doctrine which is unfortunately prevalent in many quarters, viz. that the pulse should be wholly disregarded during the administration of anæsthetics. It is urged by those from whom this doctrine emanates that any attention to the pulse may interfere with the vigilant observation of the breathing, and that, in addition to this objection, pulse-changes may actually mislead. The author cannot too strongly dissent from such teaching. As will be presently seen, there are many cases in surgical practice in which pulse indications may be of the greatest possible value; and the anæsthetist who ignores these

[1] The author has on several occasions met with what has appeared to be local pulselessness, which he has been unable to explain, except by the assumption that local vaso-motor effects have been reflexly produced.

indications is closing the door of knowledge in his own face. It is perfectly easy to feel the pulse occasionally without relaxing attention to the breathing. Moreover, should pulse indications mislead (as they unquestionably may) it is because the anæsthetist is in ignorance of the true causes of the circulatory changes which are taking place before him. Provided there be nothing in the general state of the patient to depress the circulation; that the anæsthetic be administered only to a *moderately* deep degree—in other words, without completely abolishing the corneal reflex; and that respiration be freely performed, pulse-indications will certainly be of little or no value. In modern surgical practice, however, we often have to anæsthetise patients whose circulation is in a very unsatisfactory state; whilst it is frequently necessary to administer anæsthetics to such a degree that no corneal reflex can be allowed. It is in one or other of these circumstances that the pulse will very greatly assist us. To take the peripheral circulation as the sole or even the principal guide in the administration of an anæsthetic is bad practice; but to study its changes from time to time is essential.

In all cases in which chloroform or a chloroform mixture is to be employed, and in which the exigencies of the operation may require a deep anæsthesia, it is a good plan to have the radial pulse within easy reach. This is particularly important when, as in the abdominal operations, surgical shock may complicate the anæsthesia.

There are numerous causes upon which circulatory depression or failure during anæsthesia may depend. They are summarised in the accompanying table:—

[TABLE

TABULAR Summary of Causes of (Peripheral) Circulatory Failure during General Surgical Anæsthesia: with EXAMPLES

Predisposing Causes.	Examples and References.	Exciting Causes.	Examples and References.
Profound mental disturbance.	See p. 421.	1. Embarrassed or arrested breathing (Intercurrent Asphyxia).	See Illust. Cases, Nos. 53 and 54, pp. 597, 598.
Anæmia, general debility, or cachexia.	See p. 154.	2. Overdosage by Anæsthetic producing:—	See p. 427.
Shock from injury or loss of blood.	See p. 169.	(i.) Cardio-vascular paralysis, or	
Abnormally slow pulse.	See p. 166.	(ii.) Cardio-inhibitory effects.	
Liability to "faint" (?).	See p. 594.	3. Surgical procedures causing:—	
Feeble, fatty, or dilated, or diseased heart.	See p. 167; also Illust. Case, No. 51, p. 595.	(i.) Surgical shock (circulatory), *i.e.* either reflex vaso-motor effects or reflex cardio-inhibitory effects, or both;	See Illust. Cases, Nos. 55 to 60, and pp. 603 to 607.
Grave respiratory affections attended by dyspnœa.	See p. 161.	(ii.) Hæmorrhage; or	See Illust. Cases, Nos. 73, 74, 75.
Degenerated vascular system.	See p. 167.	(iii.) Entry of air into vein.	See Illust. Case, No. 76.
Venous thrombosis.	See Illust. Case, No. 52, p. 595.	4. Change from horizontal to sitting posture during deep anæsthesia.	See p. 246.
The sitting posture.	See p. 182.	5. Detachment of thrombus and lodgment in cardiac valves.	See Illust. Case, No. 52, p. 595.
The presence of food or fluids within the stomach.	See p. 426.		

The various conditions which may act as predisposing causes of circulatory failure are summarised in the first column of the above table. In the second column will be found references to those parts of the work in which the influences of these conditions have been discussed. It must not be inferred from this somewhat extensive list that circulatory failure during anæsthesia is invariably attributable to one or other of the predisposing causes mentioned, or that such causes necessarily operate prejudicially. For example, pulse failure may readily be brought about by surgical shock during deep chloroform anæsthesia, even though the patient belong to the most healthy type; whilst the presence of anæmia, with its necessarily attendant circulatory conditions, may actually safeguard the patient against circulatory depression by the susceptibility he obviously displays in the early stages of anæsthetisation. The influences of predisposing causes of circulatory failure are best seen when some strain is thrown upon the circulation by the operation of one or other of the exciting causes mentioned in the third column. Other things being equal, the more healthy and adaptable the circulation, the better will it be able to withstand any such strain to which it may be subjected, and the greater will be the chance of re-establishing normal conditions by appropriate treatment.

Profound mental disturbance rarely induces circulatory changes of any great importance. Nothing need here be added to what has been already said concerning anæmia, general debility, cachexia, and shock from injury or loss of blood. Patients with an abnormally slow pulse are undoubtedly specially liable to circulatory depression during deep chloroform anæsthesia. In some of the cases in which the author has met with sudden and acute surgical shock during chloroform anæsthesia, the patients, although apparently in good condition, have had a history of liability to "faint" from badly ventilated rooms, pain, or other causes; but it is uncertain to what extent this liability predisposes to circulatory depression. The factor of cardiac disease has already been fully considered, and an interesting case has been referred to, in which an injudicious line of treatment led to very unfavourable symptoms in a patient with morbus cordis (p. 166). Perhaps the most important of these predisposing causes is the presence of some grave respiratory condition, in the course of which cardiac embarrassment has taken place. For example, when sudden death occurs early in the chloroformisation of a patient suffering from acute pleuro-pneumonia, attended by cyanosis and dyspnœa, death is cardiac, not asphyxial, the labouring heart coming to an abrupt and final standstill as the result of the slight additional strain imposed upon it by transient breath-holding or struggling, In less grave respiratory states, and particularly in those of a more chronic type, the circulatory failure met with during anæsthesia, although of the same nature, is not so likely to be fatal. This is well seen in the following case, which has many points of interest:—

Illustrative Case, No. 51.—F., æt. 76. Short and stout. Chronic bronchitis and dilated right heart. Respiration wheezy. Fair pulse. Operation for mammary tumour. C.E.-chloroform sequence. Skinner's mask. Operation begun before corneal reflex quite lost, but no reflex movement. Very little hæmorrhage. Gradually increasing pallor and rather slow pulse. Light anæsthesia maintained. The incision was a fairly large one, and one axillary gland was removed. Operation lasted half an hour. When nearly conscious she was pale *with no wrist pulse.* It was clear that her blood was principally in the venous system. A small quantity of ether administered on a Skinner's mask. Requested her to cough. Pulse immediately returned. It was observed by operator that the axillary vein was very large during the operation.

It is clear that in this case the dilated right heart, which was only just able to maintain the pulmonary circulation when the patient was not under an anæsthetic, became temporarily incompetent to discharge its usual functions. This was probably partly owing to the effect of the anæsthetic upon its musculature (although the anæsthesia was never deep), and partly also to a somewhat increased strain caused by altered respiratory conditions.

Amongst the changes in the vascular system which predispose to cardiac arrest, that of venous thrombosis must not be forgotten. In the following interesting though highly exceptional case, a detached thrombus became entangled in the tricuspid valve during anæsthesia and caused the death of the patient (see also p. 169).

Illustrative Case, No. 52.—F., æt. 32. Wasted. Nervous. Heart-sounds rather feeble. No heart or lung disease discoverable. There had been œdema of left leg. Operation for removal of large fungating sarcoma of left breast. Ether by Clover's inhaler. Anæsthetic taken well. No cough, struggling, or cyanosis. Good pulse. Corneal reflex had just disappeared when operation began. No reflex movement on incision. Growth removed in about three minutes. Pulse suddenly became feeble and face pale. Very little bleeding at site of operation. Pulse ceased. Respiration continued for some minutes. Operation at once stopped (15-20 minutes after commencement of administration), and every means tried to restore patient (artificial respiration, strychnine, etc.), but without success. *Post-mortem:* Rigor mortis marked. Much wasting. Pleuræ: *nil.* Lungs emphysematous; not gorged with blood: no bronchitis. Heart weighed 8 oz.: left ventricle firmly contracted and empty: right ventricle moderately contracted and containing 1 oz. of fluid blood. In right side of heart, entangled in tricuspid valve, is an ante-mortem clot, consisting of a thick portion 1 inch long, $\frac{1}{2}$ inch in diameter, and irregularly cylindrical, with three longer thinner portions from $\frac{1}{3}$ to $\frac{1}{4}$ inch in diameter, and 2 to 4 inches long (clearly formed in some vein). Pulmonary, tricuspid, and aortic valves normal. Mitral also. Partial thrombosis of left common iliac vein. Nothing else abnormal.[1]

The influences of the sitting posture and the presence of food and fluid within the stomach have been sufficiently discussed.

It will be convenient to consider the treatment of circulatory failure in relation to the exciting cause upon which the failure depends.

1. TREATMENT OF CIRCULATORY FAILURE DEPENDENT UPON EMBARRASSED OR ARRESTED BREATHING

Embarrassed breathing is a common cause of pulse-failure during anæsthesia. There is good reason, indeed, to believe that in a large number of the cases in which the first symptoms of danger observed have been disappearance of pulse and change of colour, some initial embarrassment to breathing has been overlooked. For example: a child is operated upon for the removal of post-nasal adenoid growths: the operation is successfully finished: the patient, who is beginning to "come round," is moved back to bed and placed horizontally: the breathing becomes suspended by reason of commencing vomiting (laryngeal closure), and possibly the presence of coagulated blood about the rima glottidis: cyanosis ensues: then pallor: then pulse-failure: and unless the patient's condition be observed in time, death may take place. If the surgeon be unaware of the liability of such patients to pass into this condition of asphyxial syncope, he may easily overlook the asphyxial factor and erroneously

[1] For these notes the author is indebted to the late Dr. Schorstein and Mr. E. E. Prest. It was entirely owing to the former that the true cause of death was discovered; and Mr. Prest's notes of the administration render the case complete.

attribute the fatality to one or other of the numerous causes which are believed to be capable of bringing about sudden primary cardiac arrest. It has been pointed out in preceding parts of this work that respiration is exceedingly liable to become temporarily embarrassed during anæsthesia; and the rapidity with which the peripheral circulation will cease will depend upon the normal state of the patient's vascular system, the particular anæsthetic employed, the degree of anæsthesia, and other factors.

The treatment of all states of circulatory depression dependent upon impaired or suspended breathing is sufficiently obvious. It is to correct any respiratory embarrassment, to secure a free air-entry, and, if necessary, to perform artificial respiration in the manner fully described in the preceding chapter.

The following case may be of interest as illustrating this form of circulatory failure and the proper treatment to be adopted:—

Illustrative Case, No. 53.—A thin, middle-aged man, with spinal disease. Heart displaced by distorted spine. Apex beat in fourth space outside nipple. Marked pulsation in second left space close to sternum. Blowing systolic bruit at base. No thoracic movement. Respiration wholly diaphragmatic. Laminectomy. Left lateral posture. Ether administered by Clover's inhaler. Student administering under supervision. No excitement. Breathing rather short and colour rather dusky. Patient now placed almost prone, with trunk somewhat raised. Operation begun. Very little bleeding. Breathing jerky: colour dusky: pulse bad. No ether given for about ten minutes (rather more than necessary had been administered). Pulse, however, grew worse, becoming very rapid and irregular. It then ceased at wrist. Respiration continued. Colour pale and dusky. Hands cold and blue. At this point I was obliged to ask the surgeon to alter the patient's posture. He was accordingly placed upon his side, and improvement immediately commenced. The colour of face and lips now returned, *but hands remained very blue,* showing that cyanosis is not, as some believe, necessarily an indication that the heart is satisfactorily pumping along non-oxygenated blood. The improvement continued and the operation was completed.

In the above case the embarrassed breathing (from preexisting intercostal paralysis and the prone posture) gradually led to pulselessness. Possibly the cardiac condition (the nature of which the author was unable to diagnose), together with the displacement of the heart, contributed to the pulse-failure.

In the following case the intercurrent asphyxia, with consequent pulselessness, was chiefly, if not wholly, referable to faulty posture:—

Illustrative Case, No. 54.—F., æt. 58. Thin. Asthmatic. Some emphysema and cough. Radical breast operation. *Pillows under shoulder, and head slightly extended.* C.E.-chloroform sequence. Considerable laryngeal stridor throughout from mucus, with ineffective cough. Mucus not expelled. With the "crowing" breathing there was much diaphragmatic movement, and hence negative pressure in chest. *Consequently radial pulse became very feeble, and then impalpable.* When laryngeal stridor lessened, the pulse improved; when it increased, the pulse became weaker. These effects were noted several times. The operator also observed phases of bleeding and of no bleeding corresponding to diminished and increased stridor.

The above case might easily have been diagnosed as one of surgical shock; but it was clearly one of a different nature. Possibly some slight circulatory shock of surgical origin was present and favoured the pulse disappearance from intercurrent asphyxia.

2. TREATMENT OF CIRCULATORY FAILURE DUE TO OVERDOSAGE

We have seen that when nitrous oxide or ether is administered in toxic doses to a moderately healthy subject some impairment of breathing invariably precedes pulse-failure; whereas in the case of chloroform a noticeable degree of circulatory depression is a common accompaniment, if not a precursor of respiratory arrest. When anæsthetising patients, however, whose general condition is highly unsatisfactory, the administration of toxic quantities of any anæsthetic, whether it be nitrous oxide, ether, or chloroform, may be attended by more or less sudden and primary cessation of pulse.

The treatment to be adopted in all such conditions is to withdraw the anæsthetic, to place the patient horizontally (unless he be already so placed), and to increase respiratory action. Many a life has been sacrificed by erroneously resorting to drugs. In comparatively minor cases in which the pulse has become very slow, feeble, irregular, or intermittent, whilst respiration is still continuing, all that is needed, as a rule, is to rub the lips briskly and to assist the feeble respiratory efforts by chest compression. These measures will often ward off a more alarming state, the pulse and colour quickly improving in response to this simple treatment.

But in most cases primary pulse disappearance from the toxic effects of an anæsthetic is such a grave symptom that vigorous measures are at once needed, and it is advisable to insert a Mason's gag, apply the tongue-forceps, extend the head over the end of the table, and proceed to Silvester's method of artificial respiration as already described. The gag and tongue-forceps are needed to maintain a free air-way; the lowering of the head is likely to be of use in keeping up the blood supply to the respiratory centre; and artificial respiration is the best cardiac stimulant.

Should there be no respiratory embarrassment or evidences of general venous engorgement, partial or complete inversion, as originally suggested by Nélaton in 1861, may be advantageously combined with artificial respiration. It is important, however, to remember that the essential treatment is the maintenance or re-establishment of efficient respiration, without which the elimination of the anæsthetic cannot take place. Many remarkable cases are on record [1] in which, by means of inversion, patients have apparently been rescued from imminent death. In some of the recorded cases the pulse at the wrist was observed to come and go as the patient was inverted or placed horizontally. It is probable that the beneficial effects of partial or complete inversion are principally due to the better respiratory action caused by an increased cerebral blood supply. Inversion should never be employed unless the signs of circulatory failure are distinctly marked.

In the event of these measures failing to resuscitate the patient, the question of **directly kneading the heart** should be considered.

This method of restoring an anæsthetised patient whose cardiac contractions and respiration have both ceased was

[1] See *Deutsche med. Zeitung*, Feb. 1885; Braithwaite's *Retrospect*, vol. i., 1876, p. 348; *Edin. Med. Journ.* vol. ii., 1874, p. 476. Kappeler states that Schuppert saved three patients by inversion.

first practised in 1880 by Niehaus,[1] but without success. Further attempts, also unsuccessful, were made in 1892 by Bazy,[2] and in 1898 by Michaux,[3] and by Tuffier and Hallion.[4] The first successful case was that of Igelsrud in 1901.[5] In this country the earliest success on record is that reported by Starling and Lane.[6] Particulars of these cases and of all others published up to 1906 are given by Dr. T. A. Green,[7] in a careful study of the whole subject; the cases thus collected number forty.

If the case is an abdominal one, and the peritoneal cavity is already open, the heart may be grasped through the existing incision, and may be kneaded or squeezed through the diaphragm. In the presence of an acute suppurative lesion in the lower half of the abdomen, it would be preferable to make a fresh incision above the umbilicus for this purpose. If the case is not an abdominal one, an incision must be made through the epigastrium: unless the thorax has already been opened during the operation in such a way as to admit direct access through it to the pericardial sac. The heart is to be grasped through the diaphragm, and squeezed steadily about 70 times to the minute. A considerable number of cases are upon record in which this proceeding has been followed by the immediate return of rhythmic cardiac contractions. In 9 of Green's 40 cases, the result was completely successful, and in 8 others the heart was thus restarted, although it eventually failed again. Since then many other successful cases have been recorded, sometimes when to all appearance the patient has been quite dead.[8] This cardiac massage through an abdominal incision is of necessity a last resort; but if other measures fail, it should certainly be given a trial. Green puts the limit at 8 to 10 minutes from the cessation of the heart: after that interval success is most improbable, although the heart has been temporarily set going by this means after

[1] *Centralblatt für Chirurgie*, 1903, p. 588, quoted by T. A. Green, *Lancet*, 22nd Dec. 1906, p. 1713.

[2] *Bulletin et Mémoire de la Société de Chirurgie*, 1898, p. 939.

[3] *Ibid.* p. 976.

[4] *Ibid.* p. 937.

[5] *Therapeutic Gazette*, 15th April 1904.

[6] *Lancet*, 22nd November 1902, p. 1397.

[7] *Ibid.*, 22nd December 1906, p. 1708.

[8] Cf. J. W. Milne's case, *British Medical Journal*, 19th November 1910, p. 1657.

much longer intervals of time. The existence of a heart beat, however feeble, is a contra-indication to heart massage; for by semi-inversion and efficient artificial respiration a feebly acting heart may nearly always be restored.

Drugs are of little if any service in cases of this class, and if employed *should be administered, not by the anæsthetist, but by some other person present.* The anæsthetist's undivided attention must be devoted to maintaining *efficient* artificial respiration and a proper posture. To commence the treatment of a marked case of chloroform syncope by a hypodermic injection of ether or brandy is not only useless (seeing that the circulation is more or less suspended) but dangerous, in that such a procedure delays the application of artificial respiration, the remedial measure by which the elimination of the anæsthetic and the aeration of the blood are effected, and the measure of all others which is most likely to increase cardiac action. There is, of course, no objection to the employment, by some other person than the anæsthetist, of such drugs as ammonia,[1] nitrite of amyl,[2] strychnine, or caffeine;[3] but these substances should only be used as adjuncts, and in the manner described. Suprarenal extract has been given both hypodermically and by intravenous injection, but is more likely to do harm than good. Pituitrin, given by intramuscular or intravenous injection, has been much more favourably reported on (see p. 620).

It is doubtful whether faradism is of any value as a remedial measure in these cases. Professor MacWilliam[4] advises rather strong induction shocks, with the skin moistened; one electrode to be placed over the heart's apex, and one over the fourth dorsal vertebra. Schäfer and Sigmund Meyer, on the other hand, consider faradism to be as likely to inhibit as to stimulate a feebly acting heart.

The worst and most fatal cases are those in which an

[1] Ringer found that ammonia restored the action of a frog's heart which had been arrested by chloroform. See *Practitioner*, vol. xxvi., 1881, p. 436. Pickering, in his experiments with the embryonic heart of a chick, also found that he could partially restore cardiac rhythm by means of ammonia.

[2] Dr. Wood's experiments with this drug led him to regard it, at all events in chloroform syncope, as valueless.

[3] This may be given subcutaneously in 2 gr. doses.

[4] "Electric Stimulation of the Heart in Man" (*Brit. Med. Journ.*, 16th Feb. 1889).

overwhelming dose of chloroform has been given during or immediately after violent struggling. Although it is true that in cases of this kind some degree of respiratory embarrassment occurs, the prominent and appalling symptom is pallor and complete cessation of pulse. Our resources on these occasions are unfortunately very inadequate; for beyond the treatment already considered we know of no other restorative measures likely to be of service.

3. TREATMENT OF CIRCULATORY FAILURE DUE CHIEFLY TO THE SURGICAL PROCEDURE

(i.) General Remarks

We now come to a very important part of our subject—the treatment of cases in which primary circulatory failure takes place chiefly, if not wholly, as the result of some surgical procedure. The cases in which the manipulations of the surgeon primarily affect respiration have been discussed in the preceding chapter. The reader is referred to pp. 41 and 69 and 253 for remarks upon the surgical influences which may primarily affect the circulation of the anæsthetised subject. It will be seen from the summary in the foregoing table that such procedures may bring about circulatory failure in three main ways—by causing (i.) surgical shock of the circulatory type, *i.e.* reflex vaso-motor or cardio-inhibitory effects, or both; (ii.) hæmorrhage; or (iii.) the entry of air into veins.

It must be remembered that when circulation fails as the immediate result of the operation in hand, there is usually more than one factor responsible. Thus vaso-motor effects are often coupled with cardio-inhibitory effects. Again, cases present themselves in which circulatory failure, although principally due to hæmorrhage, is partly referable to vaso-motor or cardio-inhibitory depression. Then, as we have already seen, deep anæsthesia, and especially deep chloroform anæsthesia, is such an important *predisposing* cause of surgical shock of the kind now under consideration that from this point of view the anæsthetic must be regarded as a factor.

As it is often necessary, however, in the practice of modern surgery to carry the administration of the anæsthetic to its full limits, and as these full limits may be reached, *in the absence of surgical stimuli*, without circulatory depression occurring, it is clear that from the point of view of the anæsthetist the anæsthetic can hardly be considered blameworthy. Finally, in addition to these factors, there are sometimes others of a respiratory character present, but these have been already considered in the preceding chapter.

(ii.) **Cases illustrating the Occurrence of Surgical Shock (Circulatory)**

Before summarising the treatment of circulatory failure due chiefly to the surgical procedure it will be convenient to quote several cases illustrative of the various ways in which the circulation may become depressed or arrested as the result of vaso-motor or cardio-inhibitory impulses of surgical origin.

Illustrative Case, No. 55.—F., æt. 42. Rather thin. Not nervous. An excellent subject, not liable to faint. Good heart-sounds. No cough. Good colour. Dilatation of cervix. Nitrous oxide-C.E. sequence for 4 minutes: then chloroform. No movement or struggling from first. During first ten minutes pulse, colour, and breathing good. No reflex movement even though corneal reflex slightly present. Patient in lithotomy position (Clover's crutch). At a particular juncture, whilst the pupil was medium in size, the corneal reflex either just present or just absent, and whilst the retroverted uterus was being dilated, the pulse suddenly became irregular and disappeared, the face pale, and the breathing suspended. The eyes did not open. (Compare subsequent cases.) Rhythmic compression was at once applied to the chest walls; air entered and left the lungs. The operation was allowed to proceed. As the face remained pale, and automatic breathing did not recommence, the head was lowered, and the surgeon was asked to raise the pelvis by means of a pillow. By this time (two minutes after commencement of the shock) the corneal reflex was brisk. The face was still pale, the respiration feeble, and there was only a small radial pulse. Some ether was administered on a Skinner's mask. The operation, which had been suspended, was recommenced. No reflex movement. C.E. mixture now used, and pulse, breathing, and colour all gradually recovered.

Ten or twelve years ago the author would certainly have ascribed the symptoms in the above case wholly to chloroform.

He is now convinced, however, that they were chiefly of reflex (surgical) origin, the chloroform acting merely as the predisposing factor. In this particular case the patient was being most carefully watched, and it so happened that the radial pulse was being felt when the sudden shock occurred. The rapid recovery of lid-reflex clearly shows that the case was not one of simple chloroform overdosage. This, indeed, was obvious from the general state of the patient at the moment when the pulse failed. Another important point in the diagnosis between simple overdosage on the one hand and surgical shock during deep anæsthesia on the other, is that when the former condition is gradually produced experimentally the circulation does not suddenly cease.

In the two following cases the pulse-failure was also exceedingly abrupt, being caused, in the first case by vigorous traction upon the pectoral muscles, and in the second by pulling upon nervous structures in the neck.

Illustrative Case, No. 56.—F., æt. 35. Well nourished. Good heart-sounds. No cough. Reported to suffer occasionally from fainting attacks—"remains faint for hours." Removal of left breast. Nitrous oxide-ether-chloroform sequence. No reflex movement with incision. Ten minutes after administration had begun, the patient was deeply but satisfactorily under chloroform. The surgeon passed his finger behind the pectoral muscles and vigorously pulled them forwards with the object of dividing them. At the moment of traction the pulse became feeble; and whilst the muscles were being cut there was sudden and alarming pallor, with pulse disappearance; these symptoms were quickly followed by arrested breathing. The patient's body was quickly adjusted so that the head hung over the end of the operating table; the chest was compressed; and the fauces stimulated by the finger-tip. At first no effect was produced, but after 5 or 6 compressions breathing gradually recommenced. The patient soon began to "come round." Chloroform resumed and administered for rest of operation.

The points of interest in the preceding case are (1) the obvious dependence of the symptoms upon the surgical procedure; (2) the short interval between the occurrence of shock and the phenomena of recovery; and (3) the immobility of the chest wall. There was no muscular spasm such as there usually is when the chest fails to respond to compression. The gradual resumption of breathing was probably due to the better blood supply caused by lowering the head. In the following case, one of amputation of the breast, the shock was less severe. Some degree of surgical shock is exceedingly common in these operations under chloroform or chloroform mixtures.

Illustrative Case, No. 57.—F., about 61. Fat. Lives sedentary life. Radical breast operation. Induction by C.E.; then chloroform on Skinner. No excitement. Operation begun when patient under chloroform with trace of corneal reflex. Portion of breast first removed for microscopic examination. No abnormal phenomena. Ten minutes later, whilst patient well under, but not too deeply under chloroform, and whilst breast being removed and a good deal of traction taking place, pulse disappeared at radial, superior coronary, and temporal arteries. Respiration appeared to be about to cease. Pallor. Cold face. No movement. Anæsthetic withheld. Corneal reflex soon returned. Changed to C.E. mixture, but condition remained about the same for 20 to 25 minutes after first shock, when pulse and colour returned. During this 20 or 25 minutes there was very little bleeding. Pulse not good till operation over.

In the above case the corneal reflex was absent when the shock came on. The author has notes of several similar cases. He also has notes of a case in which the breast was pulled away from its attachments whilst the corneal reflex was present, with the result that simple slowing of the heart took place. It is quite possible that with such stimuli during comparatively light anæsthesia, cardio-inhibitory effects, as opposed to cardio-inhibitory and vaso-motor effects combined, are most likely to be met with. (Cf. Illust. Case, No. 71.)

Deeply seated operations in the neck are not unfrequently attended by surgical shock, as the three following interesting cases testify. Unfortunately it is not always an easy matter to say what particular nerve or nerves are being dragged upon or injured at the moment when shock takes place.

Illustrative Case, No. 58.—M., æt. 35. Healthy-looking. No thoracic abnormality detected. Operation for removal of deeply seated cervical glands. Nitrous oxide-ether-chloroform sequence. Smooth induction. Fifteen minutes after incision, patient being fully but not too deeply under chloroform, traction upon the glands and their surrounding structures was at its height when the eyes suddenly opened, the pupils dilated widely, and the breathing ceased. I was not observing the pulse at the time. The surgeon admitted that he might have been dragging upon the vagus. After two or three compressions of the chest there was immediate improvement in the patient's condition.

The pulse at the wrist was slow. This slowness of pulse and some pallor persisted for the rest of the operation, but no further difficulties occurred.

The sudden separation of eyelids was the most remarkable feature of this case. For the moment the patient displayed a most alarming appearance, similar to that described in Illustrative Case, No. 76, in which the syncope was caused by air entering a vein.

Illustrative Case, No. 59.—M., about 35, of average build. Good general health. Not markedly nervous. Removal of sarcomatous tumour of soft palate. Chloroform. Junker's inhaler. Anæsthesia in 8 to 10 minutes. Muscular flaccidity; abolition of lid-reflex; and slight stertor. Two stages in the operation: (1) Placing a temporary ligature round the carotid artery; (2) removing growth of palate. The skin incision was unattended by movement or other phenomena. Whilst artery being exposed pulse became extremely feeble, face pale, respiration shallow, and operator had some difficulty in recognising vessel by reason of its diminution in size. Head lowered and legs raised. After three or four compressions of chest, pulse gradually improved, and rigidity and lid-reflex reappeared. Ether then given for remainder of operation.

The next day, whilst the wound over the carotid was being examined without an anæsthetic, the patient's face suddenly became pale, the artery contracted as on the previous occasion, the eyes turned up, the muscles of the jaw twitched, and for a few seconds the patient was unconscious.

I anæsthetised this patient two years later, and gave him ether for the removal of a very small recurrent nodule. No difficulty occurred. It is fair, however, to add that no ligature was placed round the carotid.

I anæsthetised this patient for a third time, just three years after the last administration. Another recurrent nodule had to be removed. I used the A.C.E.-ether-chloroform sequence, and secured a deep ether anæsthesia for the commencement and first stages of the operation. No abnormal symptoms were noted under ether; but during the subsequent chloroformisation, whilst the palate was being held, and a further portion of the growth excised, the pulse became very slow for three or four beats and for 20-30 seconds could not be felt. The respiration was deep and regular all the time. The colour was perhaps a trifle paler. The anæsthetic was withheld, and the pulse gradually returned. Though the patient was well under chloroform at the time the pulse vanished, he was not too deeply anæsthetised, for he began to show signs of recovery half a minute after the anæsthetic had been discontinued.

Illustrative Case, No. 60.—M., æt. 60. Healthy and muscular. Florid cheeks. Iron-grey beard. Had his tongue removed some months ago. Now has epitheliomatous glands of neck requiring removal. Heart-sounds good; not nervous. Chloroform administered on Skinner's mask. No struggling. Some temporary respiratory difficulty before deeply under; easily removed by pushing jaw well forward. Fully anæsthetised in 5-6 minutes. No movement with skin incision; no corneal reflex; pupils 3½ mm.; good colour. As the pupil was a trifle larger than the ordinary chloroform pupil, I instructed the student who was administering the chloroform to lessen the amount of anæsthetic. This brought the pupil to 2½ mm. in about half a minute. A few minutes later, during the manipulations of the surgeon for the removal of the glands (which were intimately connected with the carotid, jugular, vagus, and phrenic), the patient became pale, and his jaw muscles flaccid. In a few seconds from this his breathing became irregular and shallow. No sound of obstruction. Respiration assisted by pressing with each expiratory effort upon the lower part of thorax. The pulse, which had not been observed before, was barely perceptible and slow. (It had probably ceased altogether when the pallor came on.) Lid-reflex now returned, and some moaning. Carotid and jugular both ligatured and glands completely and successfully removed. The operation was never suspended, as no further remedy besides chest-compression was necessary. A comparatively light anæsthesia was kept up for the rest of operation. Any attempt to abolish lid-reflex was at once followed by feeble breathing. The colour and pulse improved after the chest-compression; but patient remained pale, and with rather slow and weak but regular pulse till end of operation. Administration lasted 50 minutes. 14 dr. of chloroform used.

The patient referred to in Case 59 was apparently specially susceptible to reflex cardiac inhibition. During the second operation, in which ether was employed, and during the first part of the third operation, which was also conducted under this anæsthetic, no surgical shock occurred. But in the first operation, and in the latter part of the third operation, on both of which occasions chloroform was being used, reflex circulatory depression ensued. It is interesting, too, that a similar condition was noted in the absence of anæsthesia. In this case, as in many others, the stimulation produced by ether seems to have prevented the inhibitory effects of the surgical procedure.

The next case is of interest inasmuch as it is an example of surgical shock during light anæsthesia; owing probably to this latter fact the effect upon the vaso-motor and cardio-inhibitory centres was not sufficient to produce complete syncope or to affect the respiration. Whether the effect is chiefly on the vaso-motor or chiefly on the cardio-inhibitory centre is difficult to decide; the fact that such shock is rare when morphine and atropine have been given beforehand may perhaps point to cardiac inhibition rather than vaso-motor paralysis.

Illustrative Case, No. 61.—F., æt. about 30. Good heart-sounds. No cough. Operation for hæmorrhoids. Induction by "gas and ether," followed by chloroform. No difficulty whatever. The sphincter was dilated whilst the corneal reflex was still present; slight movement and some crowing occurred. Five minutes later, with a brisk corneal reflex in both eyes, the pulse in the superior coronary and radial arteries had disappeared. The face was rather pale, and the eyes were closed. Respiration was regular and good. "Open" ether was then substituted for chloroform, and after two or three minutes the pulse began to return, though feebly. A pile was then ligatured, and this caused reflex movement and stridor again. The patient was kept lightly under, and by the end of the operation, which lasted 35 minutes, pulse and colour were fairly good.

Though acute shock is rare when morphine and atropine have been given, nevertheless it does occur. The next case illustrates this distinctly unusual occurrence.

Illustrative Case, No. 62.—F., æt. 41. Thin, grey hair, ? alcoholic. No cough. Heart-sounds quick, but normal, though slightly muffled. No food since previous evening. Morphine ($\frac{1}{4}$ gr.) and atropine ($\frac{1}{100}$ gr.) at 10.45 A.M. Induction at 11.15 with gas and ether; then chloroform, and then C.E. During manipulation of the intestines for appendicectomy the pulse became very small, indistinct, and irregular. "Open" ether was then resorted to, and matters soon improved. Later, the same thing happened again; the pulse could not be felt either in the radial, temporal, or superior coronary arteries. Respiration, however, remained fair, and the colour was not pale. A return to "open" ether was followed by rapid improvement.

It is always dangerous to guess what might have happened if something had been done which was not done; but it is tempting to suggest that but for the morphine and atropine this might have developed into a serious case of surgical shock.

Intra-abdominal operations are particularly likely to be attended by surgical shock of a circulatory type; and as such shock is favoured by deep chloroform anæsthesia, the symptoms are often erroneously ascribed to the latter condition. The five following cases are typical of many others:—

Illustrative Case, No. 63.—F., æt. 42. Good colour. Rather grey. General condition good. Operation for gastric ulcer (abdominal section).

Administration lasted about seventy minutes. Chloroform, Skinner's mask. No difficulty in induction. No reflex movement with incision. First part of operation consisted in pulling down stomach and plugging several large sponges into abdominal cavity. During this the lips became pale, the pulse small and slow, but the breathing was unaffected. (No corneal reflex present.) Difficult to say whether circulatory symptoms due to chloroform, to operation, or to both factors. No chloroform given for several minutes, during which there was no corneal reflex. Pulse and colour gradually improved, but by this time the dragging on stomach and insertion of sponges had ceased and the stomach had been opened. No further trouble for next forty minutes. At end of this time, *when I was perfectly sure the patient was not too deeply under chloroform, and not too lightly*, it became necessary to remove sponges; and the patient again displayed similar symptoms to those previously noted. Clearly a reflex effect.

Illustrative Case, No. 64.—F., about 42. Not nervous. Good but rapid heart-sounds. Fair chest expansion. Said to have had pleurisy four times and to be a "fainty" subject. Removal of vermiform appendix and ovary. Operation at 8.30 A.M. Foggy and raw morning. Nitrous oxide-ether-chloroform sequence. No difficulty. Ten minutes after beginning of operation there was a trace of corneal reflex, which was permitted to remain for ten minutes, there being no reflex movement during this time. The bowel was now pulled out through wound and, *although no more anæsthetic was given*, the corneal reflex vanished. Simultaneously with pulling out bowel and disappearance of corneal reflex, there were sudden pallor and suspension of breathing, with moderate dilatation of pupils. Operation not discontinued. Face and lips briskly rubbed and respiration recommenced. No further difficulty, but C.E. substituted for chloroform owing to rather unsatisfactory pulse. Breathing remained shallow.

Illustrative Case, No. 65.—F., æt. 50. Grey. Stout. Somewhat bronchitic. Fairly good heart-sounds. Had a "fainting-fit" during use of enema before operation. Is said to have "exaggerated reflexes." Ovariotomy. C.E. gradually given on Skinner's mask. Slight cough. No difficulty. Ready in 8 to 9 minutes. No reflex movement with incision. Seven or eight minutes later, after contents of cyst evacuated, and when empty cyst was being pulled up towards diaphragm, pulse (which had been about 70 and regular) became very slow, irregular, and barely perceptible. Face at first little if at all altered in colour. The patient was just well under C.E.—not too deeply. Anæsthetic withheld. Breathing became quieter. Surgical manipulations continued. *In about 45 seconds there was observed a peculiar batch of about 7 or 8 deep respirations, immediately followed by pallor, arrested breathing, upturning of lids, and dilatation of pupils.* Whilst proceeding to bring head over end of operating table, breathing recommenced and colour began to return, so that it was unnecessary to do anything in the way of treatment. The corneal reflex had by this time returned. There seemed to be a deepening of anæsthesia as the result of the shock.

Illustrative Case, No. 66.—M., middle-aged; 6 ft. 2½ in. Flat, badly developed chest. (?) Old adenoids. Imperfect nasal breathing. Removal of appendix. Small dental prop between teeth. Nitrous oxide-ether-chloroform sequence for 6 minutes; then C.E. mixture. Whilst appendix being pulled up, and patient *only just well under C.E. mixture*, the pulse disappeared at the temple, the face became pale, the lips separated, the pupils dilated, and the breathing ceased. These symptoms occurred in the order named, and within about 20 seconds. The chest was compressed, and the mattress slid lengthwise upon the table, so that the patient's head became fully extended over the end of the table. After about 15 seconds, during which the chest pressure was continued, the colour improved and the breathing returned.

Illustrative Case, No. 67.—F., æt. 63. Thin, not nervous; good condition. No cough. Heart-sounds normal. Induction by chloroform-C.E. sequence without difficulty. Pelvis then raised and two minutes later incision made, while corneal reflex still present. No reflex effect. An ovarian tumour about the size of a fœtal head was then brought out of the abdomen. The pulse was felt and found to be small, slow, and very irregular at wrist and temple; face slightly moist, eyes closed, colour good, respiration regular and ample. "Open" ether was then resorted to; at first without any effect, but in four minutes the pulse was distinctly more regular and of better quality. There was no further trouble for the remainder of the administration.

In Cases 64 and 65 the most interesting point is the deepening of the anæsthesia as the apparent result of the surgical shock. The author would also especially direct attention to the curious batch of deep respirations observed in Case 65. He has seen this phenomenon in other cases immediately before cessation of breathing from suspended cerebral circulation. (See also Case 49, in the preceding chapter.)

Rectal operations are frequently attended by slight circulatory shock, even though ether be employed. (See Illustrative Case, No. 61.)

In the following case the surgical shock was much more severe. It is of interest, because no special remedial measures were employed, and yet the patient made a good recovery:—

Illustrative Case, No. 68.—F., about 57. Thin. Slight bronchial catarrh. Said to be liable to faint. First stage of Kraske's operation. C.E. given gradually. No excitement. When anæsthesia nearly complete patient placed nearly prone, with raised buttocks, and knees below level of table and resting on chair. Pulse quick—about 110. Breathing somewhat hampered by posture. Slight corneal reflex maintained. Very slight movement with incision. During sawing of bone, whilst corneal reflex only just absent, pulse suddenly disappeared, face became pale and dusky, and hands cold. The head was brought to the side of operating table and the anæsthetic discontinued. Corneal reflex soon reappeared. From this point onwards no anæsthetic given beyond a little ether occasionally. Operation not stopped. Still no pulse, but breathing continued feebly. One shoulder raised in order to relieve respiration. *No pulse at wrist for* 20 *minutes.* Operation rapidly completed. Brisk corneal reflex. When flaps brought together pulse began to reappear and breathing became deeper. Gradual recovery. When legs placed horizontally pulse at once improved. When patient moved to bed, and end of bed much raised, further distinct improvement in pulse observed, with warm hands, better colour, and restoration of consciousness.

Three days later patient's condition quite as good as before first operation. Second half of operation now necessary. Excision of rectum. Quick pulse. C.E. for 50 minutes: ether 20 minutes: C.E. again for 25 minutes. After 10 minutes' anæsthesia patient placed in prone-Trendelenburg posture (p. 244). During first 50 minutes much reflex laryngeal stridor (?) from peritoneal traction. Stridor stopped by changing to ether. No shock for first 25 or 30 minutes. Then increasingly rapid pulse: cold hands and forehead: and pulse nearly imperceptible. Respiration good. Shock never alarming. Pulse rather better when wound closed, but difficult to count. Distinct improvement when patient placed horizontally, owing to better chest expansion.

The acute surgical shock in the first of these two operations occurred during properly established C.E. anæsthesia. It was obviously not due to hæmorrhage, as evidenced by the quick and good recovery, nor was it due to the anæsthetic, for reasons already given. It was, in fact, of that type specially discussed by Crile (p. 70), and was probably chiefly of vasomotor origin.

Operations upon the kidney, particularly if associated with traction upon that organ, frequently cause intercurrent surgical shock.

Illustrative Case, No. 69.—Healthy-looking child, about five years of age. Nephrectomy for sarcoma of kidney. Chloroform on Skinner's mask administered by a student under supervision. All went well till fifteen minutes after the commencement of the operation, when, during the manipulations of the surgeon, the following events occurred in the order mentioned. (1) The pulse became very slow, the respiration being regular and the colour good. The anæsthetic was withheld. (2) The pulse became slower and feebler, and the respiration almost imperceptible, whilst the lips remained of good colour. (3) The radial pulse ceased and the colour became dusky. Inversion and artificial respiration very quickly restored the circulation.

Illustrative Case, No. 70.—F., æt. about 35. Very anæmic from long-standing hæmaturia. Short stature and spare build. Pulse 84, regular and extremely compressible. No respiratory difficulty. Nephrectomy for renal tumour. Time, 10.40 A.M. Administration commenced with A.C.E. mixture on Skinner's mask. At 10.42 respiration rather rapid—suggestive of hysteria. 10.43, Ormsby's inhaler, charged with ether, gradually applied. Deep anæsthesia rapidly produced. Pulse fair, but quicker than before commencement. Patient lying on side with pillow under loin: head low: face towards bed. Respiration regular, and not hampered. 10.52, operation begun. No reflex movement. At 11, whilst pedicle was being tied, distinct evidences of shock began to manifest themselves. Pulse rapid and feeble. Allowed patient to regain conjunctival reflex to a slight extent. Respiration regular and snoring. Pulse soon became barely perceptible at wrist. Hands warm. Fair colour. Respiration less deep and non-stertorous. As pulse now almost imperceptible, operation rapidly completed. Whilst the patient was in this condition the breathing was suddenly "held," as if straining or coughing were imminent. As the suspended respiration persisted, the sternum was pressed five or six times, and air was heard to enter and leave the chest. Automatic breathing then returned and continued, though with occasional pauses. End of table raised. Operation completed. Patient's condition gradually improved. Fifteen minutes after operation the pulse could be counted at wrist. Patient moved to bed and kept very warm. No vomiting. Made a good recovery.

Nephrectomy in a feeble and very anæmic patient is liable to be attended by shock, and, as the above case shows, the resources of the administrator may be severely taxed. That the symptoms were not due to loss of blood is perfectly certain, seeing that every care was taken, and with the most perfect success, to avoid unnecessary hæmorrhage. Nor was the anæsthetic to blame, for the symptoms in no way corresponded to those dependent upon an overdose of ether. The author has notes of several other cases of nephrectomy in which profound surgical shock (coming on independently of hæmorrhage) has occurred. In one instance yawning was a prominent symptom and the wrist pulse vanished. The patient, however, made a good recovery.

In the following case reflex cardiac inhibition took place as the result of the skin incision for a Syme's amputation, the patient being at the time lightly under ether:—

Illustrative Case, No. 71.—M., æt. about 18. Thin: breathless on slight exertion: has some dulness at bases of lungs: Syme's amputation for sarcoma of foot. Administration commenced with a small quantity of the A.C.E. mixture on Skinner's mask. Then pure ether from a Clover's portable inhaler. Patient breathed well at first;

but soon commenced to give some trouble. The upper lids became raised, and it was difficult to secure tranquil anæsthesia. The lid-reflex persisted, and also some muscular movements, for about 10 minutes, Breathing somewhat hampered. Whilst in this condition the operation was commenced. It so happened that I had my finger upon the radial pulse, and that the student who was administering the ether under my supervision had his finger upon the carotid artery. The pulse was good but quick. At the moment the skin incision was made, the pulse suddenly ceased both at the wrist and at the neck, and remained absent for (?) four or five seconds. No loss of colour. Pulse resumed its previous character. Some movement of patient, showing he was not deeply anæsthetised. Attempted to secure a better and more profound anæsthesia, but respiration tended to become feeble and face pale No further trouble during rest of operation. This patient died some weeks later, and at the autopsy a large mediastinal (sarcomatous) tumour was discovered. This had probably caused the respiratory difficulties in the administration.

Cardio-inhibitory effects under ether are very rarely met with. Another instance which shows very well how relatively benign are such phenomena when exhibited under ether is the following:—

Illustrative Case, No. 72.—F., æt. 45. Dilatation of the cervix. Some cardiac bruits, exact nature of lesion doubtful; very slight irregularity of cardiac rhythm. Chloroform - C.E. - open ether sequence. When well under ether (corneal reflex abolished) the pulse became very irregular each time a dilator was put into the cervix. When once the instrument had been inserted, the pulse became regular until the next one was being put in. This also occurred when the anæsthesia was allowed to become less deep, and the corneal reflex had returned.

(iii.) Cases illustrating the Occurrence of Hæmorrhage

The three following cases illustrate the effects of profuse hæmorrhage upon the circulation of the anæsthetised patient. In Case 73, the patient was at the time of operation considerably depressed by purgation, and this may have had some influence in the causation of the symptoms:—

Illustrative Case, No. 73.—F., æt. 60. Rather stout; not very strong. Fair chest expansion. Heart-sounds rather distant. No winter cough. Had one ounce of castor-oil the night before operation. Three actions of bowels. Operation 8.30 A.M. for removal of left upper jaw for sarcomatous growth. "Gas and ether" given. Deep ether anæsthesia soon came on. Operation commenced after five minutes of ether anæsthesia. Head on side, with right cheek on pillow, and face turned towards floor. Operation begun. No embarrassment to breathing from blood, as all drained into, and then out of, right cheek. As effects of ether passed off, anæsthesia kept up by chloroform from a Skinner's mask. Very profuse hæmorrhage. Less anæsthetic given. Respiration quite regular. Pulse not observed. Head always kept low. Conjunctival reflex just present. As the hæmorrhage continued to be free, I attempted to feel pulse, but could not detect one at either wrist. Hands quite warm. Respiration proceeding regularly. Lion forceps now applied and jaw removed. Very little hæmorrhage, probably from feeble circulation. Sutures rapidly inserted, and operation finished. Respiration still regular, but occasionally feeble. Still no pulse. Half an ounce of brandy, with some water, given per rectum: a subcutaneous injection of ether administered,[1] and ammonia applied to nostrils. No effect produced. Respiration could be kept proceeding satisfactorily so long as the lips were occasionally briskly rubbed with a towel (see pp. 434 and 582). Lips pale, but pinkish. Ears and cheeks pale. The wrist pulse remained absent for 20 or 25 minutes, and then gradually returned. Head kept low. Hot cloths applied to head. Even when the patient became half-conscious, the wrist pulse was barely perceptible. The patient made an excellent recovery.

Illustrative Case, No. 74.—F., 24. Thin. Healthy-looking from open-air treatment. Has had several operations for fæcal fistula. Good heart-sounds. Occasionally becomes "blue" on exertion, with a pulse of 140. No pulmonary symptoms. Abdominal section. Nitrous oxide-ether-chloroform sequence. Easily affected by nitrous oxide (suggestive of anæmia). Posture slightly on left side. Nothing abnormal for first hour except quick pulse and breathing. Pulse, 140-150. Respiration, 40-45. Good colour. Colon and ileum exposed. Rather free hæmorrhage. Kept her as lightly under as was compatible with quietude. Respiration always good. Hæmorrhage still noticeable. After one and a half hours, pulse very rapid—about 200. Eyelids closed. Hands became rather dusky. Less anæsthetic. Face pale. Vomited once. Warned operator as to patient's state. Hot coffee and brandy *per rectum.* Corneal reflex allowed to return; *but condition did not improve.* Pulse never became slower. It became necessary to finish operation quickly and return patient to bed. She soon began to come round. Pulse difficult to count. Hands cold. Lips pale, but pink on rubbing. 10 oz. of saline per rectum and end of bed raised. 1 hour later, hands warm and skin acting. Pulse, 154: regular.

Illustrative Case, No. 75.—M., æt. 45. Very ill, with offensive brown sputum, believed to be due to gangrene of the right lung: left lung said to be unaffected. Alcoholic in habits. Pulse quick. Induction with chloroform and occasional doses of C.E. mixture: oxygen given continuously from the start. Some excitement and a good deal of moderate struggling for 10 minutes; also almost continuous slight cough, improved by turning the patient on to his right side. Induction occupied 12 minutes, and the patient was then turned on to his back again for the

[1] This we now know to be of little or no value.

convenience of the operator. Still slight phonation, cough, and rigidity. Continual sponging of the fauces was necessary to remove fluid secretion. A cavity in the lung was found by the surgeon, and free hæmorrhage followed. Clots were coughed out, and a cast of the trachea more than a foot long was pulled out (through the mouth). Hæmorrhage became very severe, probably from erosion of some large vessel. The pulse was very rapid. Up to this point the corneal reflex had been brisk, but it now got weaker and soon after disappeared. The patient was turned on to the right side, and this improved matters for a short time. Then respiration began to be shallow from cerebral anæmia; the operator's assistant was requested to auscultate the left chest, and reported that air was entering the left lung freely. Artificial respiration was started, by assisting the now feeble spontaneous breathing. The surgeon opened the trachea to make quite sure it was free—as it turned out to be—and oxygen was delivered directly through the opening. The condition grew worse and worse, and the patient died. It is interesting that almost up to the very last spontaneous respiration the pharyngeal reflex was present. Lowering the head and Schäfer's method of artificial respiration were also fruitlessly tried. Respiration was in fact arrested from cerebral anæmia, the result of severe hæmorrhage in a much debilitated subject.

(iv.) **Case illustrating the Entry of Air into a Vein**

The most profound syncope that the author ever witnessed during anæsthesia came about as the immediate result of air entering a vein. The following are the notes of the case:—

Illustrative Case, No. 76.—F., 14. Florid and fairly well-nourished. Removal of cervical glands. "Gas and ether" followed by chloroform. Whilst the operator was working in the supra-clavicular region, a small quantity of air was heard to enter a vein. This was followed by rapid pulse and some pallor. A minute or two later, whilst I was carefully feeling the superior coronary artery and watching the patient, who was well under, but not too deeply under chloroform, there was a very distinct sound as of a considerable quantity of air entering a vein. The pulse suddenly vanished at the superior coronary and radial arteries; the face became deadly pale; the lids separated; the eyes became glassy; and the breathing barely perceptible. There were, in fact, all the appearances of death. I immediately lowered the head and raised the legs, and as the chest walls were remarkedly elastic and yielding, and the abdomen relaxed, I was able, with my hands, to encircle the heart to such an extent that rhythmic compression of that organ became possible. The intermittent squeezing movements thus brought to bear also had the effect of forcing air into and out of the chest. At the end of three or four minutes signs of returning animation began to appear, and with the assistance of other restorative measures (strychnine, a brandy enema, warmth, etc.) the patient recovered.

It is highly probable that in the above case the patient's life was saved by cardiac compression.

(v.) **Diagnosis**

A few words may here be said as to the differential diagnosis between surgical shock during deep anæsthesia on the one hand, and simple overdosage on the other. The first point to be brought forward in favour of the contention that surgical shock in deep anæsthesia constitutes a frequent and readily recognisable condition is to be found in the fact that a striking similarity will be observed between many of the foregoing illustrative cases. In minor examples of surgical shock it may be difficult, or even impossible, to make a satisfactory diagnosis, but the following points will usually assist in the differentiation:—(1) Surgical (circulatory) shock is common in certain operations and at certain stages of such operations, whilst it is uncommon and perhaps unknown in connection with other operations; (2) Although more common under chloroform than under ether, surgical shock may occur under the latter anæsthetic; (3) Acute surgical shock, although often alarming, is usually transient, a few compressions of the chest and lowering the head sufficing to restore the patient; (4) The arrest of breathing due to acute surgical shock is often immediately preceded by a few abnormally deep respirations (see Illust. Case, No. 65); (5) The re-establishment of corneal reflex takes place more quickly in circulatory failure of traumatic origin than in circulatory failure from simple chloroform overdosage.

The diagnosis between surgical shock on the one hand, and hæmorrhage on the other, has been discussed in Chap. VIII. (p. 251 *et seq.*).

(vi.) **Treatment**

It now remains to summarise briefly the treatment of circulatory failure due chiefly to the surgical procedure. This may be discussed under two heads—preventive and immediate.

The **preventive treatment** of this form of circulatory failure is of greater importance perhaps than the immediate treatment.

In cases in which surgical shock is likely to arise, special precautionary measures should be adopted, particularly when dealing with feeble subjects. Violent purgation should be avoided; the room kept warm; the bodily heat maintained by woollen clothing, and, if necessary, by a hot-water bed; the surface of the body exposed as little as possible; and all undue delay both in anæsthetisation and in operation avoided. In very feeble subjects an enema of beef-tea and brandy may be given half an hour before the operation. The use of subcutaneous saline infusion (*vide infra*) is doubtless beneficial in preventing surgical shock. Some surgeons commence the infusion before the anæsthetic is given, introducing the needle into the pectoral region immediately the patient is in position for the anæsthetic. It would seem to be preferable, however, to defer this measure till consciousness has been annulled. Careful attention to posture is advisable (p. 238). As already mentioned, shock may be largely, if not wholly, prevented by the use of the Trendelenburg posture. As regards the best anæsthetic to be employed, there can be no doubt whatever that surgical shock is distinctly less common under ether than under chloroform or chloroform mixtures. The open ether method, preceded by morphine and atropine narcosis, has placed in our hands a valuable means of prophylaxis against this kind of circulatory failure. But if ether be inadmissible, the C.E. mixture should be used rather than chloroform itself. The most important precautionary measure, however, is the regulation of the depth of anæsthesia. All clinical evidence goes to show that grave circulatory shock is almost exclusively met with in deep anæsthesia. If the operation be of such a nature that shock is likely to arise, the depth of anæsthesia should, if possible, be lessened just before the critical point. Clinical evidence seems to indicate that the surgical stimuli which are capable of producing an acute and possibly an alarming state during deep anæsthesia, produce only a slight, and possibly only a temporary cardio-inhibitory effect when the anæsthesia is light.

The **immediate treatment** of this form of circulatory failure must depend upon the degree and nature of the depression. If sitting, or semi-recumbent, the patient should be brought into the horizontal position. If the anæsthesia be deep when the shock declares itself, the anæsthetic should be withheld in order to lessen the depth. The general rule may be laid down—the greater the shock the lighter should be the anæsthesia. It is an interesting fact that when some degree of circulatory shock is present, the corneal reflex may generally be allowed to persist without the patient displaying any inconvenient recovery phenomena. In minor cases there is usually no need for anything more than lip and face friction, the maintenance of free respiration, and a reduction in the depth of anæsthesia. It must be remembered that surgical shock often is, so to speak, a conservative process, limiting hæmorrhage and rendering deep narcosis unnecessary. It may, in fact, be of questionable benefit to the patient to correct a minor degree of this condition. In acute cases, however, in which the pulse suddenly disappears, treatment must, of course, be promptly applied, the head being lowered and the chest rhythmically compressed, as in the illustrative cases above cited. If the shock be very acute, it may be necessary to resort to formal artificial respiration for a short time, or even to combine this with partial inversion. Directly the peripheral circulation has become restored, and signs of recovery have begun to show themselves, the anæsthetic may be resumed, a change from chloroform to the C.E. mixture, or to "open ether," being effected if the circumstances seem to indicate such a course. It is exceptional for true circulatory shock to persist after recovery of vaso-motor control has been brought about by the simple measures above described. Should it do so it may be necessary to complete the operation with the patient in the Trendelenburg posture, or to supplement the above treatment by the administration of saline fluid (*vide infra*).

In practice true circulatory shock is often complicated by the effects of hæmorrhage or other intercurrent conditions, and it is in such cases as these that treatment other than that above described may be of value. Thus, benefit may often be derived from the use of saline infusions or injections; whilst in prolonged or desperate cases the administration of certain drugs and the application of tight bandages to the abdomen and extremities may be indicated. Strictly speaking, cases requiring treatment of this kind belong rather to the province of the surgeon than to that of the anæsthetist.

Saline fluid may be introduced intravenously, subcutaneously, rectally, or into the peritoneal cavity.[1] Crile found that the intravenous infusion of saline fluid raised the blood-pressure in all stages of shock, but, as Mummery points out, the use of saline injections does not combat the cause of the fall in blood-pressure, *i.e.* the loss of peripheral resistance in the circulation. Crile observed that after the introduction of about 320 c.c. of fluid per kilo. of body weight, œdema resulted. Saline infusion, by reducing its specific gravity, counteracts the tendency of the blood to become thickened. A sharp metal cannula, carefully sterilised, should be employed and pushed through the skin and vein-wall in a direction towards the heart. The cannula may be left in the vein ready for re-infusion. The fluid employed should consist of a sterilised salt solution of 1½ drachms to the pint, 3° above body temperature. One pint at a time may be slowly infused. **Continuous saline infusion** into the loose cellular tissue under the breasts, scapulæ, or other regions is strongly advocated by Arbuthnot Lane in all operations where shock is anticipated. This method is less suited for very severe shock already present, but for mild cases and especially as a prophylactic measure it answers extremely well. It is necessary in all these methods to make sure that the solution is at 100°-105° F. *as it enters the body.* It is therefore as a rule necessary to maintain it at 110°-115° F. in the reservoir from which it flows, as it rapidly chills during its passage through the tubes. It is a good plan to place the jug containing the solution inside a wider vessel containing water nearer boiling point. If the operation be an abdominal one an intra-abdominal infusion of physiological salt solution at a temperature of 104°-108° F. may be introduced immediately before the wound is closed. Rectal injections have the disadvantage of comparatively slow action. They are, however, of great value as being readily applicable.

Much discussion has taken place on the use of **Strychnine**. Crile and Mummery, in their respective researches, agree that it is practically useless. The former writer found that repeated injections of strychnine brought about, in a normal animal, a condition comparable to shock. In animals suffering from shock, strychnine only produced an effect if the shock were slight. Animals passed into a deeper degree of shock as soon as the effects of the drug passed off. Yandell Henderson and Malcolm, on the other hand, who adopt a theory of shock diametrically opposed to that of Crile and Mummery, believe that strychnine does good; they denounce the use of suprarenal extract and pituitrin (see p. 70).

The effects of **alcohol** have also been much discussed. Crile found that in a normal animal the intravenous injection of alcohol generally caused a fall in blood-pressure, and that in an animal suffering from shock

[1] See Mr. Lockhart Mummery's lectures on "Surgical Shock," *Lancet*, 18th March 1905, p. 698.

the blood-pressure was still further lowered by this agent. Mummery corroborates this view by observations with the sphygmomanometer. Wood and Hoyt [1] have studied the physiological action of alcohol. According to these writers it increases arterial pressure when the general vascular system has been separated from its dominant vaso-motor centres; it stimulates the action of the isolated reptilian heart; and it lowers blood-pressure by dilating arterioles. The stimulant cardiac effect is thus neutralised by the vaso-dilator effect, and little or no alteration in blood-pressure takes place.

Suprarenal extract has been said to be useful in cases of this class. It acts directly upon the vessel walls, causing constriction, and so raises blood-pressure. Subcutaneously administered it produces little or no effect. It should be given by intravenous infusion in solutions having the strength of 1 in 20,000,[2] and as the effect is transient the infusion should be frequently repeated. It is hardly necessary to add that the use of suprarenal extract is only likely to be called for in the most severe and threatening cases of surgical shock, and that if the patient's condition is such that other measures have failed there will be but little chance of success even with this powerful drug, which has disappointed the expectations once formed of it.

Ergot, which is best administered intramuscularly or intravenously, appears to be uncertain in its action. In some experiments upon cats, however, in which its effects were observed by Mummery [3] it markedly raised blood-pressure which had been reduced by shock. Aseptic ergot was employed, 2 gm. of the drug being diluted with 20 c.c. of normal salt solution, of which from 5 to 10 c.c. were injected at a time into the jugular vein. Unlike ergot, **ergotin** produced only a temporary effect.

At the termination of operations which have been attended by severe shock the application of a **tight binder** to the abdomen, or of bandages to the extremities, has been found useful. Crile has employed a "pneumatic suit," by means of which he has found it possible to raise the blood-pressure in such cases.

Pituitrin has been widely used since the last edition of this book was published. There is a consensus of opinion that for post partum hæmorrhage its effect is marvellous; but some observers do not find it so useful for surgical shock. The majority, however, believe that it is the most reliable drug we have for this condition,[4] apart from saline solution. As far as our own experience goes, we have not seen it do harm, and we believe we have seen it do good.

Pituitrin further has a very marked effect in promoting intestinal peristalsis after abdominal operations, and in checking distension. Thus L. A. Bidwell in a recent paper [5] shows that by the routine use of this

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[1] *Brit. Med. Journ.*, 17th February 1906.

[2] See a letter by Mr. Lockhart Mummery, *Lancet*, 17th March 1906, p. 790.

[3] *Lancet*, 1st April 1905, p. 850.

[4] Rowell, *Brit. Med. Jour.*, vol. ii, 1910, p. 758.

[5] *Clinical Journal*, Oct. 1911.

substance intestinal evacuation occurs in most cases without the use of any other purgative. This observation shows that the theoretical objection which has been urged against the use of morphine before anæsthesia, viz. that peristalsis may be thus inhibited afterwards, can be easily surmounted by the use of small doses of pituitrin.

In cases in which hæmorrhage has been free, numerous important structures have been divided, and large cutaneous or cut surfaces have been exposed for a considerable time, the anæsthetist may be consulted as to the propriety of **discontinuing the operation.** Speaking generally, it may be said that the procedure of the surgeon may be permitted to proceed so long as the pulse can be counted at the wrist. If it be difficult or impossible to count the pulse, no time should be lost, as a general rule, in removing the patient to bed and in applying suitable restorative measures. These remarks do not apply to cases of acute circulatory shock, in some of which (*e.g.* Illust. Case, No. 68) it may be necessary to complete the operation, even though the patient be pulseless.

4 AND 5. TREATMENT OF CIRCULATORY FAILURE DUE TO OTHER CAUSES

Reference has already been made to the risks of raising a patient deeply under chloroform from the Trendelenburg to the horizontal, or from the latter to the sitting posture. The treatment of syncope thus arising is sufficiently obvious. Unfortunately nothing is likely to be of any service in the treatment of syncope caused by the lodgment of a detached thrombus in the cardiac valves.

CHAPTER XXI

THE AFTER-CONDITION OF THE PATIENT

Recovery Period: Posture during Recovery, etc.—We have seen, in considering the after-effects of each anæsthetic, that, when the administration is discontinued and fresh air admitted to the lungs, a kind of **retrogression** in the patient's symptoms commences. A true retrogression is rarely if ever observed—that is to say, a patient rarely if ever displays, in reverse order, precisely the same symptoms which occurred whilst he was passing under the influence of the anæsthetic. With nitrous oxide, nitrous oxide and oxygen, ethyl chloride, and similar agents, **recovery** from anæsthesia quickly takes place, consciousness frequently becoming completely re-established in from 30 to 60 seconds after the administration has ceased. With agents of this kind the length of the recovery period is only to a very slight extent dependent upon the length of the administration period. With anæsthetics such as ether, chloroform, and the C.E. mixture, however, there is a distinct and direct relation between these two periods, prolonged anæsthetisation being followed by prolonged recovery, and *vice versa.* But whether the anæsthetic be one like nitrous oxide, which is rapidly eliminated, or one like chloroform, which after a protracted administration is slowly eliminated, the rapidity of recovery will largely depend upon the freedom with which lung ventilation takes place at the conclusion of the administration. For example, should some obstructive condition be present whilst a patient is recovering from nitrous oxide, consciousness may not be regained for several minutes; whereas a prolonged administration of chloroform may be followed by an unusually rapid recovery, if respiratory action be unusually vigorous. In ordinary surgical practice the first change usually observed after the withdrawal of the anæsthetic is quieter breathing and a lessening of stertor, if present. The next sign of recovery is usually the reappearance of the lid-reflex. Deglutition movements sometimes occur first. If the patient be left undisturbed, the pupil generally grows smaller; but dilatation may occur, more especially if the patient be disturbed, or the operation be still in progress. Dilatation may also be met with prior to vomiting. The globes now commence to move from their fixed positions; the breathing becomes intermittently obstructed, from the temporary laryngeal closure incidental to swallowing; expiratory phonation and inspiratory crowing may be heard; and coughing, retching, or actual vomiting may then follow.

After a protracted administration, and particularly after preliminary narcotisation, it is generally possible, and distinctly advisable from the patient's point of view, to withdraw the anæsthetic for some five, ten, or even fifteen minutes before the operation is actually finished. It is only in those cases in which retching or vomiting would inconvenience the surgeon that full anæsthesia should be maintained till the bandages are applied.

Towards the conclusion of an operation the bed prepared for the patient should be warmed by means of **hot-water bottles**; but the bottles should always be removed from the bed before the patient is placed in it.

It is an excellent practice, when circumstances permit, to **turn the patient well upon his side** when he is put back to bed. This is the posture which Bowles[1] so strongly recommends in apoplectic seizures. In this position stertor generally ceases; the tongue gravitates to the side of the mouth; a free air-way is established; mucus and saliva are not swallowed; and should vomiting occur, any vomited matter will readily find an escape without interfering with breathing. If the patient's head be allowed to remain in the mid-line, and more especially if his chin be permitted to rest more or less upon his sternum, breathing cannot take place freely, and recovery

[1] *Stertor and Apoplexy.*

will therefore be tardy and unsatisfactory. It is a good plan in all patients of muscular build and accurately-meeting teeth to insert a small prop just before recovery begins, and to keep it in position till the recovery period is well advanced. Neglect of this precaution may involve the anæsthetist in considerable difficulties at the moment when such a patient, with clenched jaws and perhaps an inadequate air-way, is attempting to eject quantities of viscid and frothy mucus through a temporarily closed channel. Those who have not had to deal with the intense jaw spasm of such subjects cannot form any idea of the difficulty that may attend the maintenance of a free air-way during the recovery period. Many anæsthetists push forward the lower jaw to relieve the cyanosis which may arise from minor degrees of this condition. J. D. Mortimer [1] objects to this practice, on the ground that it may open the larynx just as vomited matter is being ejected, and thus lead to the entrance of such vomitus into the trachea. He advises instead retraction of the cheek by hooking a finger into the side of the mouth which is least dependent. We have tried this suggestion and found it to answer.

Within recent years the so-called **Fowler posture** has been somewhat extensively used, particularly after abdominal sections. It is effected by propping the patient up by pillows, or some kind of bed-rest or sling, so that his body forms an angle of from 45° to 80° with the horizontal plane. As far back as 1898 this propped-up posture was in use in Leeds,[2] but it was not till 1904, when Dr. Russell S. Fowler [3] of Brooklyn advocated it after operations for septic peritonitis, that its advantages attracted attention. One of the strongest advocates of the Fowler posture in this country is Mr. Mayo Robson, who employs it after practically every case in which a general anæsthetic has been given. If pillows be used, from six to eight are generally necessary, the hard ones being

[1] *Anæsthesia and Analgesia*, 1911.

[2] For this information I am indebted to one of the great advocates of this posture, Mr. J. A. Cairns Forsyth. His "sling-pillow" mentioned in the text is manufactured by The Medical Supply Association, 228 and 238 Grays Inn Road, W.C.

[3] See "Results in Diffuse Septic Peritonitis treated by the Elevated Head and Trunk Position," *Medical News*, vol. lxxxiv. (1904) p. 1011, by Russell S. Fowler, M.D.

placed below. One simple and efficient way of securing the position is to adjust an ordinary chair under the hair mattress of the bed in such a way that its back and back legs are in contact with the under surface of the mattress, whilst the front of the chair seat rests upon the upper surface of the under or spring mattress. The chair, which is thus made to act as a large wedge, cannot slip backwards because the free ends of its front legs rest against the head of the bed. But whatever means be chosen for propping the patient up it will be necessary to adopt some plan to prevent him sliding downwards towards the dorsal position. The simplest device is to place a bolster across the bed below the buttocks and to connect its free ends by means of bandages to the head of the bed. Mr. J. A. Cairns Forsyth has devised a special sling-pillow for this purpose. The advocates of the Fowler posture maintain that, by its use, (1) post-anæsthetic vomiting is rarely met with, (2) the frequency of respiratory complications is greatly reduced, and (3) the patient is much more comfortable than in any other posture. The author has not had sufficient experience with this posture to warrant him in making any definite comparisons between it and other postures, but he is inclined to think that it has the advantages claimed. There can be no doubt of its propriety when, as in all patients liable to or suffering from respiratory affections, it is important to secure the maximum degree of lung ventilation after anæsthesia. If it be decided to employ the Fowler posture care should be taken that the patient has sufficiently regained his reflexes to permit of his being thus propped up. After prolonged operations it is often advisable to place the patient in the lateral posture till semi-consciousness has returned, and then to change this for the Fowler position.

If it be necessary to **transfer** the recovering patient from one spot to another, care must be taken to avoid the respiratory difficulties which, as already mentioned (p. 247), may attend such transference. The patient should be carried on his side, and the anæsthetist should himself take charge of the head during the process of transfer. When the bed prepared for the reception of the patient is in the room in which the operation has taken place, there is no objection to his being moved whilst still in a state of deep anæsthesia, but when he has to be transferred to another room he should have passed through the stage of coughing and retching before the transference is effected.

It is important that **the administrator should stay by his patient** till some semi-voluntary action has taken place. The following case illustrates the importance of carefully watching patients after anæsthesia, and the ease with which mistakes as to the causes and nature of symptoms may arise.

Illustrative Case, No. 77.—M., about 45. Good condition. Excision of rectum. Nitrous oxide-ether sequence. When operation, which lasted one hour and a quarter, was over, the pulse was regular, but rather weak and collapsing in quality, and the face pale. There had been rather free hæmorrhage. Some mucous râle audible. During the temporary suspension of breathing incidental to the dislodgment of this mucus by cough, the wrist pulse almost vanished and the patient's aspect became somewhat alarming. Had one not realised the presence of an asphyxial element, one might have attributed the circulatory failure to fresh hæmorrhage. Mouth opened; cough excited, and much mucus sponged out. Immediate improvement in pulse and colour.

The administration of an **opiate** after an operation is a question which the surgeon usually likes to decide himself. From the anæsthetist's point of view there is no objection, provided the administration has been eased towards the close of the operation; but if the patient is still very deeply under, it is advisable to wait until signs of a lighter form of anæsthesia are manifested. The advantage to the patient is that pain is subdued or relieved by the morphia before the analgesia due to the anæsthetic has disappeared.

Pallor and feebleness of pulse are not uncommon after the administration of anæsthetics, but such symptoms very rarely indicate the existence of a dangerous degree of circulatory depression. They are naturally more common in feeble and bad subjects and in those who have displayed symptoms of surgical shock or of hæmorrhage than in other patients. The commonest cause of temporary circulatory failure at this stage is the respiratory embarrassment incidental to recovery. Sometimes pallor and pulse feebleness seem to arise in connection with vomiting, although the act of vomiting never takes place. On other occasions, as in the case referred to on

p. 328, in which nitrous oxide was the anæsthetic used, the faintness would seem to be of traumatic (reflex) origin. In other cases again, the sitting posture is doubtless a contributory factor. Whatever the cause of such symptoms may be, it is always advisable, if the patient be sitting or semi-recumbent, that he should at once be placed in the lateral posture, his lips and face briskly rubbed with a towel, and free respiratory action encouraged. When the pulse depression seems to be connected with approaching vomiting and the patient is still unconscious, it is a good plan to tickle the fauces, the coughing or vomiting thus excited being quickly followed by a better pulse and colour. As a general rule no other treatment than this will be necessary unless, of course, the patient be suffering from surgical shock or hæmorrhage, in which case the remedial measures already advocated for these conditions must be applied.

The **room** in which the patient is recovering should be well ventilated after the operation, and then kept quiet and dark in order to encourage natural sleep.

Nourishment.—After the use of ether or chloroform for a surgical operation, no **nourishment** should be given by the mouth for about four hours, and if at the expiration of this period the patient be disinclined for food, he should be allowed to continue his fast till this disinclination has passed away. Some clear soup or broth may then be given. Properly made beef-tea, to which a small quantity of a reliable meat extract has been added, will be found to answer well. Some patients prefer solid Brand's Essence to any liquid nourishment. After short administrations some tea or coffee with dry toast may be permitted, and in these cases it is not always necessary to withhold all fluid for the full four hours. If there be much thirst, sips of water, hot or cold, may be allowed as a preliminary to liquid nourishment. Sips of lemon juice and water in equal proportions will often be found very refreshing. Lemon juice is particularly useful in removing the unpleasant taste produced by ether.

Nausea, Retching, and Vomiting.—As the prevention and treatment of **nausea, retching, and vomiting** are matters of considerable importance, not only to the patient but to the surgeon, a few remarks, in addition to those already made concerning their causation, may not be out of place. It may be premised that the single act of vomiting which often takes place just before consciousness returns is usually an advantage rather than a disadvantage, for it clears the air-passages of mucus, and the stomach of bilious or other fluids which would otherwise remain in that viscus, to be ejected at a less opportune moment. During such an act of vomiting, the best treatment is to hook back the angle of the mouth with a finger or a tongue depressor, so as to allow access of air. It is not good practice to push the angle of the jaw forward, as this may facilitate the entrance of vomitus into the larynx (see p. 624). It is the vomiting of consciousness which here concerns us—that which disturbs the patient and in certain cases prejudicially affects the success of the operation.

In the first place, the preparation of the patient, which has already been fully discussed, is of paramount importance. Preliminary dosage with morphine, scopolamine, atropine, and similar combinations does not, in our experience, reduce the incidence of after-vomiting, but if anything slightly increases it.

Secondly, the choice of the anæsthetic has its influence. We have already seen that of all anæsthetics nitrous oxide is least likely to be followed by the after-effects in question; that ethyl chloride is much more often attended by gastric disturbances; that transient retching and vomiting are more common after ether than after chloroform; but that persistent and even dangerous emesis is more frequently observed after chloroform than after ether. "Open" etherisation is less likely to be followed by nausea and vomiting than "close" etherisation.

Thirdly, patients differ widely in their liability to these sequelæ. Rosy-cheeked children, young women of good colour, fair hair, and full lips, and flabby-looking individuals with an unhealthy and dusky appearance are much more likely to suffer from after-vomiting than others. Such patients nearly always secrete large quantities of mucus, which is swallowed and subsequently ejected. Similarly, patients with chronic naso-pharyngeal catarrh, whose stomachs contain swallowed mucus even before the administration, are specially liable to after-vomiting. Patients of "bilious" habit frequently suffer a good deal after ether or chloroform—a fact recognised by Snow. Moreover, those who are liable to sea-sickness, as well as those whose digestion is upset by travelling on land, usually display nausea and vomiting after general anæsthesia. On the other hand, elderly persons, alcoholic subjects, and muscular young men who have "lived hard" are rarely affected by these gastric sequelæ.

Fourthly, the nature of the operation may possibly affect the question. Thus, it is believed by some surgeons that patients who have undergone operations in which the intestines have been freely manipulated are specially liable to after-vomiting. The precise source from which the anæsthetic has been manufactured is, so long as the drug is pure, a matter of indifference (see pp. 25 and 28).

If, then, we wish to avoid after-vomiting, an appropriate laxative or purgative must be given; the diet carefully regulated; an equable anæsthesia with the purest anæsthetics maintained; the head kept turned well to one side for the escape of mucus and saliva; and the patient placed upon his side directly the operation is over. For the prevention of vomiting after chloroform the administration of considerable quantities of water beforehand has been recommended[1] by Prof. Denucé.

If nausea and vomiting arise, and prove distressing, an endeavour must be made to relieve them. Should the patient have been lying in the lateral position a change to the Fowler posture (*vide supra*) may be tried. Should no improvement result a tumblerful of hot water to which has been added a small teaspoonful of bicarbonate of soda may be given. The author has often known this treatment to arrest post-anæsthetic vomiting. Should it not do so, it may be repeated in a few hours' time. The remedy in question is most likely to succeed when the vomiting is dependent upon swallowed naso-pharyngeal mucus or muco-pus, as it often is in so-called "throaty" subjects. For the treatment of vomiting occurring independently of swallowed mucus and

[1] *Lancet*, 21st Jan. 1905, p. 176.

especially for that met with in certain highly emotional and nervous patients, enemata of bromide of potassium—30 or 40 grains of the bromide to 4 or 5 ounces of water—every four hours will often answer well. In the most obstinate cases of vomiting all attempts to administer nourishment by the mouth should be abandoned, and enemata of potassium bromide and of plain saline solution alternately administered.

The author was consulted some time ago about a patient who had vomited more or less continuously for six days after chloroform. She was a young woman who had undergone curetting. When seen she was listless and emaciated; her eyes were sunken and her face had a grey colour. Her pulse was 90. Her cardiac sounds were audible, but there were both basic and apical bruits. There was fine tremor of both arms. The epigastrium and loins were very tender. The abdomen and breasts were painful and tender. The abdomen was flat. The breath was offensive. The tongue and mouth were dry. Several ounces of greenish fluid had just been vomited. There was much hiccough. I suggested the discontinuance of all attempts to give nourishment by the mouth, and the commencement of rectal injections. In this particular case it was found best to alternate injections of 5 ounces of saline with injections of 30 grains of bromide of potassium in 5 ounces of water. Larger enemata were not retained. The vomiting quickly began to subside under this treatment. On the following day two meat suppositories were given. On the second day the patient was able to take mutton broth by the mouth.

Although numerous remedies have been and are still employed for the treatment of post-anæsthetic vomiting, it is questionable whether they give such good results as those above suggested. Thus some writers advocate strong hot coffee without milk or sugar; others give small quantities of iced champagne from time to time; whilst others again administer oxalate of cerium in five grain doses, or drop doses of tincture of iodine. The administration of oxygen during the recovery period has been lately recommended. A small blister to the epigastrium will sometimes act beneficially in obstinate cases. Lenevitch[1] advises washing out the stomach with lukewarm alkaline solutions in severe after-vomiting; and Blumfeld,[2] who employs plain water for the purpose, speaks favourably of this line of treatment.[3]

[1] *Annual Univ. Med. Sci.*, 1892, p. 13.
[2] *Lancet*, 23rd September 1899, p. 833.
[3] In one case, that of a boy who had suffered on previous occasions from distressing vomiting after anæsthesia, the author washed out the stomach with

Moderate degrees of **acute dilatation of the stomach** are common after operations, especially abdominal operations. This is no doubt due more to the surgical manipulations than to the anæsthetic, though possibly the latter may play a subsidiary part in the causation. In this connection it is of interest to note that Röntgen ray examination after a bismuth meal shows that handling of the stomach or intestines prevents food leaving the stomach for several hours.[1] The majority of the patients recover after copious emesis or after the use of a stomach tube; but occasionally the condition is serious and even fatal. A case of this complication has recently been recorded following an operation for hernia under local anæsthesia. The patient recovered after passing through a period of grave danger; but the hernia recurred and was afterwards repaired under ether without any gastric dilation supervening.[2]

Respiratory Complications.—These are far more common after ether than after other anæsthetics, and the reader is therefore referred to Chap. X., in which these complications have been discussed in their relation to ether anæsthesia. They may, however, occur after other agents, and under these circumstances are generally attributable, at all events in large measure, to influences other than the anæsthetic itself. It is difficult to summarise these respiratory sequelæ, as they differ very considerably from one another, not only in their mode of origin but in their nature and degree. It would seem, however, that they are of four kinds:—

(1) Those which are primarily referable to the presence of some pre-existing bronchial or pulmonary affection, and secondarily, referable to the direct or indirect action of the anæsthetic.

(2) Those wholly referable to some inflammatory condition of the lower respiratory passages coming on *de novo, i.e.* shortly after the administration of the anæsthetic.

(3) Those wholly referable to some congestive or œdematous condition of the lungs, also arising *de novo.*

(4) Those wholly referable to the entry of some solid or fluid substance into the air-passages during anæsthesia.

hot alkaline water during the recovery period. The after-vomiting, however, was quite as severe as it had previously been.

[1] Rutherford Morison, *Medical Annual*, 1909, p. 534.

[2] *New York Med. Journ.*, Feb. 1912.

Respiratory complications of the first kind arise if ether be given for a short time or chloroform for a long time to a patient with chronic bronchitis, the chronic condition passing into an acute condition as the result of the local action of the anæsthetic. Similarly, a patient with quiescent pulmonary phthisis, who is subjected to a somewhat protracted operation, may develop acute pulmonary symptoms. Or again, the presence of diaphragmatic paralysis may, as in Illustrative Case, No. 15, p. 380, predispose to acute pulmonary œdema after ether. Respiratory sequelæ of the second and third kinds seem to be mainly, though not quite exclusively, met with after ether (see Chap. X., p. 375). As regards respiratory complications of the fourth class, these may obviously be met with after all anæsthetics. They are, however, more common after ether than after other agents, owing to the frequency with which ether causes an excessive mucous secretion within the bronchi. The various foreign substances, both solid and liquid, which may enter the respiratory passages during anæsthesia have been considered in Chap. XIX. (p. 566 *et seq.*); and it is clear that symptoms referable to the entry of these substances may, in certain cases, persist after the restoration of consciousness.

The preventive treatment of respiratory complications is an exceedingly important matter. There can be no doubt indeed, that by carefully selecting appropriate anæsthetics, and by judiciously administering them, these complications may, as a general rule, be completely prevented. In the first place, it is believed by a large number of surgeons that the exposure of anæsthetised patients to air-currents is a common cause of bronchial and pulmonary complications. There is, however, very little evidence to support this view. At the same time, it is certainly prudent to preserve an equable temperature during anæsthesia, and to expose the patient as little as possible to draughts of cold air. Then again the judicious surgeon will take care that the administration shall be as short as possible. He will see that everything and every one (himself included) are ready to start the very moment that the anæsthetist gives permission. One of the very great advantages of Grossich's method of skin disinfection with iodine is the time thus saved and the avoidance of a long exposure on the operating table while the skin is being prepared with ether and other chilling fluids. Completion of the operation in as short a time as possible consistent with good surgery is another factor worthy of attention; for not only will less anæsthetic have been absorbed, but the likelihood of local venous thrombosis and subsequent pulmonary embolism is also reduced: careful hæmostasis is an additional safeguard. In the next place, all respiratory embarrassment, whether from faulty posture, undue air-limitation, or other causes, should be avoided. Thirdly—and this is the most important point—the anæsthetic chosen should not be permitted to excite the secretion of mucus to any great extent. Ether, administered by "close" methods, is undoubtedly the agent which is most likely to produce respiratory after-effects. Speaking generally, we may say that this anæsthetic should be given when possible by the "perhalation" system; that unless its vapour be well borne, it should not be used for any very prolonged period, particularly when the operation is within or about the abdomen; and that its administration should not be unnecessarily pushed. When ether is badly borne, *i.e.* when it produces much mucus and irritation, a change to some other anæsthetic should be effected *early in the administration.* If this rule be not followed, and if frothy mucus be allowed to accumulate for a considerable time within the air-passages, the state of the patient at the termination of the administration may be that described in the case referred to on p. 379. Mucus-inundation is certainly one of the special risks of ether anæsthesia, although it is a risk which is easily avoided. Moist rattling and laboured breathing should in fact be taken as warning notes, indicating a tendency towards the occurrence of respiratory complications and the necessity for a lighter anæsthesia. Fourthly, the rule should be followed whenever practicable of keeping the patient's head turned well to one side for the escape of mucus; whilst in any case in which mucous secretion is excessive, the fauces should be frequently sponged out. Lastly, should the patient have displayed moist breathing during anæsthesia, whether from the presence of mucus, blood, or vomited fluid, it is important, at the conclusion of the administration, to keep him for some time in the lateral posture, substituting the right for the left side, and *vice versa*, at intervals, in order to encourage the free expansion of each lung. Even more important still is the adoption of the semi-sitting, or Fowler position, as soon as the patient is sufficiently recovered from the anæsthetic to render it practicable.

For remarks on the **renal** complications of anæsthesia, the reader is referred to Chap. XI. p. 383, Chap. XII. p. 440, and Chap. XVII. p. 531.

Post-Anæsthetic Toxæmia.—Acidosis, acid intoxication, and delayed chloroform poisoning are synonyms for a dangerous and often fatal condition which develops occasionally after anæsthesia. Although in the great majority of cases the drug used has been chloroform, or a mixture containing it, yet there are now many recorded instances of the onset of symptoms after other general anæsthetics have been exhibited. It is therefore preferable to abandon the name delayed chloroform poisoning, and to adopt instead that which, while indicating the sequence of events, implies no preconceived view as to their exact ætiological relation.

As far back as 1850 Casper[1] expressed the belief that chloroform might leave behind it a state of "chronic poisoning," which might possibly terminate fatally hours, days, or weeks after the administration. In the same year Langenbeck[2] reported a case in which a patient died from the supposed delayed action of chloroform 17 hours after an operation. Leonard Guthrie[3] was the first to draw attention to similar cases in this country. He reported a number of cases from a children's hospital in which chloroform anæsthesia was followed by fatal after-effects of a toxic character. The symptoms were: copious, violent, and persistent vomiting supervening some hours after the anæsthesia, the vomit often resembling beef-tea dregs; restlessness and screaming; delirium, alternating with apathy; later on, pyrexia, coma, and death. At the time there was a disposition to attribute these symptoms to sepsis, fat-embolism, carbolic acid poisoning, or uræmia; but Guthrie maintained that in some of his cases he could

[1] Casper's *Wochenschrift*, 1850.
[2] Berend's *Chloroform Statistik*, 1850, Hanover.
[3] *Lancet*, 1894, vol. i. p. 193.

exclude all these factors, and that the prime cause of the condition was the anæsthetic. Guthrie found that the liver was markedly fatty in half of his cases, and suggested that this was probably a pre-existing condition and a predisposing factor; he regarded the chloroform as the last straw in producing results in such patients as would not otherwise occur. Jaundice was not observed in this series, but has been noted in a fair percentage of cases subsequently reported.

After this paper interest in the question seems to have died down in Great Britain, though Heintz,[1] Schenk, Fränkel, Bastianelli, Roth, Eisendroth, Ambrosius, Thiem and Fischer, Bandler, and Cohn reported cases from time to time.[2] The association of this form of toxæmia with the presence of acetone in the urine was noted by Brackett, Stone, and Low,[3] who reported a series of cases, very similar to those described by Guthrie, after the administration of ether to children. Observing the sweetish odour of acetone in the breath, they tested the urine and found both acetone and diacetic acid present. In the seven operation cases described the symptoms did not come on until twelve to twenty-four hours after the anæsthesia. They found that the amount of acetone excreted bore no relation to the severity of the toxæmia: in one of their fatal cases the acetone excreted was very small in amount. They concluded that the toxic symptoms were due to fatty antecedents of acetone rather than to acetone itself; and, after a careful review of the subject, that in their cases anæsthesia alone "did not bring on the condition, or at least, in a serious form." They drew attention to Becker's researches, according to whom acetonuria usually ensues after anæsthesia.

Meanwhile Guthrie[4] had reported further cases, and shortly afterwards Stiles and McDonald[5] reported several cases of "delayed chloroform poisoning," and gave a full résumé of the literature of the subject up to the date of their paper. The next year Kelly[6] recorded 46 cases of acid intoxication among

[1] *Der Chloroform Tod*, Rotterdam, 1896.
[2] Guthrie, *Lancet*, 4th July 1903.
[3] *Boston Medical Journal*, 7th July 1903.
[4] *Lancet*, 4th July 1903.
[5] *Scottish Medical and Surgical Journal*, Aug. 1904, p. 97.
[6] *Annals of Surgery*, Feb. 1905, p. 161.

400 hospital patients. According to this author, acetone in very minute traces is a normal constituent of physiological urine; and he also enumerates many conditions, medical and surgical, in which excess of acetone and diacetic acid may be present in the urine, quite apart from a precedent anæsthesia. Scott Carmichael and Beattie,[1] who reported a case in the same year, agreed with Stiles and McDonald that the fatty liver of chloroform poisoning cannot be distinguished from the fatty liver of sepsis; and were distinctly inclined to believe that the septic state of the patient was a factor of importance in the case as great as, if not greater than, the administration of chloroform. Bevan and Favill,[2] on the other hand, who published a case in the same year, favoured Guthrie's views, and attributed the symptoms of their patient to acid intoxication rather than sepsis.

Investigations of the urine both before and after operation were conducted at the Royal Hospital for Sick Children, Edinburgh, by Beesly,[3] who found that both ether and chloroform invariably produced a temporary acute acetonuria; but that if acetonuria were previously present, chloroform was much more dangerous than ether. His most important deductions are that the symptoms of intoxication only occur when the kidneys fail to excrete the acetone, and that when death takes place it is due to the inability of these organs to meet abnormal demands made upon them. Beesly recommended the administration of sodium bicarbonate in cases of post-anæsthetic acidosis, and also its use as a prophylactic before operation if there seemed to be any likelihood of this complication.

Since the last edition of this work a very large number of cases of this post-anæsthetic toxæmia have been recorded, and the whole subject has been carefully studied by many observers. Among numerous others, the papers of Telford,[4] Hunter,[5] Beddard,[6] Wallace and Gillespie,[7] Gundrum,[8] Whipple and

[1] *Lancet*, 12th Aug. 1905, p. 437.
[2] *Journal of the American Medical Association*, 2nd Sept. 1905, p. 691.
[3] *British Medical Journal*, 19th May 1906, p. 1142.
[4] *Lancet*, 17th Nov. 1906; 29th Feb. 1908; 29th Oct. 1910.
[5] *Ibid.*, 4th April 1908. [6] *Ibid.*, 14th March 1908.
[7] *Ibid.*, 5th Dec. 1908, p. 1665.
[8] *Johns Hopkins Hospital Bulletin*, June 1909.

Sterry,[1] and Cunningham[2] are of interest. Thus Telford showed in 1906 that acetonuria followed the administration of ethyl chloride as well as that of chloroform and of ether. Cunningham two years later reported a case of actual post-anæsthetic toxæmia after an administration of this agent lasting only one minute. This case did not end fatally, though at one time it seemed about to do so. Sodium bicarbonate was given freely per rectum and recovery ensued. Beddard suggested glucose as a prophylactic; and this has been tested by Wallace and Gillespie, who report most favourably on it. These authors compared three series of cases: one series in which no prophylactic treatment was adopted, as a control; a second in which eight half drachm doses of sodium bicarbonate were given every four hours, the last four hours before operation; and a third in which half an ounce of glucose was given every four hours for six doses, the last four hours before operation. They tested the urine before and after operation in all cases, and noted the incidence of vomiting. Emesis occurring in the first twelve hours after operation they class as "primary vomiting"; "secondary vomiting" means emesis after that interval; and "marked vomiting" means emesis lasting more than twenty-four hours. Their results are shown in tabular form thus:—

	Series 1.	Series 2.	Series 3.
	Per cent.	Per cent.	Per cent.
Acetonuria before operation	25·2	25·4	3
,, after ,,	60·4	53·4	22
Primary vomiting	54·3	67	53
Secondary vomiting	30	34·2	21
Acetone in cases of secondary vomiting	89	88	28
Marked vomiting	13·4	12	2

They further conclude that septic cases, especially if abdominal, are particularly liable to symptoms; and that the duration of the anæsthesia is not a great factor in determining their incidence. In the treatment of the developed condition they find sodium bicarbonate to be the

[1] *Johns Hopkins Hospital Bulletin*, Sept. 1909.
[2] *Lancet*, 1st Feb. 1908.

best drug; and they recommend that in any case of vomiting lasting more than twelve hours, the stomach should be washed out with a solution of this salt, and that some of the solution should be left in. They quote experiments which show that acetone is less than half as common after ether given by the "open" method as after closed methods.

Gundrum found that acetonuria ensues even after the use of cocaine as a local anæsthetic. Whipple and Sterry's work is principally experimental, and shows that by prolonged chloroformisation both the clinical symptoms and the morbid histology of post-anæsthetic acidosis can be produced in dogs.

One of the most remarkable points about this condition as it is seen clinically in human beings is the fact that it may develop after very short anæsthesia, when but extremely small quantities of anæsthetic can have been absorbed by the system. This is notably the case in children, in whom the great majority of the cases of post-anæsthetic toxæmia are encountered. It has hence been supposed, both by Guthrie and by most subsequent writers, that a liver to some extent already fatty is probably responsible for post-anæsthetic toxæmia. Such a condition is common among the rickety and poorly-nourished children in whom this form of toxæmia is most commonly seen. In the remarkable condition known as "cyclic vomiting" in children the liver is said to be always in some degree fatty,[1] and the urine to contain acetone. Except that cyclic vomiting is hardly ever fatal, it presents many analogies to post-anæsthetic acidosis; and in some of the reported cases of the latter, the patient had previously suffered from the former. Telford,[2] while admitting the resemblance, lays stress upon the differences between these two conditions. He says that in the rare fatal cases of cyclic vomiting the liver is not always fatty, and that in these cases death, instead of occurring rapidly, ensues only as a termination of a long series of attacks. He suggests that some of the reported cases of post-anæsthetic acidosis in which rapid recovery has taken place have really been instances of cyclic vomiting precipitated by the stress of the operation.

[1] Hunter, *Lancet*, 4th April 1908, p. 993.
[2] *Ibid.*, 29th Oct. 1910.

One of his most interesting cases is that of a woman aged forty-seven who died of post-anæsthetic acidosis four days after a gastro-enterostomy, during which the liver had been freely viewed and handled. At operation it was apparently normal, but at the post-mortem examination it was found in a state of marked fatty degeneration macroscopically as well as under the microscope.

To sum up, we may say that post-anæsthetic toxæmia is a condition which especially, though not exclusively, affects children. It is particularly likely to attack those who already have acetonuria, diabetes, fatty liver, a tendency to cyclic vomiting, rickets, or who are seriously wasted by the nature of their disease. It may occur after the use of any quantity of any general anæsthetic; but is commonest after chloroform. Fatty degeneration of the liver, kidneys, and heart is found post-mortem; and acetone and diacetic acid are present in the urine.

The symptoms are exhibited after an interval of ten to forty-eight hours from the operation, until which time there is nothing to distinguish the case. Frequently the patients seem to be recovering quite normally from their operation, until they develop intractable vomiting; frequently this vomit contains altered blood, and sometimes even a frank hæmatemesis occurs. Restlessness, delirium, and screaming ensue; and sometimes icterus is evident. The pulse becomes very rapid, but the temperature remains at or near normal except towards the terminal stage of a case which does not respond to treatment; considerable pyrexia may then develop. In a favourable case the symptoms subside gradually under treatment; but otherwise, coma, cyanosis, "air-hunger," convulsions—any or all of these—set in, and death speedily ensues, as a rule within five days of the anæsthesia.

The prophylactic treatment consists of feeding up all patients who have acetonuria in pathological degree before operation, especially those known to be suffering from rickets, diabetes, or fatty liver. In addition the administration, as a routine, of glucose four-hourly for twelve doses is of value; adults should have one drachm for a dose, young children ten grains. Care should be taken that the pre-anæsthetic fast is not too lengthy. In a recent paper Corner[1] suggests stomach lavage also, and states that a certain amount of post-anæsthetic vomiting is beneficial; this was a belief held long ago by surgeons, that patients who vomited after operations "did better" than those who did not vomit.

When the condition has already arisen, the best treatment is sodium bicarbonate in large doses: if possible, by the mouth; but if rejected, then by enema or by intravenous transfusion. Small repeated doses of calomel, oxygen, and stimulants as required will also be found useful.

There seems to be a growing conviction amongst those who have studied this mysterious affection that the acidosis and acetonuria are merely symptoms of the altered hepatic function which seems to be the dominant factor in the causation of the malady. In spite of the large amount of work that has been done in attempting to ascertain the causation and true nature of post-anæsthetic toxæmia it must be confessed that our knowledge is still exceedingly imperfect and that much in the above description may, in the near future, require to be revised or even altogether withdrawn.

Other Exceptional Sequelæ.—Certain other **exceptional sequelæ** may be met with after general anæsthesia. These have been referred to in Chapters X., XI., and XII. (pp. 302, 373, and 438) when discussing the special after-affects of nitrous oxide, ether, and chloroform respectively.

Finally, certain **posture-paralyses** may be met with in patients who have been anæsthetised. These have already been discussed (p. 248).

[1] *Lancet*, 27th April 1912, p. 1130.

CHAPTER XXII

THE MEDICO-LEGAL ASPECTS OF SURGICAL ANÆSTHESIA

(By Digby Cotes-Preedy, M.A., LL.M., Barrister-at-Law.)

It is proposed in this chapter to review briefly the main legal considerations that arise in relation to the administration of anæsthetics: such as the present state of the law, the legal liability of the anæsthetist, the public investigation of deaths under anæsthetics, and the steps that have been, and are still being, taken to remedy a state of affairs in this department of practice which, in the words of the recently-appointed Home Office Committee, is a serious menace to the public.[1]

(1) PRESENT STATE OF THE LAW

As the law now stands, any person may administer any kind of anæsthetic for any surgical, medical, obstetrical, or other purpose, though the circumstances in which the major operations of surgery are performed are generally such that anæsthesia is conducted by medically qualified practitioners. Thousands of minor operations, particularly upon the teeth, take place annually under general and local anæsthetics, administered by those who are utterly devoid of all professional training. The department of anæsthetics is, however, only one of the departments of medical practice which are open to the unqualified practitioner.

The so-called Magna Charta of the medical profession[2] does not, as so many seem to think, prohibit the practice of

[1] See par. 5 Report of Coroners' Committee, dated 18th March 1910.

[2] The Medical Act (21 and 22 Vict. c. 90) 1858.

medicine and surgery by the unqualified, neither does it fully protect medical titles. It only enacts a penalty on those persons who dare to assume wilfully and falsely such titles, which penalty, if past cases are any guide, seems difficult to enforce.[1]

At present any person may undertake, with or without remuneration, the cure of his fellows. Nevertheless, as it is well put by a writer on this subject, "every thoughtful person will agree that all unqualified practice is an evil, especially to the public at large; but this evil becomes greatly accentuated when the unqualified practitioner employs such powerful drugs as fall within the armamentarium of the anæsthetist."[2]

On the other hand, the law says that a person who acts as a medical practitioner is liable as such;[3] and that an unqualified person, not known as such to the patient, must attain to the standard of skill possessed by the registered practitioner, or, if known to be unqualified, then of the skill he professes or announces.[4]

But, whether qualified or unqualified, a person is not held responsible by the criminal law for the death of a patient occasioned by his treatment, *unless* his conduct is characterised either by (1) gross ignorance of his art, (2) gross negligence, or (3) gross rashness in the application of a remedy:[5] circumstances which are almost impossible to prove to the satisfaction of juries. The General Medical Council has striven to safeguard the public by prohibiting those over whom the legislature has given it control from "covering" unqualified persons. From time to time it is recorded in the medical press that the heavy punishment of erasure of a practitioner's name from the Register has been inflicted for this offence. A case in point occurred in 1911 in which a registered practitioner who acted in the capacity of anæsthetist to a bone-setter had his name removed. But notwithstanding the penalty the "sufferer" is not prevented by the law from continuing to officiate in a similar capacity. It is worthy of note that at the present

[1] See the remarks of Lord Collins in *Reg.* v. *Lewis,* 1896, 60 J.P. 392.
[2] *The Lancet*, 16th September 1911.
[3] *Jones* v. *Fay*, 1865, 4 F. and F. 525.
[4] *Dickson* v. *Hygienic Institute*, 1910, S.C. 352.
[5] *R.* v. *Long.*, 4 C. and P. 398 and 423.

moment the bodies of domestic animals are better protected from the attentions of unqualified healers than those of their masters.[1]

(2) THE LEGAL LIABILITY OF THE ANÆSTHETIST

Before administering an anæsthetic to any person, consent must be obtained: from the patient if of age, and from the parents or guardians if not of age. Administration without such consent is an assault, exactly as is the performance of a surgical operation in the same circumstances. The power of parents to forbid anæsthetisation, even for a necessary operation, is said to be absolute[2]; but in the case of young people nearing the termination of their minority, it is doubtful whether any jury would be willing to penalise an anæsthetist (or a surgeon) who accepted consent from the patient notwithstanding the contrary wishes of the parents. In Canada such a case arose recently. The patient was twenty years of age, and wished to undergo an operation; his parents refused consent and brought an action against the medical attendants for damages. The action fortunately failed.

In cases of emergency, where immediate operation is necessary as the best chance of saving life, there may be no time or opportunity to communicate with and obtain consent from the parents or guardians of an infant. In such a case the anæsthetist is in a similar position to the surgeon; and the acts of both, though technically illegal, will be held excused and justified by the urgent circumstances of the case. The onus of showing such urgency will rest upon the surgeon, not upon the anæsthetist.

It sometimes happens that an excitable patient who has consented to an operation, and to anæsthesia as a part of it, changes his mind when brought to the operating table and refuses to accept the administration. In such an event the anæsthetist may endeavour by argument to convince the patient and so persuade him to submit to anæsthetisation. But he may not forcibly restrain the patient and then proceed

[1] See The Veterinary Surgeons Act (44 and 45 Vict. c. 62) 1881.
[2] *Lancet*, 6th May 1911.

to anæsthetise him. On the other hand, if a patient accepts the administration, and when partly anæsthetised struggles to tear the mask from his face and to interrupt the anæsthetisation, the anæsthetist is justified in restraining his struggles and forcibly completing the induction, if satisfied that the patient's powers of reason and judgment are sufficiently suspended to render him irresponsible for his actions. This sequence of events is not very rare, and it furnishes a valid reason for the presence of a third party at every induction of anæsthesia. Another reason for this necessary precaution is that in certain cases patients have erotic dreams while anæsthetised (especially under nitrous oxide gas), and that on a few occasions the result of such a dream has been a baseless charge of criminal assault against the anæsthetist.

There are still certain differences of opinion as to the exact relative status and liability of the surgeon and the anæsthetist. This is, perhaps, due to the fact that the Courts have not been called upon as yet to lay down any ruling on the point. Should this question ever come up for a clear decision, the tribunal will probably apply the ordinary principles of law, and the result will depend upon the application of those principles to the special circumstances attending the case.

It should be remembered that this question of legal responsibility can only arise when there has in fact been negligence, or where negligence is alleged. As regards negligence the position of a professional man was well defined by Chief Justice Tindall when he said "Every person who enters into a learned profession undertakes to bring to the exercise of it a reasonable degree of care and skill. He does not undertake, if he is an attorney, that at all events you will gain your case, nor does a surgeon undertake that he will perform a cure; nor does he undertake to use the highest possible degree of skill. There may be persons who have higher education and greater advantages than he has, but he undertakes to bring a fair, reasonable and competent degree of skill."[1] Moreover, it is a settled rule of law that *a man*

[1] *Lanphier* v. *Phipos*, 1835, 8 C. and P. 475. This statement of the law has been approved by the American Courts. See *Carpenter* v. *Blake*, 75 *New York Reports*, 12.

is liable for the result of his own negligence; in other words, every man is responsible for his own acts, and should he be incompetent to perform what he undertakes to do he must bear the consequences.

It would seem to follow that if injury or death is brought about by the want of a reasonable degree of care and skill on the part of an anæsthetist amounting, in the opinion of a judge or jury, to negligence, the anæsthetist is liable to be mulcted in damages for his negligence, or to a conviction for manslaughter if the negligence be so gross as to cause death. The fact that the anæsthetist is not generally regarded as controlling the operation does not, in the writer's opinion, affect his legal liability. It is *his* duty to decide whether the patient is reasonably fit to take an anæsthetic, and with him lies the choice of the anæsthetic suitable for the case. A surgeon may express the wish for the employment of a certain anæsthetic; but should disastrous results follow the anæsthetist will probably find little protection in the plea that he acquiesced in the suggestion of his surgical colleague. It may be that where an anæsthetist can prove he has been compelled, owing to his position, to obey the surgeon's directions, the Courts will take a more lenient view of the course followed. On the other hand, a surgeon who, either knowingly or through lack of proper inquiry, permits his patient to be in the hands of an incompetent anæsthetist will probably find himself held liable for the acts of the latter. It must not be forgotten that a greater degree of skill and care will be expected and required of a specialist in anæsthetics than of a less experienced practitioner. While it is true that the onus of proof lies on him who formulates a charge of negligence, it is advisable that an anæsthetist be ready to prove that he is possessed of the necessary skill, knowledge, and experience for rendering the administration efficient; that he employed the most suitable anæsthetics [1] and method of administration; that he showed constant care and vigilance during the administration; that he was prepared to meet any complica-

[1] A French Judge awarded damages against a country practitioner who had administered chloroform to a patient of alcoholic tendencies, for the sole purpose of examining an injured shoulder, untoward results following. *British Medical Journal*, 3rd February 1906, p. 282.

tion; and in fact that he did everything possible to remedy danger and prevent death.

The defective state of the law in regard to anæsthetics is well exemplified by a case[1] which occurred some years ago in which a servant girl died after chloroform had been administered to her by a herbalist for the extraction of teeth. The girl had just partaken of a heavy meal, and her corsets were not unfastened. The herbalist, according to his own account, used about $\frac{1}{2}$ oz. of chloroform. He then attempted the operation. The Coroner's jury committed the herbalist for trial on a charge of manslaughter, but the jury of the higher Court, after prolonged deliberation, were unable to agree and were discharged. It is stated that as the majority of the jury were in favour of the accused a verdict of "not guilty" was returned. The Judge said the verdict was a merciful one; that the prisoner had had a very narrow escape from conviction on a very serious charge, and that he hoped it would be a warning to him, and to all whom it might concern. Similar charges of manslaughter have been preferred against unqualified persons who have employed cocaine for dental operations with fatal results[2]; whilst numerous actions for negligence in the use of such local anæsthetics might be cited.[3]

[1] *Journal Brit. Dental Assoc.* vol. xvii., 1896, p. 313; *Dental Record*, 1896, vol. xvi. p. 218; *ibid.*, 1896, vol. xvi. p. 282; and *Brit. Journal of Dental Science*, vol. xxxix., 1896, p. 424.

[2] The case of *R.* v. *Zeifert* (C.C.C. Sess. Papers, vol. cxlviii. p. 630) is worthy of mention. A Russian, who for thirteen years had practised in this country as an unqualified dentist, was indicted for the alleged manslaughter of a patient to whom he had administered cocaine for the purpose of a dental operation. The jury found the accused "not guilty," and in discharging him, *Bucknill J.*, remarked that with the knowledge of cocaine and its properties which he (the accused) must now possess it would be extremely unwise if he ever administered it again, without first ascertaining the condition of the patient's heart (*vide The Times* newspaper, 6th March 1908). The words of the learned judge would appear to be a direct incentive to unqualified practice, as was the *obiter dictum* of *Ridley J.*, in *Royal College of Veterinary Surgeons* v. *Collinson* (1908, 2 K.B. 253) that "many a quack is a good doctor."

[3] On 17th October 1908, at the Evesham County Court, an auctioneer's clerk was awarded damages against a druggist, whose assistant had negligently administered cocaine to him before extracting a tooth. A medical witness stated in evidence that the plaintiff had been "as near death as could be." Quite recently a sum of £300 was recovered (by private arrangement at the conclusion of the action) as damages for the negligent administration of cocaine by an unqualified dentist acting on behalf of an advertising Dental Company.—ED.

Single-handed Operations under Anæsthetics

From time to time fatal cases have been recorded in which the operator has first produced general anæsthesia and has then performed the operation. Of twelve fatalities under anæsthetics in dental practice collected by a writer upon the subject, there was incontrovertible evidence that in no less than eleven of them the dentist had acted both as anæsthetist and surgeon.[1] The Home Office Departmental Committee, whose report will be referred to below, and the general Medical Council have independently expressed opinions strongly condemnatory of this practice. On more than one occasion Coroner's juries have deprecated this single-handed anæsthetising and operating.

Any one venturesome enough to assume this dual rôle, unless in a case of emergency or when only analgesia is desired as in the case of a parturient woman, is taking upon himself legal risks by no means imaginary. The objection to this practice of being both anæsthetist and operator would appear to have quite as much force even if nitrous oxide is administered, to judge by numerous fatalities that have thus occurred in dental practice. Apart from the likelihood of an inquest with its unpleasant publicity, the "quick-change" practitioner may find himself involved in an action for damages on account of negligence which has caused injury to his patient's health, or standing his trial for alleged manslaughter.

It may be noted that the charge of manslaughter is a very grave one; to substantiate it, the prosecution would have to satisfy a jury that the death of the patient was due to the anæsthetic employed; that there was culpable negligence on the part of the administrator who must have known he was doing something that was dangerous and did it recklessly; that the death was not due to some contributory cause on the part of the patient—such as a pathological condition present but not diagnosed prior to the administration, or an idiosyncrasy; and finally that the death was not due to the operation.

[1] *Lancet*, 13th March 1909, p. 790.

Anæsthetics in Hospitals

The governing bodies of most hospitals to which medical schools are attached are now fully alive to the importance of having anæsthetics administered by men who have received proper instruction and possess practical experience. Anæsthetists are at last being treated as equal in position to the other members of the staff. The public are beginning to recognise that the administration of the anæsthetic is an important part of the operation. Among the older generation the idea of an anæsthetist is that of a person who has the "easy work of sending the patient to sleep." The writer once had great difficulty in persuading a leading county magistrate that for an ordinary operation at least two medical men are required. The gallant officer regarded the anæsthetist as something akin to the doctor of the sixteenth century and rated him accordingly.

The liability of anæsthetists in hospitals would appear to be identical with that of their fellows practising their art outside, and is not altered because small salaries may be paid them or because their attendance in the operating theatres is at fixed hours. It seems to be clear law that neither the relation of master and servant, nor that of principal and agent, exists between a hospital authority and an anæsthetist. The former has discharged its duty to its patients when it has exercised due care and skill in the selection of the members of its staff[1]; and therefore it follows that the anæsthetist, who has been so appointed, must himself be prepared to meet any action brought by a patient alleged to have been injured through any negligent act on his part. At some future time difficult questions as to the liability of hospital authorities for the acts of medical students may require consideration by a Court of Law; but as regards anæsthetics, it is submitted that the anæsthetist, under whose supervision a student is learning the art of administration, will probably be held liable for the student's want of care which may have caused injury to a patient. Of course if a student is guilty

[1] *Hillyer* v. *St. Bartholomew's Hospital*, 1909, 2 K.B. 820.

of gross negligence he probably will be amenable to the criminal law.

(3) THE PUBLIC INVESTIGATION OF DEATHS UNDER ANÆSTHETICS

Coroners derive their jurisdiction to hold inquests touching deaths alleged to have occurred under anæsthetics from the Coroners' Act of 1887.[1] Section 3 of that Act empowers the holding of an inquest where a coroner has reasonable cause to suspect that a person "has died either a violent or an unnatural death, or has died a sudden death of which the cause is unknown." From this it will be gathered that the coroners are the sole judges of what is an unnatural death, and therefore may be at variance with one another. As that erudite lawyer the late Mr. Justice Walton hinted,[2] the Courts may some day be asked to decide whether "death by chloroform administered as an anæsthetic in the ordinary course of medical and surgical practice is such a death as an unnatural death." Chloroform is administered daily by medical men in combination with other drugs, but no coroner has been venturesome enough to hold an inquest upon a patient who may have taken a dose of medicine containing chloroform a few hours prior to his death. If a death under an anæsthetic is to be classed —as most coroners class it—under the heading of unnatural deaths, like murders and suicides, then, as the same learned judge pertinently remarked, it surely follows, "that if the man died from an operation, that plainly would be an unnatural death, and there would be an inquest in every case in which a man died from an operation."[3] The science of surgery would soon relapse into a retrograde condition, if surgeons were called upon to justify in public every detail of their operations; but it would appear that at present coroners think it their duty to put upon the rack of publicity only the unhappy anæsthetist. The Coroners' Society prepared a set of questions—worthy of the Inquisition—for an anæsthetist to answer in writing, before an inquest took place. It would be

[1] 50 and 51 Vict. c. 71.
[2] *Trans. Med.-Leg. Soc.* vol. v. p. 76.
[3] *Ibid.* vol. v. p. 76.

interesting to know from whence the Society derived the authority to frame such questions, or the right of any coroner to require them to be answered. There would appear to be no legal authority for their existence, and still less for any penalty—such as adverse comment—for refusal to answer them. It is true the coroner can put the questions when the anæsthetist is in the witness box; in fact there is no limit to the power of a coroner to ask questions, and he may even rake up the past "accidents" of the anæsthetist to the detriment of the latter's reputation. A felon with the blackest of characters stands in a better position when on trial, for he may not be asked questions as to previous convictions unless he puts himself forward as a man of good character. Coroners are, doubtless, acting in all sincerity in holding these public inquiries into deaths which may unfortunately be due to an anæsthetic, however well administered. But is it for the benefit of any one that professional men should be paraded in public, owing to an accident that may happen to the most skilled and careful? Can it be suggested that the newspaper report of such an inquest, with the usual startling head-lines, is of any real utility? The public are unnecessarily alarmed, and no account is taken of the many thousand anæsthetics administered yearly, under which beneficent operations are performed. If the present method of inquiry be retained, it is to be hoped that all coroners will adopt, if possible, the custom initiated in London of calling upon a pathologist of recognised ability and experience to perform the post-mortem examination which should always be made where the death is alleged to have been due to an anæsthetic. This may, of course, be difficult and expensive in country districts, far away from large centres; but in fairness to the anæsthetist, every effort should be made to determine the true cause of death. To allow the typical inquest jury to find a verdict in these cases, without any post-mortem examination, is neither just to the anæsthetist nor to the public; yet there was recently recorded an inquest upon a patient who died during the administration of nitrous oxide gas where the jury were permitted to intimate that they considered a post-mortem examination unnecessary.

Despite the report of the Coroners' Committee, it is respectfully submitted that the Scotch method of inquiry is the one suitable for anæsthetic "accidents." The Procurator-Fiscal, on being informed of the death, makes his own private inquiries as to the possible cause, generally orders a post-mortem to be performed by one skilled in that branch, and may also interview any person present at the operation. The result is that the cause of death is determined, without the public being alarmed by newspaper paragraphs, without the feelings of the relatives being further wounded by a public inquiry, and without the anæsthetist—a man deserving rather of sympathy than censure—being called upon, in public, to submit to what often amounts to a severe cross-examination.

(4) THE NEED FOR REFORMS AND THE STEPS THAT ARE BEING TAKEN TO SECURE THEM

The need for certain reforms in regard to anæsthetics will be sufficiently obvious from the following considerations :—

(1) Anæsthetics are now used upon a vast and increasing scale, and the number of fatalities which annually take place under their influence is a very considerable one.[1]

(2) As experience has shown that the risks of anæsthetics may very greatly be reduced by placing their administration in the hands of competent and scientifically trained persons, it is obviously important that the public should be protected as far as possible against such risks.

(3) As the law now stands any person whatsoever may administer any kind of anæsthetic for any kind of operation or procedure.

(4) Single-handed anæsthetising and operating is still practised, particularly in dental surgery.

[1] It must be borne in mind that the returns of the Registrar-General are practically useless for statistical purposes, owing partly to the fact that our present system of death notification and registration are highly unsatisfactory, and partly to the fact that it is impossible to say from the Registrar-General's figures what numerical relation exists between those figures and the total number of administrations. Some kind of idea, however, as to the annual increase of anæsthetic fatalities may be obtained by referring to a chart published in the *First Report of the Coroners' Committee*, 1909, Part II. Appendix No. 4.

(5) The instruction of our medical and dental students in regard to anæsthetics is often very inadequate.

(6) At many hospitals and public institutions insufficient attention is paid to the administration of anæsthetics.

(7) The present systems of inquiry into deaths under anæsthetics and of registering such deaths are wholly inadequate.

The position of the present reform movement in the administration of anæsthetics has been recently set forth at length,[1] but this chapter would not seem complete unless the reader were briefly put in possession of the various steps that have been taken in this direction.

In 1901, the General Medical Council in response to representations of the (then) Society of Anæsthetists expressed the opinion that it was inexpedient that anæsthetics "should be compulsorily included as a separate subject of the medical curriculum"; but the Conjoint Board issued a special regulation that on and after 1st May 1902 every candidate presenting himself for his final examination should produce evidence of "having received at a recognised medical school and hospital instruction in the administration of anæsthetics to the satisfaction of his teachers." In 1907 the General Medical Council, in the form of a "Recommendation," requested all examining bodies to require of candidates evidence of having received such instruction. In the same year the question of deaths occurring under anæsthetics received public attention when it was raised at the meeting of the British Association for the Advancement of Science held at Leicester. It was suggested with probable truth that the mortality might be reduced if students were properly instructed in the use of anæsthetics and if hospital authorities placed—as most do at the present time—the administration of anæsthetics in the hands of those who have special experience and training in this particular branch. On inquiry it was subsequently found that out of twenty-two medical examining bodies in the United Kingdom only eight required candidates to produce evidence of having received instruction, in spite of the "Recommendation" of the General Medical Council.

[1] *The Lancet*, 3rd and 10th June 1911.

In February and March 1908 the subject of "Deaths under Anæsthetics" was brought before the Medico-Legal Society of London,[1] and at the conclusion of the discussion two resolutions were adopted by that Society and forwarded to the General Medical Council and to the Privy Council respectively. The former body was asked to add instruction in anæsthetics to its "Requirements" in regard to professional education, while the resolution forwarded to the Privy Council petitioned for legislation making it a penal offence for any person other than a legally qualified medical practitioner to administer any anæsthetic with the object of destroying consciousness during any surgical operation. This latter resolution was also referred by the Privy Council to the General Medical Council, which expressed its willingness to support legislation on the lines suggested.

In June 1908 the then Home Secretary (now Lord Gladstone) consented to receive and consider a draft Bill which proposed to prohibit all persons other than registered medical practitioners, and dental practitioners registered before the passing of the Act, from administering any general anæsthetic, including nitrous oxide, for any medical or surgical operation, act, or procedure, or during childbirth. This Bill was subsequently referred by him to the Departmental Committee on Coroners' Law,—appointed 15th December 1908,—and to the Privy Council, who again referred it to the General Medical Council. This last-named body, in November 1908, expressed approval of the principle involved therein. In March 1909, a Bill almost identical with the General Anæsthetics Bill, received by the Home Secretary, was introduced into Parliament by a private member. It was attacked by both the registered and unregistered dentists, and eventually gave place to a second Bill which proposed to give dentists the right to administer any anæsthetics for any operation, but was subsequently withdrawn. On 27th November 1909 the report of its Anæsthetic Committee was adopted by the General Medical Council. This report embodied several important conclusions, the chief being that it is "desirable in the public interest" that the administration

[1] *Trans. Med.-Leg. Soc.* vol. v. p. 21 *et seq.*

of general anæsthetics "should be restricted by the law to duly qualified practitioners" and "that duly qualified dental practitioners should be authorised to administer certain specified anæsthetics, such as nitrous oxide gas for dental operations or procedures." The Council also pronounced against the practice of single-handed anæsthetising and operating.

On 18th March 1910 the Home Office Departmental Committee issued its Report upon the question of deaths resulting from the administration of anæsthetics, which should be studied by all those interested in the subject under review. The Report concluded with nine Recommendations which are worthy of being set out *in extenso* :—

(1) Every death under an anæsthetic should be reported to the coroner, who, after inquiry, should determine whether it is desirable to hold an inquest or not.

(2) In the case of every death under an anæsthetic the medical certificate of death should specify the fact, whether the anæsthetic was the actual cause of death or not.

(3) No general respirable anæsthetic should be administered by any person who is not a registered medical or dental practitioner.

(4) Registered dentists should be confined to the use of nitrous oxide gas for dental operations, and should not employ the general respirable anæsthetics of longer duration.

(5) Intra-spinal anæsthesia should be practised only by registered medical practitioners.

(6) Practical and theoretical instruction in the administration of anæsthetics should be an essential part of the medical curriculum.

(7) Such instruction in the administration of nitrous oxide gas should be an essential part of the dental curriculum.

(8) In the case of any death under an anæsthetic in a hospital or other similar public institution, there should be a scientific investigation into the actual cause of death conducted by the authorities of the institution.

(9) A small standing scientific Committee on Anæsthetics should be instituted under the authority of the Home Office.

With one exception, the conclusions arrived at by the General Medical Council, which by the way were very similar to those of the Departmental Committee, were endorsed by the Council of the Royal College of Surgeons. The latter Council were of opinion that registered dentists should be permitted to give such anæsthetics as the General Medical Council had suggested, not only in dental but in general surgical cases.

In July 1910 at the annual meeting of the British Medical Association held in London, the Section of Anæsthetics unanimously expressed approval of the conclusions of the Departmental Committee and of the General Medical Council. At the end of the following month a memorandum setting out the present state of the law and the Recommendations of the General Medical Council and Departmental Committee together with a set of Draft Clauses for a Bill dealing with both general and local anæsthesia were sent to the then Home Secretary (Mr. Churchill). This Bill was referred to the General Medical Council, which expressed the opinion that it gave practical effect to the Council's conclusions and suggested certain minor additions. Subject to a slight reservation the British Dental Association intimated to the Home Secretary its general approval of this last Anæsthetics Bill.

Apart from the apparent indifference of the Government there does not seem to be any reason why there should be any delay in protecting the public by passing this Bill into law. All the leading professional bodies have expressed approval of this attempt to reduce "those terrible and regrettable fatalities which seem to constitute a standing reproach to a scientific profession."

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