LOCAL AND REGIONAL ANESTHESIA

With Chapters on Spinal, Epidural, Paravertebral, and Parasacral Analgesia, and on other Applications of Local and Regional Anesthesia to the Surgery of the Eye, Ear, Nose and Throat, and to Dental Practice

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To

PROFESSOR RUDOLPH MATAS

Surgeon, scholar, teacher; one of the pioneers in the field of local and regional anesthesia under whose guidance the author was initiated into surgery, whose example and friendship prompted the conception of this work, and whose teachings and writings have contributed many pages of the text, this volume is gratefully dedicated.

INTRODUCTION

For nearly twenty years the control of pain in surgical operations by local and regional methods has been the subject of our earnest study. As director of the surgical clinics of the College of Medicine of the Tulane University since 1895, we began to utilize the large clinical material at our command in the effort to diminish the indications for general narcosis, and to substitute for the immediate dangers of chloroform, which was then the routine anesthetic in almost all Southern clinics, the more laborious but far safer methods of peripheral analgesia. Beginning with a purely local and peripheral technic, in which intradermal infiltration and massive edematization with dilute isotonic cocain solutions were chiefly utilized, in accordance with the principles laid down by Corning, Halsted, Reclus, and Schleich, we soon advanced from the minor work of the dispensary to the more ambitious fields of major surgery.

In 1897 we discarded cocain and adopted beta-eucain and soon became engrossed in the neuroregional methods[1] alone or combined with massive infiltration, which rapidly expanded in every direction, yielding the most gratifying and, at that time, almost incredible results. The pursuit of this regional method was carried out with so much vigor and enthusiasm that in 1900[2] we were able to publish two extensive reports which reviewed the progress of our work and

[1] In referring to regional methods we exclude the spinal or subarachnoid method (L. Corning, 1886–1894); Bier (1899) as a central method.

After an experience with over 300 applications of this method with cocain and its various substitutes, we experienced a transition from a state of great enthusiasm to one of decided depression, having learned by hard experience and careful study of our results that the benefits of this procedure were more apparent than real. Since then we have restricted the application of spinal analgesia to a very circumscribed and steadily smaller group of indications.

[2] "The Growing Importance and Value of Local and Regional Anesthesia in Minor and Major Surgery," Transaction of Louisiana State Med. Assoc., April, 1900, pp. 1–78; "Local and Regional Anesthesia with Cocain and Other Analgesic Drugs," Philadelphia Med. Jour., November 3, 1900, pp. 1–72.

that of others and gave an account of the considerable success that we had obtained in the invasion of new territories.

By blocking the nerve-trunks at their exit from the cranial foramina, jaws were resected, the tongue and floor of the mouth excised, and, by a similar process, craniotomy, thyroid and laryngeal resections, amputations of the extremities, resection of joints, thoracotomies, hernias, and the entire domain of genito-urinary, rectal, and a considerable share of pelvic and abdominal surgery became subservient to the new methods. In this way we were able to show in 1900 that fully 50 to 60 per cent. of the operations, which six years before would have required a general narcosis, had become amenable to local and regional anesthesia.

Fourteen years have elapsed since that time. Great transformations have taken place in our methods of general narcosis. Chloroform, which for half a century had reigned supreme as the autocrat of the operating theater, has been practically banished from the clinics of the South—its last stronghold. Ether by the open mask and drop method has entirely supplanted it; and now nitrous-oxid gas in combination with ether, alone or with oxygen, is gaining favor steadily in our main operative and especially private clinics. The effect of this revolution in reducing the immediate mortality of general narcosis, and, to some extent, in diminishing the postanesthetic risks, is universally recognized. However, the problem of shock, the secondary nausea and vomiting, the pulmonary complications, embolism and thrombosis, and, above all, the degenerative auto-intoxications following the action of these somatic poisons on the eliminating and other organs still remain to be reckoned with.

On the other hand, the synthetic chemist and pharmacologist have not been idle, and their untiring and brilliant efforts to find substitutes for the dangerous and costly cocain have given us a succession of remarkable synthetic products, such as beta-eucain, nirvanin, alypin, stovain, anesthesin, etc., which have been successively displaced by what now appears to be the nearest approach to the ideal local analgesic—novocain.

In like manner, the genius of synthetic chemistry and the biologic laboratory have found in suprarenin a less perishable substitute for adrenalin, the active product directly obtained from the gland. The advent of adrenalin and its synthetic substitutes has marked a new era in the history of local anesthesia. By its powerful and lasting vasoconstrictor and ischemic action it gives the operator a bloodless field, which has deserved for it the name of the "chemical tourniquet" (Braun). Combinations of novocain and adrenalin in various isotonic dilutions—by practically eliminating the toxicity of the analgesic, increasing its stability, durability, and intensity—have so expanded the technic that in the hand of an expert peripheral analgesia may be made to encompass in its grasp almost the entire domain of operative surgery.

* * *

But with all its great achievements the art of local and regional anesthesia is still young. Barely three decades have elapsed since Karl Köller made his epochal demonstration of the anesthetic properties of cocain at Heidelberg in 1884, and yet, in spite of the stupendous distance that we have traveled since then, the horizon of peripheral anesthesia is ever widening and offering new opportunities for profitable exploitation. It is still in process of development; it still offers many difficult problems that await solution.

In dealing with major operations, its successful application demands patience, time, and skill—a skill that can only be acquired and exercised on the human cadaver by those who, being anatomists, can alone survey the field of operation with fluoroscopic eyes. For this reason the practice of peripheral anesthesia, especially in its neuroregional aspects, appeals most pointedly to the young, ambitious, and well-trained surgeon, who, fresh from the anatomic laboratory, finds here, as nowhere else, an immediate and practical application for a knowledge that he has acquired at the cost of long nights of vigil, labor, and thought.

In these days when exact topographic and applied anatomy is rated somewhat at a discount, it is a source of no small gratification for the young but well-trained man to discover that his anatomic knowledge is a living, palpable, and productive asset. Not a thing to be learned solely as a matter of academic culture and soon to be forgotten, but a practical tool to be used in unlocking his most immediate technical problems. It is only through the aid of applied anatomy that regional anesthesia is what it is to-day. It is for this reason that all, or nearly all, the notable advances that have been made in its technic have been due to the enterprise and the activities of young surgeons. Leonard Corning, Halsted, Reclus, Schleich, Crile, Cushing, Bier, Oberst, Braun, and a host of others who have laid the fundamentals of this work did so in their earlier professional years. It is this same potential spirit in the young man fresh from the anatomic and physiologic laboratories that animates their followers—the builders of the present day. Such men as Offerhaus, Härtel, Peuckert, Hirschel, Kulenkampf, Danis, Finsterer, Läwen, and others in Europe, not to mention a group of young surgeons in this country and in our own immediate surroundings—who are enriching the foundation laid down by the masters by their contributions, based chiefly upon anatomic and physiologic researches.

Whatever may be the limitations of regional anesthesia and the objections that have been argued against it, no one can deny that it has given a new impetus to anatomic teaching; that it has placed a high valuation upon an exact anatomic training, and that in this way it is making it less possible for the mere cutter—the "cut and tie" type of practitioner—to be confused with the real surgeon. For this reason alone it deserves the encouragement and fostering care of every surgeon and every teacher who has at heart the higher welfare of his science and his art.

* * *

To review and summarize the evidences of progress in local and regional analgesia; to study and analyze the copious and constantly growing literature which is rapidly piling up to pyramidal and almost inaccessible heights; to scrutinize the various analgesics that are born yearly in the laboratory of the chemist, and try the methods by which they may be utilized with special advantage in the different regions of the body and in connection with the surgical specialties; to gauge the value of the various technics proposed by the criterion of clinical observation and personal experience, and, in a like manner, to judge of their advantages and limitations in their relation to the general narcosis, was a task which I had set to myself, and which, after an experience of over two decades in this mode of practice, I felt might prove profitable to the profession, if only in the interests of a useful propaganda.

But, unfortunately, many circumstances and more urgent interests directed my attention into other channels, and the time has never come when I could sit down peacefully and calmly to the realization of my project. Fortunately for my purpose, the seed sown in earlier years appears to have yielded good and seasonable fruit. Associated with me as pupils and assistants were a group of young men who entered into the spirit of the work with zeal and enthusiasm. The results obtained in our clinics and exhibited in our reports of 1900, and subsequently, have been made possible largely through their faithful collaboration. Several of these have already attained enviable reputations in our community and elsewhere, as teachers and surgeons especially skilled in the methods of local and regional anesthesia, and to all these I owe a debt of gratitude. Conspicuous among these is Dr. Carroll W. Allen, whose steadfast loyalty to these methods for many years has been rewarded by a reputation for special skill and judgment in their application which is eminently deserved. He has assiduously cultivated the technic in all its variations, many of which are his own, and in our joint services at the Charity Hospital the results obtained have proved so satisfactory that fully 55 or 60 per cent. of the major operations in the division under his charge are performed solely by peripheral anesthetic procedures, exclusive of the spinal or subarachnoid analgesias which are not included in this category. One of the best proofs of the success of any method of practice is the confidence it inspires among the men of the profession and in their willingness to have it applied to themselves. Schleich, in his "Schmerzlose Operationen," tells us how his clinic was besieged by doctors who, needing surgical relief for various ailments, were anxious to be operated on by him painlessly, but without the unconsciousness of general narcosis. This is the experience of every operator whose reputation for skill in local and regional methods is confirmed by his results. Dr. Allen is no exception to this rule.

Now, returning to the book. I had almost abandoned all expectation of accomplishing this self-appointed task when Dr. Allen generously offered his collaboration. I had hoped that this valued offer would have made the task lighter. Dr. Allen set himself seriously and earnestly to work and gathered a large mass of material which I found it impossible to edit with him without the sacrifice of other and more pressing obligations, or subjecting the publishers to unwarranted delays. All that I could do was to give him the full and free use of my previous writings and original observations on this subject and such general counsel as my experience dictated. This volume as it stands is, therefore, the result of Dr. Allen's sole industry, thought, and labor. My regret is that I have not been able to join forces with him in accomplishing a task which it was my privilege to initiate even though indirectly, and in which I have always had a deep and abiding interest. Without having had an opportunity to revise the text or to read it thoroughly—through no fault of Dr. Allen or lack of willingness on my part—I am satisfied, by many years of professional and friendly association with the author, that the methods and teachings expounded for the last twenty years in the surgical clinics of the Tulane University will not only be well represented, but will be strengthened, and thereby diffused over a greater and growing area.

If Dr. Allen's book will only encourage others to follow his example, and stimulate his contemporaries, and especially the young surgeons of the rising generation, to cultivate the "qualities of head, heart, and hand" that are necessary for the successful practice of the art of peripheral anesthesia, it will have served a useful purpose and discharged a worthy mission. In this hope I wish it Godspeed.

Rudolph Matas.

PREFACE

In presenting this volume to the profession I have hoped to fill what I have learned by my experience as a teacher is a real want in the surgical literature of the English language.

Many small monographs have been available for the general surgeon, and some excellent books dealing exclusively with the specialties have been published, but no book in our language has attempted to survey the entire field, giving the essential elements in the successful application of local anesthesia to major surgery, as well as a systematic and detailed description of the methods of anesthesia suitable to operations in the different regions of the body. The excellent work of Professor Heinrich Braun is a masterpiece and a model of German thoroughness and comprehensiveness, and I have availed myself of this fountain source of information in both text and illustrations through the courtesy of Professor Braun himself and of his obliging publisher, Herr J. A. Barth.

When this volume was first undertaken it was intended that it should be a joint contribution from Professor Rudolph Matas and myself, an accomplishment of which I would truly have been proud; however, lack of time and the urgent press of other duties have forced Professor Matas to withdraw his direct collaboration, leaving to me this responsibility.

I feel it is fitting that a pupil and close associate of his should assume this task. It was at his side that I received my first lesson in local anesthesia, and derived from him that enthusiasm and zeal for this work that has made this book possible. It was his hand that opened the door to my surgical career, and from that hand I have received a generous bounty since. His name will always be numbered among the pioneers of local and regional anesthesia—with Corning, Halsted, Crile, and Cushing in this country; Schleich, Braun, Reclus, and Barker, abroad.

While deprived of his collaboration in the authorship of this work, I have quoted liberally from his writings and drawn still more liberally from his ideas and spoken teachings on this subject. To him is due the credit of working out successfully the first route to the second division of the trigeminus and blocking it with Meckel's ganglion and its branches, through the sphenomaxillary fissure and, in this way, painlessly resecting the upper maxilla, a method which by German authors is still erroneously credited to Payr. The Germans (Braun, Härtel, et al.), however, credit him with the inframalar route for reaching the inferior maxillary division at the foramen ovale to which they have attached his name. With the aid of this procedure he had resected the lower jaw many times, long before Schlösser had popularized this route for the alcoholization of this nerve in trifacial neuralgia. He first worked out a satisfactory method of regional anesthesia of the forearm by blocking the nerves at the elbow, and, independently of Crile's earlier work, he had amputated the leg and thigh several times by blocking the sciatic, anterior crural, obturator, and saphenous nerves. He performed the first operation under spinal analgesia in America, and devised several types of apparatus for massive infiltration anesthesia. Such terms as "intraneural," "perineural," and "paraneural," as applied to regional neural methods, were first introduced by him, as acknowledged by Braun, at a time when such niceties of classification were unknown in the literature.

His earlier accomplishments in this field have been overshadowed by his later and far-reaching contributions to other departments of surgery, more particularly by the various operations for the radical cure of aneurysm which are permanently linked with his name. In this way, his work in anesthesia has been overlooked or forgotten by many, who aware only of the marvelous efficiency of this branch of surgery at the present time, are oblivious of the laborious steps that have led to its present evolution. I feel it a fitting task, therefore, that the recital of Professor Matas' early achievements as they appear in the following pages should devolve upon me.

The fundamental work on "nerve-blocking," which has so intimately and inseparably associated the name of Crile with the early history of regional anesthesia, is now supplemented by his epoch-making studies in anoci-association and in their practical application. The growing appreciation of these principles has made a thorough knowledge of local, and especially regional, analgesia more than ever necessary to the progressive surgeon who would follow the teachings of this eminent leader.

A very extensive bibliography had been prepared upon which the author had expended much time and laborious research; it was intended as an appendix to the volume, which would have been of service to the student of the history and literature of the subject. It embraced a list of over six thousand references, covering several hundred pages. Unfortunately, as the text grew in size, it was found that even an abridged bibliography would have so far exceeded the proposed dimensions of the volume that it would have been too ponderous for the purpose for which it was originally intended. At the suggestion of the publishers it was deemed best to abandon this publication, a determination which has been a sore disappointment to the author, who in this way had expected to make a full acknowledgment of every publication referred to in the text; as it is, many important references have been regretfully omitted.

The author now desires to express his special and grateful obligation to the many authors and investigators quoted, whose writings have so largely and generously contributed to the making of this book.

In the preparation of this volume I am under particular obligation to my friend, Professor M. Feingold, for valuable assistance and advice in the chapter on the Eye as well as in the general text; to Professor C. J. Lanfried for assistance in the chapter on the Ear, Nose, and Throat; to Drs. E. C. Samuel and R. M. Blakely, of Touro Infirmary, for their kind assistance in the illustrations; and to Miss L. Ambrose for her assistance in the translations. I am also much indebted to Professors Arthur E. Barker, of London; Fritz Härtel, of Berlin; and Guido Fischer, of Marburg, for the privilege of making many quotations and the use of valuable illustrations.

CARROLL W. ALLEN.

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LOCAL ANESTHESIA

CHAPTER I

HISTORY

Divinum est opus sedare dolorem (divine is the work to subdue pain). Thus spoke Hippocrates.

The history of the efforts of the human race to find a means to control pain during operative procedure forms one of the most interesting chapters in medicine. The writings of authors, from earliest antiquity down through the long centuries, deal with efforts in the behalf of human suffering. Sometimes surrounded by superstitions at times the most ridiculous; later, as knowledge increased, based upon more or less reason, but all futile and attaining the desired end only to a limited degree.

Among the earlier references to the use of narcotics is to be found the following from Homer's "Odyssey," when Helen gave to Ulysses and his comrades the "sorrow easing drug," which probably consisted of the juice of the poppy and Indian hemp:

"Presently she 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 cheek, not though his mother and father died, not though men slew his brother or dear son with the sword before his face and his own eyes beheld it."

During the siege of Troy the Greek surgeons used anodyne and astringent applications to ease the pain of their wounded, which probably had some antiseptic effect of which they were not aware.

The following is found in the "Iliad," when Petroclus, in administering to the sufferings of Euryphylus, removed a dagger from his thigh:

> "Cut out the biting shaft; and from the wound
> With tepid water cleansed the clotted blood;
> Then, pounded in his hands, the root applied
> Astringent, anodyne, which all his pain
> Allay'd; the wound was dried, and stanched the blood."

It is probable that primitive men used pressure and cold to benumb the parts and thus lessen pain. In time they no doubt learned that pressure over the region of the nerves and arteries had a more pronounced effect, though they probably did not know why. The ancient Assyrians employed pressure over the carotids and produced a certain degree of anesthesia by cutting off the blood-supply to the brain, and performed their operation of circumcision in this way. The aboriginal natives of some countries practice this method to-day. That this practice must have been widespread is borne out by the fact that the literal translation of the Greek and Russian names of the carotid artery is "the artery of sleep."

The ancient Egyptians used the juice of the poppy and Indian hemp before surgical operations. They also used a certain kind of "Stone of Memphis," which was supposed to have special virtues, and was probably a carbonated rock. This they wet with sour wine and applied it to the wound or the region to be operated upon, thus, no doubt, generating carbonic acid gas. Accounts do not say whether they were aware of this chemical reaction or knew the action of carbonic acid gas. The Egyptians also used the fat of the "holy animal of the land," the crocodile, or its dried and powdered skin, to produce local anesthesia. What results were obtained by these methods is not known, but they were nearly always combined with the internal administration of alcoholics and such narcotics as they knew of.

Gold and silver instruments were supposed to cause less pain than others; also warmed and greased instruments. This practice was made use of in later times. It is stated that Lord Nelson was so painfully affected by the chill of the surgeon's knife when his right arm was amputated at Teneriffe, that at the Battle of the Nile he ordered his surgeons to keep hot water ready to warm their knives before using them.

The ancient Greeks also knew of the sedative and anodyne properties of many plants, from which they made ointments and lotions. Aphrodite is said to have thrown herself on a bed of lettuce and mandragora to lessen her feelings of grief over the death of Adonis.

There is probably no medicinal plant with which was associated more ridiculous and absurd superstition than Mandragora atropa. Much of this superstition no doubt grew out of its fancied resemblance to parts of the human body, and the more accurate this resemblance, the more highly was it valued. The growth of this plant must have been widely distributed throughout Europe, Asia, and Africa, for it was used by all of the ancient races. The Babylonians used it two thousand years before Christ. The ancient Egyptians, Hebrews, Hindus, and Chinese all used it.

The Chinese early recognized the local anesthetic action of many drugs. Certain subjective tribes were made to pay their tribute in such plants. In the middle of the twelfth century a pupil of the Salernitana School wrote a treatise on the local sedative action of opium, mandragora, and hyoscyamus. Even up to comparatively recent times many native Chinese surgeons, who knew of the discovery of chloroform, continued to practice anesthesia by the older methods. Fat, marrow, and lizard oil were also used by the Chinese, who attributed to them certain sedative action.

Freezing by the use of ice or snow was sometimes resorted to to produce local anesthesia, thus foreshadowing the use of ether and ethyl chlorid for this purpose. Thomas Bartholinus, a pupil of the Neapolitan anatomist, Marcus Aurelio, first introduced it in the middle of the sixteenth century.

At times many methods were forgotten and again revived. In the middle ages pressure, which seemed to have been forgotten, was again brought into use. Constrictors were then first used to deaden the sensibility of the parts by cutting off the circulation and to prevent hemorrhage after amputation. Velpeau later recommended it.

In 1784 J. Moore, of England, devised a constricting apparatus which, when left in place one and a half hours, combined with the use of large doses of morphin, permitted painless peripheral operations. Moore's apparatus produced a high grade of venous stasis, and, through many failures, fell into disuse and was forgotten.

In the middle of the last century Esmarch introduced his constrictor and bloodless method of operating, which was soon adopted in all countries, and is the same as is in use to-day.

Cold, like other anesthetic methods, was forgotten, but revived again by J. Hunter, who carried out painless experiments on animals.

Larrey, Napoleon's chief surgeon, reported that at the battle of Eylau in 1807, with a temperature of —19° F., amputations were almost painless. Later, through the observations of Arnott in 1848, Guerard and Richet, 1854, but especially through Richardson, 1866, was the refrigerating of the tissues for surgical purposes put upon a firm foundation by the use of ether sprays.

Percival in 1772 discovered the anesthetic properties of carbonic acid gas when sprayed on a raw or denuded surface, but was found to have little or no action on the intact epidermis.

The electric current was first used in the middle of the last century to produce local anesthesia through cataphoresis with various drugs.

The discovery of the hypodermic syringe by F. Rynd, of Edinburgh in 1845, though erroneously attributed to Wood, marked the beginning of a new era. Morphin solutions and tincture of opium were injected into the tissues and around nerve-trunks with the idea of deadening them, but, while these agents possess some slight local anesthetic action, any decided effect which was obtained was due to their general action; however, many operations were performed under their use, administered in this way, and are reported as having been comparatively painless.

Other substances, such as chloroform, which also has slight local anesthetic action, were similarly used, but the irritating results of their injection soon caused them to be abandoned.

The introduction of general anesthesia about this time, instead of lessening the interest in local anesthesia, seemed only to intensify the efforts and increase the zeal of those engaged in the search for a safe and efficient local anesthetic; these labors were soon to be rewarded.

The first cocain was obtained from the coca leaves, but later was prepared synthetically. The first report of the anesthetic properties of cocain was when Scherzir reported anesthesia of the tongue after chewing the leaves.

Godeke, as early as 1855, had isolated a principal from the leaves of the plant, which he called erythroxylin. A few years later Niemann, in a further investigation of its action, noticed that it produced numbness of the tongue, both when the leaves were chewed and when the alkaloid was placed on the tongue. He first gave the name cocain to the active principal.

In 1874 Bennet demonstrated that cocain possessed anesthetic properties.

Von Anrep in 1879 made a thorough investigation of the drug, and used it hypodermically upon himself, injecting a weak solution under the skin of his arm, and found that it first produced a sense of warmness, followed by anesthesia. The stick of the needle at this point no longer gave pain. The anesthesia lasted about thirty-five minutes. In his discussion he suggests the possibility of its being used as a local anesthetic for surgical purposes.

Cocain had already been known as a mydriatic, but Coupard and Borderon in 1880 discovered its local anesthetic action when dropped into the eye.

Karl Koller undertook a series of experiments on animals in Prof. Sticker's laboratory, and demonstrated the complete anesthesia of the eye by the use of a 2 per cent. solution. The anesthesia lasted, on an average, ten minutes. This was followed in 1884 by his announcement at the Ophthalmological Congress at Heidelberg.

The tremendous value of this discovery soon led to the universal use of the drug in ophthalmic operations all over the civilized world. Its use soon spread to other fields, and was applied to the mucous membrane of the nose, throat, and larynx, with gratifying success as an anesthetic.

"Within the short period of twelve months the newly discovered properties of the drug had been tested in every important clinic of the world, and the utility of cocain as a surface anesthetic had been put to trial in every form of intervention in which the insensibility of exposed or accessible mucous or cutaneous surfaces could serve the purpose of the surgical specialist or therapeutist. Thus it happened that, within an incredibly short space of time, a new literature sprang into existence, in which was reflected the experiences of ophthalmologists, otologists, stomatologists, dermatologists, genito-urinary surgeons, gynecologists, and obstetricians" (Matas).

Untaught by experience, and too early yet for experimentation to have shown the toxicity of the potent yet dangerous drug, many cases of poisoning and death naturally followed its use in concentrated solutions and in large quantities.

Owing to the importance of this drug, the first and representative type, as well as the standard by which the action and therapeutic value of all other similar agents are judged by comparison, and its early record so replete with interesting facts, it seems that a few remarks regarding the history which surrounds its earlier cultivation and use may prove desirable.

The plant formerly played a large part in the religious rites of the natives of Peru. It was considered as a heavenly gift, which "satisfied the hungry, gave life to the tired and exhausted, and made the unfortunates forget their troubles" (Novinny). Those forced to heavy labor or long, fatiguing journeys found exhilaration and stimulation by chewing the leaves. During the time of the Incas its cultivation was controlled by the royal family, who levied a tax on its production. When Pizarro invaded the country in 1532 he found its use widely distributed and much abused by excessive use. After conquering the country the Spaniards first forbade its culture, but later monopolized it and levied a heavy tax upon its cultivation.

The leaves in use by the natives are obtained from cultivated plants, the wild leaves are unfit for use; its cultivation is generally like that of coffee and tea shrubs. It is now more particularly cultivated in Bolivia, and large quantities are exported to Peru. Other varieties of the plant grow in most South American countries—Mexico, India, and Java.

The coca bush grows from 5 to 8 feet in height and is widely branched, its flower is white or cream colored, and grows in little fascicles, close against the bark on the older and leafless part of the twigs. There is no particular season for gathering the leaves, which are picked when they reach a certain degree of maturity. The first crop can be gathered after about two and a half years from plants grown from the seed, and continue to bear for about twenty to thirty years. The leaves are picked by hand and dried in the sun, and must be kept absolutely free from wetting by rain or other moisture. Considerable care is necessary for their proper curing, as much deterioration may result when improperly done, resulting in change of taste, due probably to the formation of other products in the leaf.

In the countries in which the plant is indigenous the lower classes still chew the leaves, but the better classes drink it when prepared as a kind of cordial, liquor, or pousse café.

There are several varieties of the plant—the Huanuco or Bolivian leaf, the Peruvian and Truxillo varieties—all varying slightly in some particulars, as regards to size and shape of leaf, as well as to their value therapeutically. In a general way the leaf is about 1 to 3 inches in length, and from $\frac{3}{4}$ to $1\frac{1}{2}$ inches in breadth, and of oval shape. There is not much doubt that the species originated upon the eastern slope of the Andes, probably in Peru, where it grows wild and has lost some of its cultivated characteristics.

The following history of the plant is quoted from Rusby's article in the Reference Handbook Medical Sciences, 1901:

"The coca plant was under cultivation at the time of the discovery, and no clew to its introduction to cultivation could then be, or has since been, obtained. It occupied an important place in the religious and mythologic history of the people. This is of interest here only because of the unquestionable fact that such esteem was the result of an appreciation of its useful properties rather than, upon the contrary, and as for centuries believed, the superstitious reason for its being used.

"We may, therefore, dismiss its mythical history (see 'Coca at Home and Abroad,' Ther. Gaz., March and May, 1888; also p. 14,

1886) as being here unimportant, and consider its physiologic and therapeutic history. Its expectorant, sialogogue, stomachic, carminative, emmenagogue, and aphrodisiac properties are among the minor ones for which it was and is used by the natives. As a stomachic it is recognized that its use before meals detracts from the appetite, but its use thereafter relieves any discomfort resulting from excess, while not appreciably inhibiting digestion. In fact, its general repute is that of aiding digestion. The more important objects of its use is as a limited cerebral stimulant, an anesthetic, a very peculiar muscular stimulant, and an ordinary masticatory. As a cerebral stimulant it filled the place of coffee. It was used before the latter was introduced, and after that event it continued to be used by the natives, while the much more expensive coffee was used by the foreign element. In this direction its characteristics were to promote cheerful and hopeful views and sentiments, without excitability, but rather with increased calm. As an anesthetic its use was a general more than a local one, though it was locally applied to ease pain, and its carminative and stomachic uses were clearly of this nature.

"The object of overcoming the pains of hunger and of fatigue were pre-eminent, while that of securing relief from pain by a mild general anesthetic, in spite of increased wakefulness, was general.

"The term 'muscular stimulant' is not accurate, but is used for want of a better. More lengthily stated, the plant was used to enable man to perform more labor with less fatigue and with less nutrition. Without regard to the facts of the case, this was the belief of its users. In consequence of these effects, bodily or mental, they performed almost incredible physical tasks, long-continued, upon a food supply the scantiness of which is equally astonishing, and with results not injurious beyond causing temporary inconvenience.

"The special adverse conditions to be met with in these efforts were the continued scaling of steep and high acclivities, with little food and with a very scanty supply of oxygen, and under the necessity of either attaining a high speed or transporting heavy loads.

"The above statements, in substance, were among the earliest historic records promulgated concerning its use by the people of the countries concerned, and they have been repeated, with assurance, by all subsequent investigating travelers.

"Many of these travelers went to extraordinary lengths to test their accuracy, and always with affirmative results.

"Travelers and foreign residents verified them by personal experience and very frequently relied upon them for personal help.

These assertions were met abroad by religious opposition because of the heathen relations of the coca customs, by very great professional conservatism, and, lastly, by discredit, because the leaves exported for use largely failed, in the condition in which they were received, to verify them. All the present importance of the drug in its own form, or that of cocain, cannot be said to cover the same ground involved by the native uses of coca leaves.

"There appears to be but one rational explanation of this broad discrepancy, namely, change in properties which the leaves undergo after being dried. This view has been verified by the writer by numerous assays of the leaves soon after collection compared with others made later.

"Preparations made upon the spot have also been found, by extended trial, to act more like the leaves as chewed by the natives than like preparations made from the exported leaves.

"The details of the methods of use have been so often published that any account of them appears scarcely necessary in this article.

"The use of Llipta, or ashes with the bolus, is to be regarded partly like that of condiments, especially of salt as such, without food. At the same time, the suggestion made by Holmes that the effect of this alkali is to decompose the alkaloid, cocain, developing new constituents which exert the desired physiologic action, is full of food for thought experiment."

The reader will find a continuation of the history of local and regional anesthesia in the chapters on cocain and other anesthetics that follow, beginning with Chapter IV.

CHAPTER II

NERVES AND THEIR SENSATIONS—ESPECIALLY PAIN

In the practical part of this discussion we are interested only in the afferent nerves, and of these particularly those that transmit painful impressions—the sensory nerves. However, the subject of pain and nerve sensations generally is of such tremendous interest to the physician as well as to the surgeon, as it is this one subjective symptom which brings us most of our patients, and which in its protean and manifold manifestations we are daily striving to relieve.

No other phenomena connected with the life-history of the human body has been so great a factor in the historic development of medicine as pain. It can readily be conceived that the first medical thought and first effort on the part of primitive man was directed to the relief of pain. And yet, though it is the most universal symptom of disease, it is the least understood, as there has been no adequate or entirely satisfactory explanation of its nature and mode of action. It would, therefore, not seem out of place, particularly in a discussion of this kind, to deal more liberally with the subject and attempt to advance some theory as to what is pain. We must admit that we know less about the nervous system than about any of the other great systems of the human body, and the function of many parts of the brain is as great a mystery to-day as it was to our medical forefathers. We know absolutely nothing about the metabolism of the nervous system, but certain anatomic and functional facts have been established upon which various theories have been built, and it is from this information that we will draw in the present discussion, considering first such anatomic and physiologic points that should be borne in mind.

To many, most of these facts are an old familiar story, and their repetition would scarcely be excusable, and may be regarded as a superfluous waste of time, were it not necessary to consider them for a proper conception of the theories to be later advanced.

The sensory nerves have their sensory organs at their peripheral termination. These are of several kinds—touch corpuscles, end bulbs, touch cells, and free nerve-endings—most of which are distributed to the peripheral tissues, cutaneous, mucous, etc. In addition to the above, there are the Pacinian corpuscles, distributed in the subcutaneous parts, usually lying in cellular tissue, at times deeply situated between muscle bundles; their function is not clearly understood, but they seem to be connected with the sensory apparatus, probably with the pressure sense.

In addition to these, we have the nerves of special sense, which are sensory nerves, only highly specialized in their function. Aside from nerves of special sense, the various qualities ascribed to these nerves are: (1) pain; (2) tactility, or common sensation; (3) locality; (4) pressure sense, and (5) temperature sense. While in all operations under local anesthesia we are concerned more especially at the time with the pain-conducting function of the nerve, we must not lose sight of the fact that most cutaneous nerves are trophic as well, and the deeper nerves contain, in addition, motor fibers. The operator, under local anesthesia, becomes especially a nerve anatomist, learning to search out, inject, and protect each individual nerve, and does not needlessly divide them, thus saving its sensory as well as its motor and trophic function.

We have said that sensory nerves have their sensory organs at their peripheral terminations, and we say that it is the brain that feels, but the brain is absolutely devoid of painful sensations; the exposed brain of a thoroughly conscious patient can be operated upon without any sensations whatever of pain; stimulation of various parts of the brain may give rise to other sensations, but never pain.

The nerves themselves have very little sensation, but refer any stimulation or irritation applied to them to their peripheral distribution.

What is pain? Is it a special sense of these afferent nerves, or is it an exaggeration of common sensation, a quantitative increase of sensibility? If pain were a special sense and traveled along definite nerve paths there ought, logically, to exist a pain center, for all special senses possess a special center, and the same may be said of the other cutaneous senses. All of our numerous experiments and many clinical observations have failed to locate such centers.

The destruction in animals of the gyrus fornicatus, or the hippocampal region, is said to be followed by more or less loss of common or tactile sensation, and the entire destruction of these regions on one side of the brain is followed by protracted hemianesthesia.

There is, however, no pathologic evidence to make the conclusions drawn from these experiments applicable to man, and the anatomic distribution of the sensory fibers, as their path turns outward from the internal capsule, seems to prove that it is not. It is, indeed, a wonderful thing that the most highly organized and complex structure within the human body should be entirely devoid of painful impressions.

Although we are most familiar with the sensibility of the skin, and believe that we perfectly understand the nature of the impressions upon it, and the mode of conveyance to the sensorium, yet there is a difficulty in comprehending the operation of all the organs of the senses—a difficulty not removed by the apparent simplicity of that of touch.

But, although the impression be thus traced to the extremity of the nerve, still we comprehend nothing of the nature of that impression or of the manner in which it is transmitted to the sensorium. To the most minute examination the nerves in all their course, and when they are expanded into the external organs of sense, seem the same in substance and in structure. The disturbance of the extremity of the nerve, the vibrations upon it, or the images painted upon its surface, cannot be transmitted to the brain according to any physical laws that we are acquainted with. Experiments prove what is suggested by anatomy, that not only the organs are appropriated to particular classes of sensation, but that the nerves intermediate between the brain and the outward organs are respectively capable of receiving no other sensations but such as are adapted to their particular organ. Any impression on the nerve of the eye, the ear, or on the nerve of smell or of taste, excite only ideas of vision, sound, or smell, etc. No education or amount of exercise will enable one nerve to replace the other. We cannot comprehend anything of the manner in which nerves are affected; certainly we know nothing of the manner in which sensation is propagated or the mind ultimately influenced.

The manner of determining the relative sensibility of different nerves by comparison or a study of the many different causes affecting sensibility is, at times, made extremely difficult, for the observer must depend entirely upon the statements of the individual experimented upon for his information; and in animals, as can be well understood, the difficulties and possibilities of error are greater.

The senses are not equally developed in all individuals, and are differently developed in man and animals, according to their different needs. We find every organ of sense, with the exception of that of touch, more highly developed in the brute than in man. In the eagle and the hawk, in the gazelle and the feline tribe, the perfection of the sense of sight is admirable; in the dog, wolf, hyena, and most animals and birds of prey the sense of smell is uncommonly acute.

The term "anesthesia" denotes the loss of tactility and in its broad acceptation of all other sensations as well; "analgesia" means the loss of the sense of pain alone; "thermo-anesthesia," the loss of temperature sense.

Some individuals are affected peculiarly by what should be painful stimuli, and do not complain of pain as the most trying symptom; thus, it is related that in the pre-anesthetic days a French surgeon was amputating a limb, and, noticing an expression of great distress upon the patient's face, said, "I fear that I am causing you great pain." The reply was, "No; the pain is nothing, but the noise of the saw sets my teeth on edge."

We find it equally difficult to give a satisfactory definition for pain. It may, however, be regarded as a peculiar discomfort or suffering caused by disturbances of the sensory nerves or nerve-cells, which induce a condition of overstimulation; thus, any of our sensations may become painful if the stimulus is sufficiently strong or prolonged. This will be illustrated later.

From a restricted philosophic point of view pain may be considered as a reaction of the organism, in part or in whole, to harmful influences. This latter is more in accord with the views of the biologists who see in the contractions and expansions occurring in minute protoplasmic life an expression, in a primordial way, of the senses of pleasure and pain, expanding in response to pleasurable, healthful influences, and contracting in reaction to painful or harmful stimuli. These reactions are considered the germ of the idea which, by many multiplications, complications, and added phenomena, have come to make the many-sided, complex figure of the human pleasure-pain sense.

There may be many kinds of pain, and no less real than those pains due to the injury of a sensory nerve. We may have pain in consciousness connected with the more complex processes, such as fear, anxiety, anger, or the pain of sorrow or a "broken heart," and other conditions.

If pain is to be regarded as a reaction, there must be at least two factors involved in its production: first, the susceptibility of the individual; and, second, the character or intensity of the stimuli or inducing agency.

Pain may be to many but an incident of little concern, they are either anesthetic or stoical, feeling very little or able to control their expressions of pain; others are hyperesthetic or exaggerational, either being extremely susceptible or they possess little or no control over their feelings. These differences are largely individual, although there exists certain factors in the race, age, social, and educational status of the individual which influence this susceptibility; thus, it is stated that the dark skinned races, Slavs and Teutons, are less susceptible to pain than other races, while the Latin and Semitic stock are most susceptible. Old age generally is less susceptible than youth or adolescence, due to the more sluggish condition of the nervous system, while infancy, due to the absence of the psychic influence and poor sense of locality, may bear certain pain well, but is easily shocked by severe trauma.

The social condition, refinement, and educational status and occupation have much to do with the susceptibility to painful impressions, as we would naturally suppose; thus, a highly refined individual, following an intellectual pursuit, would be expected, from his mode of life, breeding, and occupation, to have a more highly developed and sensitive nervous system than the laborer or farm hand, accustomed to exposure with the knocks and buffets of a hard life. The inability to bear pain on the part of certain high-strung individuals of nervous temperament must not be ascribed always to cowardice, for such persons often bear themselves with great fortitude and heroism when exposed to grave danger; this has often been noticed in military officers who have always shown great bravery on the battlefield, but who would complain bitterly when pain was inflicted during some minor attention.

In this last class of cases the psychic state of the individual plays a large part. Of this factor we shall have more to say later.

Any of our sensations may become painful if the stimulus is sufficiently strong or prolonged; the skin touched lightly affords normal tactile sensations, but if the pressure is severe, a general impression approaching that of pain is produced.

The same may be said of thermic sensations; while the power of the skin to recognize differences in temperature is very acute, the ability to judge the absolute degree of temperature is very slight. When the degree of temperature is raised or lowered beyond a certain point the thermic sense is no longer excited, but sensations of pain are produced. If we put our hand into freezing or very hot water, it is difficult to say at once whether it is hot or cold, in either case pain being the only sensation produced. The time for the arrival of temperature impressions at the brain is remarkably long when compared with the rate at which tactile impressions travel. That there must be special nerve-endings for the reception of thermic impressions would seem proved by the following facts: When heat or cold is applied to a nerve-trunk it does not give rise to these sensations; if a hot or cold object is moved slowly over the surface of the skin some parts feel no temerature change, some feel increased heat, and others only cold. These "hot" and "cold" perception areas are said to possess different kinds of nerve terminals. It would seem that these nerve-endings are different from those which receive tactile and pressure impressions, because the appreciation of differences of temperature is very delicately developed in certain areas where tactile sensation is not most acute. Thus, the cheeks and the eyelids are very sensitive to heat, while sensation is not most acute here; the middle of the chest is also very sensitive to heat, but very dull to tactile impressions.

That all the different sensations of the skin possess different nerve-endings or paths for their transmissions is again argued in the difference between the senses of locality and pressure, as the pressure sense is found to be not so keenly developed in parts where the sense of locality is most acute. This sense of pressure may be more accurately determined by the skin of the forearm than by that of the finger-tip, although the latter is nine times more sensitive to ordinary tactile impressions.

Any of these sensations, with the exception of that of locality, may become painful if increased beyond a certain point. The same may be said, in a modified way, of the exercise of the functions of special sense. Moderate light does not prove of discomfort to the normal eye, but if intense the pain may be severe. It, however, has been observed that in cases of total blindness due to atrophy of the optic nerve very intense light may produce pain. It is probably then not the optic nerve, or not it alone, which feels the pain of overstimulation, but the trigeminus. Sounds, such as music, cause pleasure when conveyed to the brain over the auditory nerve, but if it were possible that these pleasurable sounds could be magnified to a high degree they would undoubtedly become painful, but here, as in the case of the other noises which set up violent sound-waves, it is probable not the auditory nerve, or not it alone, as in the case of the eye, which feels the pain, as it is most likely due to mechanical injury to the tympanum and ossicles supplied by the fifth nerve. Certain tastes or odors, when of moderate intensity, are pleasant, but may become decidedly disagreeable, or provoke other unpleasant sensations when markedly increased. But here these special end-organs seem to have a chemical function, while the excitation of nerves generally is rather of a mechanical nature.

It will probably now not be out of place to consider certain other facts in connection with pain and sensations generally. Pain may be caused by mechanical, thermal, chemical, electric, or other means.

The duration and extent of a stimulation may determine in great measure the sensations produced, as illustrated by the contact of a hot surface for a short or long time, or by picking the skin lightly with one pin or with a number at the same time.

There are some facts which seem to point to the conclusion that pain has a functional independence, whatever may be said regarding its anatomic independence; that is, whether there are special nerve fibers which conduct pain, a point on which laboratory experiments are conflicting or in doubt. As an illustration, pain may be abolished without destroying or impairing any of the other sensibilities as is seen in analgesia, brought on by the administration of a general anesthetic, in which observations prove the fact that pain disappears first, then memory.

On the other hand, other sensations may be destroyed while pain remains. When a part of the body (an extremity) is rendered anemic, tactility disappears first, followed by pain, then the thermic sense.

Pain rarely ever remains constant in the same degree, but intermits, while the stimulus may remain constant. This intermittance may take the nature of a throb as in headache, jumps as in toothache, or as in bone-felons, in which the paroxysms become overpowering. These intermissions in some cases are no doubt synchronous with the pulse, or due to other reactions in the vascular system, bringing about distension or vascular contractions, Other influences also determine the onset of the paroxysms or increases of intensity as seen in neuralgias.

Certain other phenomena are a delay noticed in recording a painful impression following a blow. The shock from the blow is often felt an appreciable interval of time before the pain is felt; this may or may not be due to the shock having paralyzed, for a moment, the sensory nerve-endings or their power of transmission. But this would hardly seem the case in injuries of moderate severity which yet cause pain.

While we know that tactile impressions travel at the rate of 42 meters per second, and painful impressions only at the rate of 10 meters per second, still the delay is much greater than would be accounted for by this difference.

Again, the lasting quality of a painful impression is sometimes remarkable. Pains do not always pass away when the stimulation ceases, but may remain for some time as an after-image. This is probably due to the fact that the intense stimulation necessary for the production of pain produce a more decided and lasting character in the nervous changes than other sensations do. The demonstrated fact that there exists definite pain-points, cold-points, heat-points, and pressure-points in the skin would argue for the distinction and independence of each of these sensations.

The sensory apparatus, once excited, does not immediately subside into a non-active state, but the pulse or wave of molecular change which has been set up in the nerve centers remains for a longer or shorter time. To better understand this phenomenon, we can take for an illustration the optical delusion produced by a very rapidly revolving torch which appears as a circle of fire, because the impression created by the torch at any one point of the circle does not disappear before it has again reached the same point; or the same may be illustrated in the revolving spokes of a wheel.

A contrast noticed in the apparent absence of pain when the intensity of a painful stimulus is suddenly lessened, even though the lessened intensity would be painful under other conditions, is explained in the above way.

Practically, all physiologists agree that we cannot feel two entirely different sensations at the same time. One must be paramount and the other subordinate, or each impression will be diminished, so that their united influence would only equal what either would be alone. And the same is true of painful sensations: a man with both legs broken feels pain in but one at a time. The same thing takes place continually with reference to all of our sensations, whether of pleasure or pain; we are only conscious of what may be the paramount influence. This fact explains in a great measure the psychic control over pain. With the mind and attention occupied by some all-absorbing and engrossing subject, great enough to hold the attention, pain is not felt, as illustrated elsewhere in this discussion.

Another important consideration in the exercise of our sensations is the necessity for a change of stimuli. Any sensation, whether pleasurable or otherwise, if too long continued becomes weakened or exhausted. It is only by constant change, contrast, and comparison that we continue to exercise our many senses, but no two of them at the same time. We can illustrate this by pleasurable sensations, we will say at the theater, where the senses of sight and hearing are both exercised, but alternately, the change enhancing and increasing the pleasure derived from the exercise of the other. Music to the blind is not so pleasing as to the more fortunate who can see, and the deaf derive less pleasure from the sense of sight alone, although in either case it may be the only amusement or distraction which they have. Cold and heat are distinct sensations, and this is so far important that without such contrast we should not continue to enjoy the sense, for the variety of contrast is absolutely necessary to sensation. The hand placed in moderately hot water soon becomes accustomed to it, and we no longer feel the sensation, or less so, and the same with cold. The first shock is the greatest, and the hand alternately plunged from moderately hot into cold water feels the contrast more keenly as the sense is excited by the change. It is by a comparison of cold and heat that we enjoy either sensation. All senses are exhausted by exercise without change, but some are more lasting than others. We note the relish with which one enjoys cool air after a long and exhausting high temperature, or the comfort experienced by a warm fire during the midst of a cold winter.

If we take, for example, vision, and gaze fixedly at a single color or a single object, the sense is soon exhausted until we see nothing.

The psychic control over pain is very great indeed, probably much greater than even the medical mind fully appreciates on casual thought. This psychic control over pain, as well as over the other senses, is thoroughly in accord with the recognized physiologic law that we cannot be conscious of two sensations at the same time. With the mind intently fixed on the idea that pain is to be inflicted the suffering is always more acute, and vice versâ, with the mind intently fixed and absorbed by some object or aim in view the greatest mutilations are possible without complaint. This is seen in the case of religious devotees and fanatics, who often inflict the severest personal chastisement without apparent pain.

With the attention fixed on the idea that pain is to be inflicted, and all the senses keenly alive and active, awaiting the impression, the least touch or manipulation may excite the idea of pain and cause the patient to cry out. One feels the stick of a pin much more keenly when watching and waiting for it to pierce the flesh. On the other hand, the most severe injuries may often be inflicted when the attention is diverted or the mind intensely fixed upon other things, as can be illustrated by frequent incidents upon the battlefield, where arms have been shot away or other severe injuries inflicted without the individual being conscious of it until his attention is drawn to it. For instance, we are unconscious of noises when our mind and attention is firmly fixed upon other things, and with our mind so occupied we may even look at things without seeing them.

Numerous illustrations could be given of the psychic control over pain or its influence in producing shock. It is related that a French criminal was experimented upon, being led to believe that he was to be bled to death. He was accordingly blindfolded and prepared. His arm was severely pinched, when he was told that a vein had been opened. The surgeons who were making the experiment allowed a small stream of warm water to trickle over the arm, pretending that it was the escaping blood. One observer then took charge of the pulse, and, pretending to count it, reported from time to time that it was gradually growing weaker and the patient's strength failing. The psychic impression was too much for the man to resist. He accordingly grew weaker and weaker, being influenced by the suggestions of those about him, who very seriously announced every few minutes that he was gradually sinking. This was carried to the point of producing psychic inhibition of the heart, resulting in arrest of its action and death. Numerous other instances could be related, but one more will suffice to illustrate this extreme psychic influence sometimes exercised. A French soldier (Boutibonne) was in the thick of the fight at Wagram. Men were falling all around him, when he felt both his legs carried away by a cannon-ball. He sank down about 18 inches, and fell back benumbed by the shock. He was told by those around him that if he remained perfectly quiet it would lessen the hemorrhage; he accordingly lay absolutely quiet until the next morning, when the surgeons reached him and found that the cannon-ball had passed through the ground beneath his feet, which sank into the furrow, but that he had been entirely unhurt. (Related in "Sensation and Pain," Taylor, p. 55.)

The state of the mind has much to do with the activity of all our senses. By our own mental operations we can deceive ourselves by delusions of vivid reality, which at times can be controlled only by our reason. By a mental state of dread, fear, or hope continuously exercised we can excite in our senses sounds, visions, and other sensations. Shipwrecked sailors anxiously waiting and hoping for rescue, with their eyes strained across a waste of water, eagerly seeking a sail, often in their imagination see ships approaching, and these delusions occur long before the bodily forces are exhausted by hunger and thirst. Numerous similar accounts have been published by hunters and travelers lost upon the prairies or desert, and, knowing that searching parties would be sent out, have heard and seen in their anxiety the approach of galloping horsemen in vivid reality, only to have the sight and sounds fade away like a mirage on the exercise of reason. A similar experience is related by Taylor in "Sensation and Pain." In the early days of Illinois he was lost on a dark night upon the prairie, There was no danger, only the discomfort of remaining out all night. He wandered for several hours trying to find his way, but to no avail. He realized that his absence from home would make his friends anxious and he would be searched for, he accordingly was on the alert for the sound of horses' feet and a voice calling. He listened intently, and felt sure of the approach of a galloping horse. The sound gradually approached and grew more and more distinct, but finally faded away, only to be repeated time and again. In reasoning over the matter he concluded that his senses were deluding him; he then turned in the opposite direction, and, after listening intently, he heard the same sounds from that direction and from any direction from which he listened; he concluded that he was deceived by his own senses. He then laid down to sleep and next morning found his way home, and learned that no one had been searching for him. A scared child or nervous woman will hear and see a thief in the room at night when none is there.

Under similar conditions the senses of touch and pressure are equally and vividly deceptive, and the same may be said of all our senses. Hypnotism is simply a more extreme concentration of the attention.

Very practical use can be made of the fact that sensations of whatever kind are not only mental, but depend for force and quality on the actual present state of the mind. Conscious sensation, whether objective or subjective, is a mental act. A sensory impulse becomes a conscious sensation only by producing a display of energy in the cerebral nerve centers or brain of a certain or cognizable degree of force, and then only when the attention is not engaged with other relatively paramount sensations. "Attention, occupied with one sensation, excludes other sensations while thus occupied" (Taylor).

Having recognized this psychic influence over our sensations, we can readily understand why children and nervous individuals who are unable to exercise any self-control suffer such mental torture when about to undergo some trivial attention, and why such subjects, when taken into an operating-room, with its strange surroundings, white-capped and masked operators, to undergo some operation under local anesthesia, with all their senses keenly alert in dreadful anticipation of the impending procedure, magnify so greatly in their own minds their sensations that tactility is often interpreted as pain, the least touch causing them to jump and start with fright.

> "Cowards die many times before their deaths;
> The valiant never taste of death but once."

It is for this reason that the preliminary hypodermic of a small dose of morphin, alone or combined with scopolamin, by dulling their sensibilities and mental activities, producing a somnolent, tranquil, or inactive state of mind, thus protecting the patient against himself, has proved so useful a preliminary or adjunct in all local anesthetic procedures upon nervous or highly apprehensive individuals, thus rendering valuable aid in the anoci-association of fear.

DISTRIBUTION OF SENSATION

The skin is the great sensory organ of the body, and to it are distributed most of the sensory nerves, but the distribution of these nerves vary within certain limits. It is provided that the more a part is exposed, and in proportion to its delicacy of organization, the more exquisitely contrived and highly developed is the apparatus for its protection, and the more peremptory is the demand for the activity of that mechanism, as in the case of the eye protected by its lids, which acts involuntarily for protection and before the will could set them in motion; and the same with the hand, which is involuntarily withdrawn from the first touch of danger before the will can act. The more exposed a part, the more highly developed is its sensibility. The sensibility of the back and buttocks is dull when compared to that of the face or hands. Tickling the lip with a straw or feather becomes extremely unpleasant, while on the back it may not be felt.

Certain senses are limited almost exclusively to the skin, as tactility, locality, and thermic sense; although with the latter certain mucous surfaces feel both heat and cold, as experienced in the case of hot or cold drinks too rapidly swallowed, when the stomach distinctly feels the sensation, or in the case of ice-water enemas, given in cases of fever, the bowel feels the sense of cold.

Subcutaneous cellular tissue and fat have very little sensation. In the subcutaneous fat-tissue and other parts further removed from the surface are encountered the pacinian corpuscles, which are visible to the naked eye as little globular-like masses. They are connected with sensory nerves and transmit painful impressions; what other function they possess, if any, is not known.

Between the muscle bundles are numerous small nerves which are quite sensitive to pain, otherwise muscle-fiber is almost devoid of sensation.

The periosteum is quite sensitive, acutely so in the inflamed state. Bones receive nerve-fibers from the overlying periosteum, but when the periosteum has been anesthetized or has been denuded, the bone is then quite insensitive. Marrow is sensitive, but varies greatly in different individuals. It receives nerve-fibers from the same source as the bone, and when these have been anesthetized or destroyed the marrow is then insensitive. The same can be said of perichondrium and cartilage—the perichondrium is sensitive, but cartilage not so.

Tendon-sheaths are sensitive, but tendons and aponeurosis possess very little, if any, sensation. Synovial membranes are quite sensitive. The mucous membrane of all the passages communicating with the surface are quite sensitive, that covering the gums and hard palate much less so than that of the surrounding parts.

Some distance from the external openings these parts lose their sensation. The mucous membrane of the esophagus and trachea are insensitive; the esophagus, however, has a limited sensibility for heat.

Vessels (arteries and veins), except of the smallest size, are sensitive to pain, and this even in parts ordinarily devoid of sensation. Fat has no sensations, but the vessels which course through fatty tissue are quite sensitive.

In the omentum, which has no painful sensations, the large vessels are quite sensitive and should not be clamped, ligated, or cut without first blocking them. The vessels of the mesentery are also quite sensitive.

These latter facts, and the sensitiveness of the various cavities and their contents—cranial, thoracic, and abdominal—will be dealt with in dealing with these parts.

All organs have certain sensations and respond to certain impulses, nervous and otherwise, although normally we are not conscious of their actions. Thus, the heart, while insensible to touch, is yet alive to every variation in the circulation, subject to change from every alteration of posture or exertion, and is in sympathy of the strictest kind with the constitutional processes.

One of the most interesting theories of pain, and to us the most plausible, at least in the present state of knowledge, is the theory of quantitative increase of normal sensation. This beautiful theory was admirably presented by that great philosopher of medicine, Prof. C. Schleich, in his own inimitable, yet simple and effective style, in an address on anesthetics at the von Bergmann Memorial. The following quotations are extracts from this address:

"Is pain a sensation of physical discomfort conducted over nervous paths designed for this specific impression, or is this general sensation of a threatening character only an increase or abnormal excitation of the tactile sensation?

"Are these special nerves of pain implanted in the living organisms to receive disturbing impressions, or do all sensory nerves, that is, all ramifications of the cerebrospinal plexus, if abnormally stimulated, become conductors of exceptionally perceptible cerebral impressions? (2) Is pain only a quantitative increase of sensibility or is it a psychonervous function of a special kind?

"If we accept Darwin's theory of evolution, all living tissue must have been evolved by adaptation to the conditions of organic life. Thus certain nervous paths, originally only serving the simplest tactile and reflex functions, might have evolved themselves by adaptation and heredity into carriers of impressions of discomfort.

"This theory seems to me to be amply borne out by the observations, first reported by me and afterward confirmed by Lennander, Block, and Braun, that all nervous paths appertaining to the visceral system, including the sympathetic system, that intermediary brain, as it has been called, are primarily non-susceptible to painful impressions, only after the surgeon has worked for some time on the intestines, the walls of the stomach, or the uterus; the astonished ganglia and nerve branches, never before bothered by external interference, so to speak, recovering from their perplexity, become sensible of the abnormal lesion and conduct and thus produce the sensation of pain. Does not the accumulation of visceral pains after some laparotomies, with their sudden attacks of postoperative colic, speak plainly of the possibility of nervous pain, which, in the economy of nature, originally were designed for entirely different functions? Thus we see in operations, for instance, on the visceral peritoneum, the evolution of nerves in a primarily insensible region into conductors of pain, and the same process of evolution has taken place on the external surface of the body. The tactile nerves have, in the course of many thousands of years, learned to send, at the irruption of external forces, a quick, incisive warning to the soul, saying, 'there is something threatening and destructive.' Hence pain is a warner, an exhorter, calling for defense, for fight, for the employment of all measures of resistance and self-preservation. But how is it that in these central messages a contact, which is usually transmitted as tactile, heat or muscular sensation assume at once the character of a fiery streak, arousing the brain? How is it that such a peculiarly eccentric stormy wave rushes over the special paths usually transmitting only local impressions? This can only be explained by the assumption that the impression of pain necessitates a defect in the transmission, a disturbance in the current, and the isolation. Here comes my theory of the inhibitory and isolating function of the neurilemma and the neuroglia, which may be condensed in the sentence that pain is the effect of an electric short circuit of the sensory nerve paths. All nerves are embedded in an isolating sheath of connective tissue. The neurilemma plays the same rôle as the green silk thread covering the copper wire of our electric batteries. If the neurilemma is forcibly broken from the outside, or pathologically loosened or softened from the inside, there is a lateral short circuit comparable to a fiery spark into which all the radiating nerve currents are discharged, and this short circuit causes a general collective message of alarm to be registered in the brain, notifying it of a defect at the periphery, differing greatly from the usual impressions received over the same paths. This produces a general impression of discomfort at being unable to quickly localize the unusual general message, a sensation of confusion, with threats of destruction, which chaotically rushes through the different centers of perception, and it is this sensation which we conventionally call pain.

"Its cause is an organic or dynamic lesion of the lateral inhibition or isolation of the nerve branches. We must assume that the normal tissue fluids have an inhibitory isolating influence, favorable to the nerve currents, and that pathologic or artificial changes in the fluids surrounding and permeating the neurilemma may as readily cause lateral short circuits, as foreign bodies, crystals, or micro-organisms do which directly injure the isolations of the nerve branches. At this point my deductive views had reached a promising stage. If this theory of the function of connective tissue for the mutual isolation was true, then there must exist ways and means to increase or decrease this isolation at will by the infiltration of fluids. That was simpler than to investigate why, in some cases of edema of the skin, the pain on introducing a needle is less than usual and in others stronger. What was most obviously indicated was to determine the saline contents of such edematous effusions, which proved that the anesthesia of the swollen skin depended on an abnormally low amount of salt present, while the hyperesthesia was caused by unusually high percentages of sodium chlorid, and this observation was immediately confirmed by personal experiments. Welts in the writer's skin, produced with a .2 per cent. saline solution, were anesthetic, others from a 1 to 2 per cent. solution were painful, while physiologic solution produced no disturbances of sensation."

Equally interesting is the vibrating theory of nerve function, which presumes for all nerve tissue a certain degree of rapidity of vibration for functional activity, and is thoroughly compatible with the theory of a quantitative increase of stimuli necessary for the production of pain. This vibratory theory deals more with the transmission of pain than with its cause. There is much to prove this theory, both anatomically and physiologically. Many points in the structure of nerve-cells is decidedly suggestive that these cells, or their numerous processes, are in a state of active vibration at least during functional activity.

We know that all matter in the universe is in constant motion; nothing is ever at rest, organic or inorganic. Even the densest rocks are constantly undergoing a molecular readjustment. This rule applies also to all cells which go to make up animal life. Motion never ceases in any kind of matter; in animals after death the kind of motion may change, but no kind of matter is ever at rest. It is this unceasing motion which contributes to bring about the constant changes which are occurring in the world about us through the progress of time.

Nerve function or nerve force is very closely allied to electricity, with which all animal bodies are charged. Galvani first demonstrated the electric current in the sciatic nerve of the frog. Since then it has become an accepted fact that all animal tissue was capable of producing electric currents, and that electric and nerve currents obey the same general laws (Helmholtz, Humbolt, DuBois-Réymond).

Electricity is capable of exciting the function of nerves. Applied to a motor nerve, muscular contraction takes place; applied to the cheek, taste is excited; over the forehead, light is produced; and when applied to the ears, sound is heard.

Humphries, in quoting from Abrams, states: "Artificial electric stimulation of nerve-fibers corresponds most nearly to their natural excitation, and we, therefore, assume in our present state of knowledge that nerve force and electricity are identical."

If electricity is a form of motion, and moves along wires and nerve currents, obey the same general laws which govern electric currents, we are probably not far wrong in presuming that all nerve function is a special kind of motion which takes place in nerve tissue. We do not mean the constant molecular changes which are constantly taking place in all tissue and have to do with repair and growth, but a special vibratory motion, which takes place during functional activity and is stilled or lessened during rest.

If this be accepted and nerves (their atoms or ions) be in a constant state of vibration, an alteration or change in this vibration affecting the conductivity or resistance may make itself known to our consciousness by various sensations. We know that many of these sensations, which are known to our senses as sound, heat, or light, are various degrees of motion. Sound means a vibration of 36,000 per second; heat, 18,000,000 per second; while 462,000,000,000 vibrations per second produce light. Different colors are due to different rates of vibration. Violet is the highest degree of vibration which we can appreciate, 733,000,000,000 per second.

Any disturbance which may bring about a readjustment of the nerve elements, causing an altered conductivity or resistance, may produce abnormal sensations; any stimuli, able to increase these vibrations beyond the normal limit, producing pain, and when able to lessen or alter them other sensations occur, a diminution or complete stilling of the vibrations producing anesthesia; thus heat, which is motion when increased beyond a certain point, causes pain; and cold, which is the absence of motion, when lowered to a certain degree by diminishing or stilling motion, produces anesthesia. This vibratory theory explains why nervous or neurotic individuals, with highly active and impressionable nervous systems, stand pain so poorly, and why the phlegmatic, with sluggish and inactive nervous systems, stand it comparatively well.

Some observers, accepting this vibrating theory, have claimed that pressure, by bringing about an altered conductivity or resistance, producing an alteration in the nerve-cells or in the nerve currents, produced sensations of pain, and have claimed that all pain is pressure; thus, headache, toothache, burns, inflammations, malaria, etc., by irritating the cells, causes them to swell, and this increased pressure causes pain. Stasis is a form of pressure; this, however, is not always felt at the point of pressure, but may be referred.

This theory, as pointed out by Humphries, is thoroughly compatible with the action of many agents used to control pain or produce anesthesia; thus, general anesthetics paralyze the higher centers, narcotics numb them or lessen their activity, and local anesthetics paralyze the nerve-fibers or end-organs with which they come in contact. Many agents act in a mechanical way; thus, external heat or cold, a mustard poultice, massage, electricity, etc.—these may act by drawing the blood to the surface or stimulating the circulation, thus relieving the stasis or pressure at the effected point. This theory has many advocates, and is one of the most rational advanced.

The difference noted in the rapidity with which painful and tactile impressions travel, and spoken of elsewhere, is not at all incompatible with the theory, for pain being an abnormal sensation greater resistance may be offered to the transmission of the more violent and abnormal vibrations.

In connection with the theory that motion of nerve tissue is necessary for function, may it not be that in producing anesthesia by infiltration, particularly when using sterile water, that the swelling of the cells induced by their taking up water (and in this case giving off salts) may so interfere with their vibration as to prevent the transmission of painful impressions.

This analgesic effect of the absorption of hypotonic solutions does not necessarily contradict the above-mentioned views of some authors, for, as shown elsewhere, as originally proved by Schleich, it is only hypotonic solutions which possess this power; isotonic solutions when injected have no effect upon sensation and hypertonic actually cause pain.

PHILOSOPHY OF PAIN

Numerous writers and thinkers have devoted much time to the philosophy of pain, and much that is worthy of the time and attention of physicians has been written on this subject.

Plato and Aristotle have well said that neither pure pleasure nor unqualified displeasure exist in man. Both feelings are mixed in unequal proportions by the subtile art of Nature, and the definite impression on our consciousness is a resultant in which one or the other dominate. Pain is due to exhaustion, destruction, or rupture of sensitive tissue; an increase of expenditure, with insufficient reparation, produces fatigue and positive pain. All suffering is partial death which comes upon some organ or function.

"Pain is not to be reckoned as abnormal, but as Nature's protest against the abnormal. It is her finger sternly pointing the other way that she means us to go" (Crutcher).

The more consideration which we give to the subject, the more convincing becomes the proofs that the painful sensibility of the skin is a benevolent provision, making us conscious of those injuries which, but for this quality of the nervous system, would bruise and destroy the internal and vital parts which have little sensation. In the first place, we must consider that if a sensibility similar to that of the skin had been given to these internal parts, it would either have remained unexercised or have made us painfully conscious of our normal organic functions. Had they been made sensible to pricking, burning, etc., they would have possessed a quality which would never have been useful, since no such injuries could reach them, or only after ample warning had been given through the sensitive skin, and it would further inflict needless and unnecessary pain. The deeper parts have different kinds of sensations, but a limited degree of sensibility, for they may be injured without injury to the skin, as in fractures, etc.

"If we could imagine beings to have ever been created, by any sport of nature, whose pleasure was connected with injurious actions and their pains with useful ones, they must have died out speedily by virtue of the vice in their constitutions."

"All suffering is a partial death which comes upon some organ or function" (Fouillee).

To suppose that we could be moved by solicitations of pleasure, and have no experience of pain, would be to place us where injuries would meet us at every step and in every motion, and, whether felt or not, would be destructive to life. To suppose that we were to move and act without experiences of resistance and of pain is to suppose not only that man's nature be changed, but the whole of the exterior nature also. There must be nothing to bruise the body or hurt the eye, nothing noxious to be drawn in with the breath. In short, it is to imagine altogether another state of existence. Pain is the necessary contrast to pleasure; it ushers us into existence or consciousness; it alone is capable of exciting the organs into activity. It is the companion and guardian of human life.

In a broader conception of the statement we know of no instance of pain being bestowed as a source of suffering or punishment, purely, without finding it overbalanced by great and essential advantages, and without being forced to admit that no happier contrivance could be found for the protection of the body.

CHAPTER III

OSMOSIS AND DIFFUSION

In considering the subject of osmosis, so that the reader may reach a fair understanding of the action of fluids of different osmotic pressure when injected into the body tissues, and place the subject before him in a brief concise way, is no longer easy. At one time, following the discovery of osmosis by De Vries and his co-workers, the problem was thought solved, and was supposed to be limited to crystolloids or substances capable of solution, while colloids either did not diffuse at all or only with great difficulty; since then, as the result of the labors of many able investigators, the subject has been found to be not so simple; the perfection of delicate instruments and improved methods of observations have shown that the process, when applied to the movements of fluids within the human body, may at times be extremely complicated and influenced by many factors which escaped the observation of the earlier investigators, and is to-day crowded with problems difficult of solution, the discussion of which would take large volumes. It would probably suffice, for all practical purposes in a work of this kind, to make a few general statements which could be applied for all clinical purposes, but, for a more thorough understanding of the subject, we are compelled to go further and sum up a certain amount of experimental and clinical evidence which bears more or less directly upon the subject, which, if it serves no other purpose, will at least show some of the complicated problems which surround this process. In discussing this subject, if we will advance from the simple to the complex, and consider the process as it takes place outside of the body, we will ultimately arrive at a clearer understanding of some of the complicated processes taking place within the body.

If two solutions are brought together, containing different percentages of salts in solution, the process by which they mix is called diffusion.

If they are put in different containers, separated by a permeable animal membrane, they will also mix until the percentage of salts in both containers is equal; this process, discovered by De Vries, is called osmosis, and the force which brings it about osmotic pressure. The rapidity of this movement depends upon the permeability of the membrane and the difference in the concentration of the two solutions. During this process of interchange a continuous current takes place in both directions, drawing salt from the stronger to the weaker solution and water from the weaker to the stronger solution; this process continues until the percentage of salt is equal in both solutions, osmotic equilibrium is then established, and the resultant solutions are isotonic with each other.

If the content of one is increased over the other it is hypertonic or hyperosmotic, and the one containing the lesser percentage of salt is hypotonic or hyposmotic.

The above is the process in its simplest form outside the body, but this process at once becomes more complicated when the solutions contain different salts, where the molecular weight and diffusibility vary, and is further influenced by the presence in one or the other solution of a colloid to which the membrane is impermeable, but which exercises its influence upon the interchange and the resulting tonicity of the two fluids.

This is well put by Starling, in his book on "The Fluids of the Body," from which we quote the following:

"Thus, in the case of two solutions, A and B, separated by such a membrane, if the osmotic pressure or molecular concentration of B be higher than A, the force tending to move water from A to B will be equal to this osmotic difference.

"There is, at the same time, set up a diffusion of the dissolved substances from B to A and from A to B.

"The result of this diffusion must be that there is no longer a sudden drop of osmotic pressure from B to A, and the result of the primary osmotic difference on the movement of water will be minimized in proportion to the freedom of diffusion which takes place through the membrane. Now let us take a case in which A and B represent equimolecular and isomotic solutions of A and B. It is evident that the movement of water into A will vary as $Ap - Bp = O$.

"But diffusion also occurs of A into B and of B into A.

"Now the amount of substance diffusing from a solution is proportional to the concentration, and, therefore, to its osmotic pressure, as well as to its diffusion coefficient.

"Hence, the amount of A diffusing into B will vary as Ap, Ak, when K is the diffusion coefficient. In the same way the amount of B diffusing into A will vary as Bp, BK.

"Hence, if Ak is greater than BK—*i. e.*, if A is more diffusible than B—the initial result must be that a greater number of molecules of A will pass into B than B into A.

"Hence, the solutions on the two sides of the membrane will be no longer equimolecular, but to the total number of molecules of A + B in B will be greater than the number of molecules of A + B in A, and this difference will be most marked in the layers of fluid nearest the membrane.

"The result, therefore, of the unequal diffusion of the two substances is to upset the previous equality of osmotic pressures. The layer of fluid on the B side of the membrane will have an osmotic pressure greater than the layer of fluid in immediate contact with the A side of the membrane, and there will thus be a movement of water from A to B.

"Hence, if we have two equimolecular and isomotic solutions of different substances, separated by a membrane permeable to the dissolved substances, there will be an initial movement of fluid toward the side of the less diffusible substance.

"Supposing the two vessels, A and B, to be separated by a membrane which offers free passage to water and a difficult passage to salts. Let A contain 5 per cent. salt solution and B a solution isotonic with a 1 per cent. NaCl, but containing only 65 per cent. of this salt, the rest of its osmotic tension being due to other dissolved substances. If the membrane were absolutely semipermeable, water would pass from A to B until the two fluids were isotonic; *i. e.*, until A contained 1 per cent. NaCl (to simplify the argument we may regard volume B as infinitely greater).

"If, however, the membrane permitted passage of salt the course of events might be as follows: At first water would pass out of A, and salt would diffuse in until the percentage of NaCl in A was equal to that in B. There would not be an equal partial pressure of NaCl on the two sides of the membrane, but the total osmotic pressure of B would still be higher than A. Water would, therefore, still continue to pass from A to B more rapidly than the other ingredients of B could pass into A.

"As soon, however, as more water passed only from A, the percentage of NaCl in A would rise above that in B. The extent to which this occurs will depend on the permeability of the membrane. When the NaCl in A reaches a certain concentration it will pass over to B, and this will go on until equilibrium is established between A and B. Extending this argument to the conditions obtaining in the living body, we may conclude that neither the raising of percentage of a salt in a fluid above that of the same salt in the plasma, nor the passage of a salt from a hypotonic fluid into the blood-plasma, can afford in itself any proof of an active intervention of cells in the process.

"We have already seen that the effective osmotic pressure of a substance—*i. e.*, its power of attracting water across a membrane—varies inversely as its diffusibility, or as the permeability of the membrane to it. What will be the effect, supposing that on one side of the membrane we place some substance in solution to which the membrane is impermeable? We will suppose that A and B contain 1 per cent. NaCl, but that B contains in addition some substance x, to which the membrane is impermeable.

"Since the osmotic pressure of B is higher by the partial pressure of x than that of A, fluid will pass from A to B by osmosis. But the consequence of this passage of water will be to concentrate the NaCl in A, so that the partial pressure of this salt in A is greater than in B. NaCl will, therefore, diffuse from A to B, with the result that the former difference of total osmotic pressure will be re-established. Hence, there will be a continual passage of both water and salt from A to B until B has absorbed the whole of A.

"This result will be only delayed if the osmotic pressure of A is at first higher than B, in consequence of a greater concentration of NaCl in A. There may be at first a flow of fluid from B to A, but as soon as the NaCl concentration on the two sides has become the same by diffusion, the power of x to attract water from the other side will make itself felt, and this attraction will be proportional to the osmotic pressure of x."

Osmotic processes taking place in organic life, animal and vegetable, become extremely complicated, and play an important part in regulating the tissue fluids of both animal and vegetable life. The life of the cell depends upon a continuous flow of the fluids which furnish the nutrient materials, consisting, for the most part, of water, salts, and albumen, which are present in certain proportions.

In plant life we do not have a complicated vascular system to deal with, such as exists in animals, which adds further problems to complicate the process; it was accordingly in plant life, with its simpler physiology, that the problem was first understood and is still being studied by those interested in this branch of investigation.

The human body is made up largely by protiens, fats, and carbohydrates, all of complex molecular composition; the laws of osmosis, when applied to such organisms, is highly complicated, and is not yet thoroughly worked out; the colloidal proteins undoubtedly appropriate the major part of this phenomenon, but the colloidal fats, or lipoids and the carbohydrates, play their part in so far as they have an affinity for water.

We can best obtain a conception of some of these processes by considering the action of certain well-known colloids toward water outside of the body. Fisher, in his book on edema, cites the action of the two well-known animal colloids, gelatin and fibrin, toward water; in the presence of water both swell to enormous proportions, absorbing large quantities of water; we may add to these the action of the vegetable colloid starch, which acts in a similar way. The behavior of gelatin and fibrin is influenced largely by the reaction of the solution in which they are placed, taking up water more rapidly and in larger quantities when of slightly alkalin or acid reaction, but more so with acids than when in plain water; however, the rates of increase does not always correspond to the increase of alkalinity or acidity.

Many colloids may at times exist in crystalline condition, such as egg-albumen and hemoglobin; there also exists many grades between these two states when a substance may have a tendency in one or the other direction. Fibrin, a typical colloid, is readily exuded into the tissue spaces and as readily absorbed, apparently regardless of the laws of osmosis. These colloids do not form true solutions, but heterogeneous solutions, and show little or no tendency to osmosis, yet many of them readily pass in and out of the tissues; such of the colloids as gelatin and fibrin, which absorb large quantities of water, are said to be hydrophilic.

These, and other facts to be mentioned, rather show that osmosis is not the only factor at play in the movement of the body-fluids, although it may play a large part, but still leaves many phenomena which can now only be explained as the vital functions of cell life, excretion or absorption as their function may be, and not that cells are simply inert bodies which absorb or give off water to a surrounding medium regardless of other conditions, simply as this happens to have an osmotic pressure higher or lower than that existing within the cell, as certain chemical affinities may exist which exercise a strong influence in one or the other direction. Thus Fischer, in writing on this subject in regard to the rôle played by acids and alkalis, states the following:

"Two groups of substances have always stood out prominently as exceptions to the laws of osmotic pressure, as considered active in protoplasm, acids, and alkalis. The various tissue elements which have been examined in dilute solutions of these substances—red and white blood-corpuscles, muscle, kidney, and liver-cells—all show an absorption of water which is vastly greater than can be accounted for on the basis of any idea of osmotic pressure. In fact, the amount that muscle can swell in dilute acids has been employed by Overton as a powerful argument against the ordinary osmotic conception of absorption in general. He has shown very clearly that were all the proteins, carbohydrates, and fats contained in muscle split up into their simplest products, a sufficient yield of molecules and ions would not be obtained to furnish an osmotic pressure adequate to account for the water absorbed. We have no trouble in accounting for this behavior of the acids and alkalis on the basis of our colloidal conception. The acids and alkalis are the substance most capable of altering the affinity of the hydrophilic colloids for water.

"The observations of Hamburger, that the volume of red blood-corpuscles and the diameter of white blood-corpuscles increases progressively with every increase in the concentration of the acid or the alkali in the solutions surrounding them, finds a ready explanation in the facts outlined regarding the swelling of fibrin and gelatin."

The action of animal tissue, particularly muscle, has been studied in a similar way.

Loeb showed that muscle tissue does not change in weight if suspended in watery solutions having the same osmotic pressure as the blood, but that it gains or loses weight if placed in solutions of higher or lower osmotic pressure.

This varies with the kind of salts forming the solutions, being greater with potassium chlorid than if with NaCl and least of all with calcium chlorid.

"A muscle swells more in the solution of any acid than it does in pure water, but the amount of the swelling is greater in some acids than in others."

"An important relationship exists between the concentration of the acid employed and the amount that the muscle will swell."

"After a time a point is reached beyond which a further increase is followed by a diminished absorption of water."

"We have also no difficulty in accounting for the unequal swelling of cells in ostomotically equivalent solutions. We have found the same to be true of the swelling of fibrin and gelatin. We have been able to go even farther: we have found that the same group of substances which have proved exceptions in the osmotic studies on cells also show a like exceptional behavior when we deal with fibrin."

"To find an analogue for the failure of muscle, red blood-corpuscles, and cells in general to shrink the calculated amount with every unit increase in the concentration of the added salt is also simple. We need only refer once more to the experiments on the swelling of fibrin and of gelatin, in which we found that here, too, doubling the concentration does not halve the volume; the amount of decrease is always less than anticipated."

"It is somewhat difficult to say what is the effect of alkalis on the absorption of water by muscle. The statement is unquestionably true that muscles swell more in the solution of any alkali than water."

This depended upon the condition of muscle (the acid content). "When such muscles are placed in alkaline solutions the alkali combine with the acid and the salt formed by the union inhibits the swelling."

Many conditions may influence the process. "It may at first show a decided decrease, and later on equally decided increase, or the reverse may be the case."

"The addition of any salt to the solution of an acid decreases the amount that a muscle will swell in that solution, and the higher the concentration of the salt the greater is the amount of this inhibition," but different salts act unequally in this respect. Cases illustrating the spread of anesthetic solutions by diffusion through the tissues, where osmosis must play a small part, is seen in the wide distribution of anesthesia following massive infiltrations, when the anesthesia spreads quite a distance beyond the site of injection; also in hypodermoclysis the fluid is seen to diffuse over a wide area; similarly in Bier's vein-anesthesia, the solution filters through the vein wall under pressure and diffuses through the entire thickness of the limb; such extensive permeation would hardly be expected from osmosis alone. We must also not lose sight of the fact that in the human body we are dealing with a circulatory apparatus, and that the pressure in the vessels is always greater than in the cellular interspaces, and that the bulk of the absorption is done by the capillaries (lymphatics playing but a small part). While it is not impossible for salts in a solution under less pressure to find their way by osmosis into a solution under greater pressure, it is nevertheless likely that in such vital phenomena as absorption that osmosis must play a negligible or minor rôle, the same as seen in the absorption of fluids from the intestinal tract.

Theoretically, according to the laws of osmosis, a hypertonic solution should be absorbed more slowly than a hypotonic one, as the fluid must first be rendered isomotic before absorption can take place.

The hypertonic solution must first abstract enough water from the surrounding tissues, while largely retaining its salts, until it becomes isotonic when absorption can take place, while a hypotonic solution begins at once to give up its water. According to the above, on theoretic grounds at least, the salts contained in a hypertonic solution should be retained *in situ* longer, and in the case of anesthetic solutions produce a longer anesthesia. In considering this question, however, we must not lose sight of the fact that osmosis is a purely chemicophysical process which takes place through a membrane, and cannot be unqualifiedly applied to living tissue, which exercises certain physiologic functions and may absorb, regardless of the laws of osmosis, in much the same way as fluids are absorbed from the alimentary canal; but that osmosis does play a certain part we must concede, and that we can favor this process by bringing about conditions which will act favorably. Thus, it has been shown that dilute acids and alkalis favor this process, more particularly acids; alkalis, the weaker of the two in this respect, will not be considered, and should be carefully avoided in all anesthetic solutions, as their presence produces a decomposition of nearly all the anesthetic salts used.

On the other hand, acids are favorable to the stability of the anesthetic salts, which are acid derivations; the presence of small quantities of NaCl and adrenalin solution used in most anesthetic solutions, both of which have slight acid reactions, are sufficient for our purpose, and enhance decidedly the absorption of the injected solution by the tissues; as the presence of more than a minute trace of acid is hemolytic in its action upon the blood-corpuscles further additions are prevented.

Considering osmotic processes governing fluids injected into the tissues, we must also bear in mind that these laws govern fluid under equal tension, and when the tension of one or the other is increased the fluid under greater tension is forced into the other by filtration. Consequently, when we infiltrate the tissues with anesthetic solutions under pressure regardless of its being hypotonic, isotonic, or hypertonic, the injected solution, in consequence of this pressure, diffuses in all directions, regardless of the laws of osmosis, and it is only when lightly injected, in small quantities or in loose tissues, that osmosis plays any decided part in the diffusion and absorption which takes place; while hypertonic solutions may be absorbed with less rapidity than isotonic or hypotonic ones, we are not concerned so much with the value of the solutions from this standpoint as we are in selecting solutions which have no injurious action upon the tissues, for, since the introduction of adrenalin, we are able to control to a great extent the rapidity of absorption from the site of injection into the general circulation by the use of this agent.

The effect of adrenalin in influencing the osmosis and absorption of fluids injected into the tissues must also be considered; where the circulation is decidedly lessened or almost entirely arrested (except in very vascular parts) by the use of this agent, osmosis has a better opportunity to exercise its influence than in the presence of an active circulation. Nose and throat specialists, who use concentrated solutions with a large content of adrenalin, are able to closely observe its effect. Many such operators claim less constitutional effect from the same amount of the anesthetic agent, in concentrated form, than would be the case in using a larger quantity of a weaker solution; most nose and throat specialists still prefer to use cocain, which also exerts a vasoconstrictor effect. Solutions of high density are not readily absorbed by the blood-vessels, and by the time they are sufficiently diluted to be absorbed the circulation has been largely arrested by the adrenalin plus the vasoconstriction effect of cocain, if that agent is used. When injected into practically ischemic tissues, or tissues quickly rendered ischemic, the concentrated anesthetic osmoses into the surrounding cells and is largely fixed by them, and is only washed out by the returning circulation, which is delayed or held in check by small quantities of the drug as it is being absorbed. In this way many of them explain the facility which they use such strong solutions.

The following well-recognized laws of physiology explain the local retention in the parts of strong cocain-adrenalin solutions and the prolonged anesthesia and ischemia following its use:

(1) A fluid passes through a membrane with a rapidity inversely proportional to the destiny of the fluid.

(2) The rate of absorption varies directly with the fulness and tension of the blood-vessels and lymphatics.

(3) The slower the movement of the blood and lymph-streams the slower will be the rate of the absorption of the fluids.

In tissues rendered ischemic from the use of an Esmarch bandage, or by gravity with a constrictor, injected solutions have a better opportunity to enter the tissue-cells and exert the maximum effect, though a limited amount of circulation may be favorable to a distribution of the injected solution, and the same effect can be obtained by massage.

As the object of this discussion is to develop a thorough understanding of the best way and means to produce an anesthesia of surgical intensity and of sufficient duration and extent to serve every purpose, we have seen that osmosis can play but a limited part; the body-fluids are in motion within the vessels, and the anesthetic is constantly being carried away. As will be shown the action of any anesthetic is increased by a sojourn in the tissues, and arrest or absolute stilling of the circulation, as obtained by the constriction of adrenalin, favors this effect. Our object, then, is to develop an anesthetic solution which will possess as many of the desirable qualities as possible, and at the same time prove non-injurious to the tissues. A NaCl solution, containing 0.97 per cent., is isosmotic for human blood-serum, a physiologic salt solution, and has a freezing-point at .56° C., although red and white corpuscles are affected different by changes in the strength of solution as well as by the kind of salts used, yet these changes are, for the most part, slight, and for all practical purposes where NaCl is the salt used, as in the accepted anesthetic solutions of to-day, the above should serve as a basis for calculation.

The simplest method of determining the osmotic tonicity of a solution as compared to another is to determine their freezing-points; this, however, does not always decide whether or not a solution is best for our purposes, for many solutions may, as far as their osmotic tension is concerned, be perfectly isotonic with blood-serum, yet their contained salts exert a hemolytic influence upon the blood-corpuscles, as will be shown in discussing the different agents used, and as pointed out by Barker in the case of stovain, which is discussed in greater length in the chapter on Spinal Analgesia.

If a physiologic salt solution, 0.97 per cent. NaCl, is slowly injected at body temperature into the loose connective tissue of the body in moderate quantity, neither swelling or shrinkage of the cells is produced, and no after-irritation results, consequently no pain is felt. If instead simple distilled water be injected, pain is produced, due to an abstraction by the water of the salts contained within the surrounding cells, while the cells absorb water causing them to swell, thus macerating their contents, which may result in the death of the cell; after the initial pain of the injection has subsided a certain degree of anesthesia is obtained, the "anesthesia dolorosa" of Liebreich. If concentrations of NaCl greater than 0.97 per cent. are used, the solution abstracts water from the cells and causes them to shrink, giving rise to more or less pronounced pain. These manifestations are proportionally the more intense the greater the concentration of the solution, until tissue disturbances may result which may terminate in gangrene.

The relative freezing-points of a large number of solutions compared with blood-serum has been worked out by Prof. Braun. We quote the following from his recent work, as well as copy the table (Fig. 1) which he has prepared:

"On the horizontal line we find a list of the saline solutions from 0 per cent. (plain water) to 10 per cent.; of some of these solutions the freezing-points are given. The black curve represents sensory stimulation, which is felt as pain when the solutions are injected into the cuticle; the dotted curve shows the sensory paralysis (anesthesia)

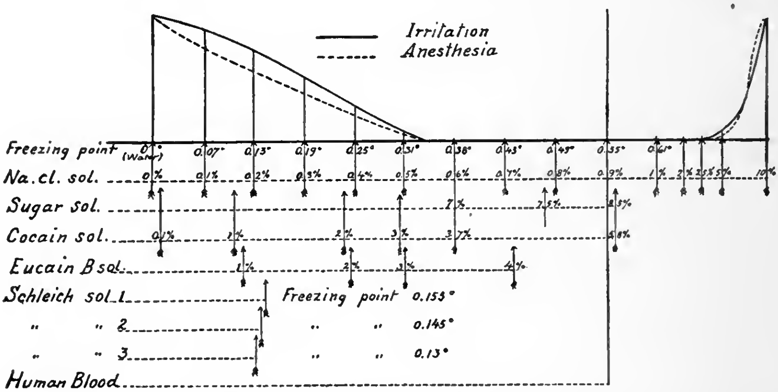


Fig. 1.—Diagrammatic representation illustrating the irritating and anesthetic action of various hypo- and hypertonic solutions on the tissues compared with human blood (after Braun).

which follows this stimulus; the distance between the two curves at any one point corresponds with the relative intensity of the stimulus and the paralysis. The central point is occupied by the saline solution of 0.9 per cent. with a freezing-point of —55° C. This solution has, therefore, about the same osmotic tension as human blood; all solutions on the left causing a swelling of the tissues, while those on the right extract water from them."

If the 0.9 per cent. saline solution is injected into the cuticle at body temperature no pain is felt, no stimulation is induced, nor can any change of sensibility be observed in the region of the welt, especially no sensory diminution. The welt thus produced disappears very soon without leaving any trace. If we now gradually decrease the strength of the solution, pain appears on injection, usually around 0.55 per cent. On further dilution this pain quickly increases in intensity and reaches its maximum when pure water is used.

"This latter injection is extremely painful; this pain which we call welt pain is only of short duration, and is followed by a diminution and then cessation of sensation in the injected area. The intensity and duration of this phenomenon gradually increases and lasts longest (about fifteen minutes) with pure water. We call it 'welt anesthesia.' Very dilute solutions cause an injury to the tissues, that shows itself in a painful infiltration at the site of injection. Pure water causes, in a number of cases, superficial necrosis of the tissues, 'infiltration necrosis.'

"With solutions containing more than 0.9 per cent. sodium chlorid the symptoms caused by their affinity for water can be observed. These symptoms also consist in stimulation, paralysis, and tissue injury.

"But the stimulation manifests itself in a different way than in the 'welt pain'; it follows the injection, which in itself is painless and lasts for several minutes, the site of the injection being strongly hyperesthetic; this is followed by anesthesia. The welt at the same time shows very peculiar and typical changes of form; when the burning pain commences to diminish and the anesthesia begins the center of the welt rapidly sinks down and forms a depression, while the margin forms a circular raised wall. The anemic margin and the anemic center are generally separated by a narrow red ring; after about fifteen minutes the welt again grows uniformly flat and its periphery becomes larger; finally, it disappears and sensation returns. These concentrated saline solutions damage the tissues. All these symptoms grow more intense with the increasing strength of the solution. With 2.5 per cent. they are already noticeable, and injection of saline solutions of more than 10 per cent. can scarcely be tolerated. A small degree of infiltration and taking up of water cannot be observed; hence, there exists around the 0.9 per cent. saline solution an indifferent zone, comprising a number of solutions (from 0.55 to 2.5 per cent.), which do not cause the above-mentioned symptoms.

"But it must be remembered that the curves showing the pain and sensory reduction do not represent absolute values. They were the result of experiments on the skin of our own forearms. If saline solutions are injected in hyperesthetic tissues, or in very sensitive persons, solutions of less strength will cause the above-mentioned symptoms. The curves will here reach the horizontal line nearer its center than in our experiments, and the apparently indifferent zone will be narrower" (Braun).

But little work has been done on the osmotic pressure exercised by the various local anesthetic agents and their hemolytic effect upon the blood. As the hemolytic action of any agent is of prime importance, the following conclusions, drawn by Bünte and Moral, which deals particularly with novocain, the anesthetic salt now attracting the most favorable attention, are deserving of consideration:

"(1) The enveloping membrane of blood-corpuscles is perfectly permeable for novocain, tropococain, etc.

"(2) Novocain solutions, etc., should never exercise an osmotic influence on blood-corpuscles.

"(3) Novocain solutions, to be isotonic for blood-corpuscles, should be dissolved in a solution containing 0.29 per cent. NaCl.

"(4) Novocain exercises a slight hemolytic action, which, in the presence of a 0.29 per cent. NaCl solution and when the novocain is not too concentrated, disappears completely.

"(5) Solutions of novocain in 0.625 per cent. NaCl solution do not cause hemolysis, but produce a swelling of the blood-corpuscles; after prolonged standing the corpuscles show distinct signs of beginning hemolysis.

"(6) If the content of a novocain-saline solution is 0.6 per cent., NaCl or less hemolysis does occur.

"(7) The values of lowering the freezing-point found in the Beckmann apparatus on a novocain-saline solution cannot without any further work be applied to the calculations of the osmotic pressure of blood-corpuscles.

"(8) No alkali, or even salts with alkaline reaction, can be added to the novocain-saline solution, since a precipitation of the novocain would occur.

"(9) The 2 per cent. novocain solution can, without diminishing its action, be reduced to 1.5 per cent. with children and feeble individuals, even so far as 0.5 per cent.

"(10) Solutions containing non-indifferent substances are unfit for injection; as such are to be considered alcohol-ether injections (after Eckstein), since they coagulate the blood-corpuscles.

"(11) The 1.5 and 0.5 per cent. novocain-saline-thymol solution, the end-result of our examinations, have come up to all expected requirements, theoretic as well as practical.

"Its osmotic pressure is equal to that of the tissues, they have no hemolytic action on the blood-corpuscles and produce no injury to the tissues."

After a consideration of the foregoing, the selection of a menstruum for anesthetic agents becomes a matter of considerable importance. The use of distilled water, as practised by some, while under some conditions producing fair surgical analgesia, is hardly to be recommended for any extensive operative undertaking, as, on physiologic grounds, it may be followed by sufficient injury to the tissues to lead to necrosis. For similar reasons the 0.2 per cent. solutions of NaCl, as recommended by Schleich, has not been followed by us, although producing good anesthesia, and, we must admit, yielding good results clinically in the healing of wounds. In the light of physiologic investigations the osmotic tension is too low; it is probable that less injury would result and less after-pain occur from the use of a solution containing slightly more NaCl. It is for that reason that we have adopted solutions containing 0.4 per cent. NaCl, which, however, according to physiologic observations, is still low enough to produce decided hemolysis, yet we have never observed any unpleasant action from its use in several hundred cases, but believe that there is a slight advantage in its favor, in that there was less after-pain and soreness complained of following its use, particularly in large operations, than when using solutions of lower concentration.

Schleich claims for his solutions that the anesthesia is largely due to their hypotonicity, upon which they largely depend for their action, the content of anesthetic salts serving principally to lessen the pain of infiltration. While their anesthetic influence is unquestionably enhanced by their hypotonicity, their anesthetic content, though weak, is still sufficient, when the tissues are thoroughly saturated, to exert a decided anesthetic influence, as can be proved by using the same strength of cocain and other salts dissolved in normal salt solution. While clinically we have no fault to find with Schleich's solutions after an extended use covering many years, yet, in the light of our present knowledge, on physiologic grounds we feel that a nearer approach to an isotonic solution with human blood would have its advantage and throw less traumatic burden upon the tissues in the operative field; we have accordingly, for this reason, preferred to use 0.4 per cent. salt solutions.

Braun, in his solutions, uses 0.8 per cent. sodium chlorid for ordinary purposes of infiltration, but when stronger solutions are used for special purposes he reduces the content of the NaCl proportionately.

CHAPTER IV

THE ANESTHETIC EFFECTS OF PRESSURE-ANEMIA—COLD AND WATER ANESTHESIA

PRESSURE

PROLONGED pressure upon a nerve paralyzes its function, either motor, sensory, or both. This is seen in many illustrations in daily life, such as when the leg "goes to sleep" after crossing it, becoming numb and difficult of motion for a few minutes. In sleeping with the arms above the head, by pressure of the clavicle upon the brachial plexus, one may awaken with a feeling as if the arms were dead, when it may require some effort to lower them when the feeling soon passes off.

This pressure, if persisted in for a sufficient length of time, and particularly if combined with anemia of the part, may produce such a degree of paralysis that the parts are practically analgesic, when it is possible to perform peripheral operations with little or no pain. However, pressure, persisted in to this extreme degree, becomes highly dangerous, and may be followed by serious consequences as a result of traumatic neuritis of the nerve-trunks, leading in extreme cases to possible atrophic changes; this is seen usually in mild form in crutch paralysis, or in paralysis of the upper extremity following anesthesia, when, during complete muscular relaxation, the arms are held above the head, causing the clavicle to compress the brachial plexus.

These consequences sometimes follow the injudicious use of the Esmarch constrictor, but here it is more especially the circulation which is interrupted, though occasionally damage may result from pressure upon the nerves.

These procedures, resorted to in earlier days, were the best that the surgeons then had at their command, as they knew nothing about exsanguination; the constrictor was placed upon the limb with its full content of blood within the parts, and was used more to prevent hemorrhage than to obtund nerve sensibility, though some made use of it for this purpose, but in either case the patient was generally narcotized with alcoholics and drugs in use at the time.

It is highly probable that prehistoric man made use of these physical means, as well as the application of cold (ice or snow) to lessen sensibility, as these practices are in use to-day among uncivilized races, where it is handed down by tradition from one generation to another. The carotid arteries were called by some of the ancients the arteries of sleep, as prolonged pressure upon them produced sleep, and this practice has been reported to have been in use in fairly recent times.

It must, however, be borne in mind that, while the resulting peripheral paralysis (motor and sensory) becomes more pronounced the longer the pressure is continued, the discomfort at the point of constriction is also progressively increasing the longer it is maintained, until it becomes decidedly painful, and may become unbearably so before any very decided impression is made upon the peripheral sensibility.

The ability of the patient to stand an effective amount of pressure will of course be determined to a large extent upon the care with which the constrictor is applied; the same amount of pressure, if applied to a narrow area by applying the successive rolls of the constrictor one on top the other, becomes much more painful than when the successive rolls, are applied progressively to a higher or lower level of the limb, thus embracing a wider area. This care in having the parts well padded before applying the constrictor has much to do with the ability of the patient to comfortably stand the needed pressure. While we now never use constriction or pressure for the purposes discussed here, these facts must be borne in mind in applying a constrictor to a limb for the purposes of ischemia when operating under local anesthesia, when it is very unpleasant to stop during the progress of an operation to loosen an uncomfortably tight constrictor. The stoutness of the patient is also a factor which must be considered in applying a constrictor; the required amount of pressure must necessarily be much greater over a stout limb than over a thin or emaciated one, and should be graduated accordingly.

The use of constriction for holding local anesthetic solutions *in situ* will be spoken of elsewhere.

The well-known benumbing effect of long-continued pressure upon any part of the body is well known; although some pain may be produced in the surrounding parts, it is possible to carry it to a point of depressing both tactile and painful impressions to a considerable degree; this is brought about in two ways, first the compression directly paralyzes the nerve-endings of the part, and, secondly, the anemia intensifies this effect.

COLD

It is highly probable that the first use of cold for its sedative effect must have occurred in the remote past. Primitive man, with his meager supply of aids and necessities, most likely made use of all physical means at his command.

Military history contains many references to the sedative and analgesic effect of cold. Larrey, Napoleon's chief surgeon, reports that at the battle of Eylau, with a temperature of —19° F., that peripheral wounds caused very little suffering, and that amputations were practically painless when the limbs were first freely exposed to the air.

The first record we have of its use in modern surgery was by Arnott in 1848, who employed bags or bladders filled with ice and salt for their depressing or sedative effect upon the sensibility of the part.

The usual means by which cold is employed for its local anesthetic effect in modern surgery is by the use of various gases or liquids of low boiling-point, which are usually projected in the form of a spray upon the skin, their rapid evaporation producing an intense cold which freezes the parts.

Sulphuric ether was the first agent used in this way. The first atomizer or spraying apparatus was devised by Richardson in 1866, and furnished the idea for all such instruments in use to-day. It was found that a perfectly pure, water-free ether was necessary, such as that used for anesthesia; it should have a specific gravity of .720, and boil at 34.5° C.

It was later found that many other substances other than sulphuric ether could be used for the same purpose, and the lower the boiling-point the more intense was the cold generated by their evaporation.

These agents belong principally to the ethyl or methyl groups. Ethyl chlorid (C_2H_5Cl), known under various trade names as kelene or antidolorin, and also called hydrochloric ether, is used for both general and local anesthesia; it is a colorless gas, liquified in tubes, and has a boiling-point at 12.5 °C.; was first introduced by Rottenstein, and has proved the most satisfactory and useful of all these agents.

In the methyl group there are several local anesthetics; methyl iodid (CH_3I) is a colorless or brownish liquid, which exerts decided local anesthetic powers, but is rarely used on account of its irritant action.

Methyl oxid is a gaseous or liquid substance which is strongly refrigerant. Methyl chlorid (CH_3Cl), the most useful of this group is a powerful agent; under high pressure it is a colorless fluid, with a boiling-point of —23° C., and has to be kept in strong metal containers. The rapid evaporation of this liquid is said to produce a temperature of —55° C., while ethyl chlorid produced —35° C. Such powerful agents as methyl chlorid have to be used with great caution, as the intense cold generated may injure the tissues and cause necrosis; to avoid this danger it has been recommended to saturate tampons with the solution and place them upon the part to be frozen; this lessens the intense cold produced by retarding evaporation; in this way freezing is said to occur in a few minutes, but even with this precaution damage may result to the tissues.

To moderate the powerful effect of methyl chlorid various combinations with ethyl chlorid and other substances have been suggested; thus methylil, which is a proprietary mixture, is a combination of methyl and ethyl chlorid with chloroform.

The rapidity and intensity of the local freezing action of any of these agents, aside from their power to abstract heat, depends upon the vascularity of the part, and the duration of its action is influenced by the same factors; in highly vascular tissues this action is less marked and of shorter duration than when the opposite conditions exist, and in parts where the circulation can be controlled a much more intense action is obtained, which is also of much longer duration, and this action is further increased if the part is first rendered ischemic, but when used under these conditions great care is necessary to avoid permanent injury to the parts resulting from coagulation of the blood in the superficial vessels terminating in localized gangrene.

The local freezing action of all of these sprays first causes an extreme degree of vasoconstriction, which is followed by a vasodilation more or less marked, depending upon the intensity and duration of the freezing process; this may persist as a red hyperemic spot at the site of application for some time. According to Boeri and Silvestro, the sense of pain is affected first and most intensely, tactility next, while the pressure sense is affected least. The reaction of the tissues from this freezing process is not always without pain, which at times may be considerable and is of an aching, burning character.

When it is desired to obtain the most intense action of the cold, in addition to the exsanguination of the part above suggested, it is well to remove all fat from the skin by either ether or benzine; but, on the other hand, it may be desirable to protect the parts, particularly such tender tissues as the face, scrotum, etc., from a too violent action of the agent, by first smearing them lightly with vaselin, or, as Prosoroff has suggested, by the interposition of thin metal plates; something of this kind should be used particularly about the eyelids. These agents are not suited for use about the anus, and when used about the anal region these parts should be first protected by tampons before applying the spray to the surrounding parts.

In using an ether spray care is necessary about an open fire or near a cautery, but the same danger does not exist with ethyl chlorid, which is not inflammable. However, none of these agents are quite satisfactory when it is intended to use a cautery upon the parts, although, if they are deeply frozen, a superficial cauterization may be accomplished, but with such evanescent anesthesia as is obtained with these agents the after-burning will be considerable; it is, therefore, better when cauterization is intended to use other means of anesthesia.

These freezing sprays are best suited to superficial minor operations, which at most do not involve more than an incision, and may have particular indications where it is not advisable to infiltrate an inflamed or infected area with local anesthesia. Their especial claim for usefulness is in the time that is saved. They will accordingly be found most useful in opening boils or superficially situated abscesses, and the removal of foreign bodies, such as splinters, etc., from beneath the skin. When skillfully used as a continuous spray they are also efficient in removing ingrowing toe-nails.

Certain venturesome operators have even attempted major operations by their use alone; thus, Dolbeau has resected a scapula practically without pain by a continuous spray, freezing as he advanced, but it is highly probable that such prolonged freezing would be followed by serious after-consequences, and the same could probably have been done simpler and easier by other measures.

Spencer Wells attempted an ovariotomy and succeeded in getting through the abdominal walls without pain, but had to abandon the attempt and resort to general anesthesia to complete the operation.

Richardson and Greenhalgh were more successful with a Cesarian section, which they completed with this means alone and almost without pain. Such procedures as these are not of practical clinical value, and are not to be recommended; they are principally of value in showing what can be done under extreme conditions by skillful operators with these agents.

To obtain the maximum effect from any of these sprays it is necessary to hold the tube just far enough from the skin so that evaporation is at its height by the time the spray strikes the skin; if held too far away much effect is lost, and if too close the liquid will run down on other parts or evaporation be delayed.

Regional anesthesia, by freezing the tissues over superficial situated nerves, such as the ulna at the condyle of the humerus, has been tried, but there are hardly any indications or emergencies which would arise to make this method preferred over the safer, surer, and more surgical use of other measures.

Ethyl chlorid and other sprays are particularly useful in dentistry; for this purpose certain mechanical arrangements have been devised with a two-pronged spray, so shaped as to spray both sides of the gum at the same time. Kühnen was the first to invent and use such an apparatus. Their particular claim for merit in dentistry is that in inflamed conditions of the gums less injury is done by a freezing process than would be the case with infiltration, which, under such conditions, may be followed by suppuration.

Many other means and agents have been used to obtain a local anesthetic effect through the agency of cold. Dr. Mellish has called attention to the fact that alcohol at —10° F. produces complete analgesia, but does not abolish tactility.

Carbon dioxid snow may also be used for its freezing effect, but is not so easily handled, as it has to be placed in lumps or balls upon the parts to be acted upon; it is principally used in this way for other therapeutic purposes; when so used, its action can be greatly intensified by dropping ether upon it. The injection of cold solutions into the tissues to obtain a direct action of the cold in this way has been tried, but such practices, to say the least, are unsurgical, are highly painful, and produce, if any, but a very ephemeral effect from the cold, and may be followed by serious consequences.

Cold intensifies the action of all local anesthetics, and is often used as an adjunct to local methods of anesthesia and will be spoken of in this connection elsewhere.

WATER ANESTHESIA

Pure water was first used for its analgesic action by Potain, who introduced it in 1869. The term aquapuncture was applied to these injections, and they were used extensively in the treatment of neuralgia. Mathieu (1869) and Siredey (1872) also describe this procedure.

This injection was used only for its therapeutic effect, and it has not been recorded whether any analgesia of the overlying skin had been observed to follow its use or not; however, its action was the same as that made use of to-day for surgical purposes. The first use of the hypodermic infiltration of the tissues for surgical analgesia has been credited to foreign surgeons, particularly Germans; this, however, as far as the literature can be depended upon, is probably an error.

W. S. Halsted, in a letter published in the New York Medical Journal, September 19, 1885, makes the following statement regarding water anesthesia:

"(1) The skin can be completely anesthetized to any extent by cutaneous injections of water.

"(2) I have at times of late used water instead of cocain in minor operations requiring skin incisions.

"(3) The anesthesia seldom oversteps the boundary of the original bloodless wheal, but does not always vanish just as soon as hyperemia supervenes."

This use of it is again referred to by Prof. Halsted in a personal communication to Dr. Dawbarn in 1885 ("Water as a Local Anesthetic, Its Discovery American and not German," Med. Rec., 1891, Dawbarn). It was not, however, until some years later that this method was brought forward by our German confrères, and it is to them, notably Liebreich, in his "Anesthesia Dolorosa," followed shortly by Schleich, that the credit is due for the thorough application and study of the method.

Prof. Bartholow, in his "Materia Medica," as early as 1885, p. 690, states the following:

"It is a remarkable circumstance that aquapuncture has the power to relieve pain in a superficial nerve. So decided is this effect that there are physicians who hold that the curative effect of the hypodermic injection of morphin is due not to morphin, but to the water."

Since its introduction it has been tried and accepted by nearly all surgeons using local anesthesia to any extent that a satisfactory operative analgesia can be secured by the injection of sterile water alone into the tissues. Just how this analgesia is produced is not clearly understood, but it is probably due to the imbibition of the water by the cells of the tissues causing them to swell and thus interfere or prevent the transmission of painful impressions. (See chapters on Osmosis and Diffusion and Infiltration.)

This method can be most effectively demonstrated in loose and relaxed tissues where infiltration can be readily carried out, and is less satisfactory when the tissues are compact or dense. The term "anesthesia dolorosa" is most appropriate to this method, as anesthesia is only secured at the expense of a certain amount of pain or discomfort of a burning character; this however, is influenced largely by certain conditions; it is more marked in dense tissues, when the injection is rapidly made and when the temperature of the injected water varies from that of the body; the pain, however, is not severe and is of short duration, and is followed by an analgesia of about ten to fifteen minutes' duration. In the hands of skillful operators, when the injected water is about body temperature and slowly and gently infiltrated with a sharp needle, little or no discomfort is complained of. To obtain the full analgesic effect, it is necessary to infiltrate the tissues to the point of producing a glassy edema, the skin or mucous membrane must be infiltrated intradermally and the infiltration carried down the full depth of the proposed incision; when this is done analgesia is usually as profound as after infiltration with the weaker anesthetic solution, but tactility is little or not at all affected; the after-pain or discomfort is about the same as that following the use of other anesthetic solutions, although Gant claims that the after-pain is less severe and less prolonged than that following other local methods. The injurious action upon the tissues should, by reasoning along purely physical grounds, be greater than when using other anesthetic solutions, which are more nearly isotonic, as the injection of sterile water causes the surrounding cells to take up large quantities as well as giving up a large part of their salts, which certainly should produce profound physical changes in the cells, and it would be expected that certain reactions or even inflammation would follow the physical readjustment of the tissues. Gant, who is a great advocate of water anesthesia in this country, and employs the method extensively for operations about the anorectal region, denies any after-inflammatory reaction.

In the experience of the writer, the experimental use of plain water upon himself, as well as a limited operative experience with the method, has failed to notice any after-pain or other unpleasant reaction following its use in a very limited way. In opening a furuncle upon my own face water anesthesia was used for the purpose of studying its action; the water was injected at about body temperature, and, when slowly injected, caused only a slight burning sensation, but when the injection was made too rapidly, this burning sensation was increased, and might, if used on a sensitive person, cause some complaint. There was absolute analgesia during the incision and no after-inflammatory action was observed.

Notwithstanding its demonstrated utility as a practical means of obtaining a surgical analgesia its use for any but minor surgical procedures is hardly to be recommended on physiologic grounds, as it is known that the use of such hypotonic solutions as distilled water causes the cells to absorb large quantities macerating their protoplasm and may be followed by necrosis.

Experimentally, it has been found that the injection of distilled water into dogs, at the ratio of 10 drams to the pound of body weight, is followed in a short time by the death of the animals.

Dr. Dawbarn, of New York, after witnessing Prof. Halsted, in 1885, perform minor operations with pure water infiltration, conceived the idea that the analgesia was due to a purely mechanical separation of the tissue-cells, and that any agent which could accomplish this purpose would yield like results. He accordingly undertook a series of experiments upon himself, injecting sterile air into the tissues instead of water; although he persisted to the point of producing a very decided degree of emphysema, there was no diminution in the sensibility of the part.

CHAPTER V

LOCAL ANESTHETICS

THE history of the use of local means of analgesia precedes that of the use of general analgesics or narcotics. Many of the older agents or methods have long since been forgotten; some few, such as cold, in its more improved use, fill an important place in our therapeutics of to-day.

Most agents used for this local anesthetic action, except purely physical means, such as pressure and cold, exert this influence through their toxic or paralyzing effects upon the tissues and their nerve-endings. All such agents when absorbed in sufficient quantities produce the same constitutional effects, though often associated with other symptoms which may predominate.

So great was the effort to find safe and practicable means of producing local anesthesia that any agent reported to possess these properties was at once put to clinical tests, and many found a field of usefulness, though limited.

The accepted local anesthetics of to-day, of which cocain is the type, exert this influence through their paralyzing actions upon all protoplasm, and this action is central as well as local. The constant effort to improve our methods and produce an agent having less central toxic action while retaining its local effect has lead to vast improvements, novocain representing the highest attainment in this direction at the present time, having largely displaced many of the older agents. How long novocain will hold this place remains to be answered by future discoveries.

The following is a brief review of some of the many agents used before and since the discovery of cocain for which a more or less degree of local analgesia or anesthesia had been claimed.

Carbolic Acid.—The anesthetic action of topical applications of pure carbolic acid has been long known, but the escharotic action following its use has limited its employment to the most superficial of applications on external and exposed parts; its solutions when injected into the tissues are painful, and, while producing anesthesia, are likely to be followed by tissue necrosis. It has been variously employed in combination with other agents, as with cocain in "cocain phenate," at one time put upon the market by Merck, and was supposed to be a distinct chemical combination, but it was later determined to be only a mixture, and to consist of 3 parts of cocain to 1 part of carbolic acid. It is now but rarely used.

Various combinations of carbolic acid and oil were also suggested with or without the addition of cocain. While the anesthesia produced by these combinations was at times intense, the objectionable feature was the tendency of carbolic acid to cause tissue necrosis, which brought these mixtures into disfavor. They are, consequently, at present rarely used except by a certain class of practitioners, who make use of the anesthetic and escharotic properties of the combination for the injection of hemorrhoids and such accessible growths as they wish to destroy by these measures, a rather unsurgical and often dangerous procedure.

Chloroform has been credited with a certain degree of local sedative action following its injection within the tissues. Eulenburg, in 1867, recommended it for this purpose. Its anesthetic action is very slight and is preceded by considerable burning pain.

Methoxycaffein is a white amorphous or crystalline powder, used as a local anesthetic and antineuralgic. It has been recommended for hypodermic use in doses of about 4 gr., given in the neighborhood of the nerve in neuralgic conditions.

Alcohol.—More recently (1903) alcohol had been brought forward by Schlosser as a highly valuable agent for destroying the sensibility of purely sensory nerves when used as an intraneural or paraneural injection. Its action is due to the resulting inflammation and fibrous changes which it induces in the tissues, blocking or destroying the nerve at this point. It was intended originally for use in neuralgias, especially in the trigeminus, and more recently for use as a paraneural injection to the superior laryngeal as a means of relieving pain in tuberculosis and cancer of the larynx. Particularly in the trigeminus is its action of considerable duration, often preventing the return of pain for periods of six to eighteen months, when, as regeneration slowly recurs, the pain usually returns, provided the original causative conditions still persist.

Reclus at one time, following the suggestion of Billon, used 20 parts of 90 per cent. alcohol in his local anesthetic mixtures (stovain was the agent used); this was done with the view of prolonging and intensifying the action of the stovain. (See latter part of this chapter.)

Dr. Mellish recorded the observation that a finger immersed in alcohol at —10° F. produced analgesia, but did not destroy tactility; here we are probably dealing entirely with the effects of cold. This use of alcohol, particularly by Reclus in solutions intended for infiltration, prompted the author to undertake some experiments upon himself, with a veiw of determining its action upon some superficial part where observations could be constantly made. It was intended, should the knowledge gained be likely to prove useful, to make a more extensive series of tests, but in view of the results only 10, 20, and 50 per cent. strengths were used in various ways.

Ten per cent. solutions in distilled water, when injected intradermally, caused a sharp burning pain for about half a minute, skin turning slightly pale, later becoming hyperemic. Sensibility slightly dulled over area, but would not permit a painless incision—normal sensibility returned in about two hours, but area remained slightly hyperemic for several days.

Twenty per cent. solutions in distilled water gave nearly similar, though slightly more pronounced, results. As this was the strength used in his anesthetic solutions by Reclus, it was accordingly combined with local anesthetics; infiltration of this mixture caused, when injected, a burning pain, nearly as intense as when used in distilled water alone, but of shorter duration (only a few seconds); this gave place to anesthesia; the anesthesia, however, seemed no more intense or prolonged than when the same solution was used without alcohol, and was followed by hyperemia of about two days' duration.

Normal salt solution was then used as a diluting agent, but did not seem to influence the reaction to any noticeable degree; both were painful and produced hyperemia.

Alcohol, 50 per cent.; distilled water, 50 per cent. (20 minims), 10.50 P. M. Injection intradermal caused a very short burning pain, lasting about one minute, produced a wheal about the size of a 5-cent piece, surrounded by an injected area about as large as a dollar; center of wheal at point of needle stick is perfectly white and slightly depressed, and surrounded by a bright red circle. If wheal is not disturbed by manipulation no sensation is experienced, but when manipulated with the fingers causes a slight return of burning sensation of short duration. It continues to react in this manner for eighteen minutes.

Depressed white area became immediately anesthetic, but remainder of the wheal only slightly less sensitive than the surrounding healthy tissue.

In thirty minutes the entire wheal, except the white center, has regained normal sensibility; the center looks as if the skin has been completely destroyed. After eight hours wheal has entirely disappeared, though tissues at that point are slightly thickened. The central white spot is still absolutely dead to feeling, but is no longer depressed below surrounding skin and the red circle has disappeared. After twelve hours slight return of red zone around central white area. Repeated observations during next ten days showed a gradual enlargement of red zone, which became quite inflamed and about $\frac{1}{2}$ inch in diameter. Central white area shows signs of gradually sloughing out. Observations discontinued after ten days, with the conclusion that its anesthetic action depends entirely upon its destructive influence upon the tissues, and may in the use of strong solutions be followed by necrosis.

That this does not occur in deep facial injections is probably due to the high vascularity and nutrition of the parts.

J. L. Corning has used alcohol and chloroform subcutaneously in studying their anesthetic effect, and found that they produced considerable pain, but no anesthesia.

"These observations tend to dissipate the expectations of Nunnely, of Leeds, who declared that by exposure to the vapor of chloroform he had been able to cause sufficient insensibility in a finger to render the performance of a surgical operation painless."

Morphin.—A solution of 4 per cent., which has the same freezing-point as the blood-serum when injected into the tissues, produces severe burning, then hyperesthesia, followed by analgesia. As the solution is diluted it rapidly loses its analgesic effect. A solution of 0.1 per cent. produces a well-marked wheal, which itches and burns like the bite of an insect, but not analgesia. This local irritating influence is felt with solution as weak as 1:100,000 parts of water.

Bromids of sodium and potassium, when in solutions injected within the tissues, are said to produce a certain degree of analgesia, but are preceded by an intense degree of irritation.

Chloral has also been credited with similar action.

Brucin in 5 per cent. solution produces a limited degree of local anesthesia.

Antipyrin is an agent which possesses mild but sufficiently well-marked anesthetic, antiseptic, and hemostatic properties to have claimed for it a decided field of usefulness in the past before the introduction of better and more active agents, and occasionally is still employed.

Cycloform is isobutyl paramidobenzoic acid and possesses some local anesthetic properties.

Many agents like thymol, menthol, guaiacol, ichthyol, monotal, spirosal, etc., exhibit local sedative or analgesic action when topically applied, and are useful over inflamed and painful parts, but are not of especial interest to us here.

Similar sedative or varying degrees of anesthetic action have been claimed for many other drugs, such as the digitalis group—digitalin, strophanthin, convallarin, helleborin, adonidin, and others too numerous to mention and of no practical value.

There are many combinations of anesthetic agents which have been upon the market under various trade names; thus, andolin contains beta-eucain, stovain, and adrenalin; eusemin, a mixture of cocain and adrenalin; and codrenin, a mixture of cocain, chloretone, and adrenalin, and many others.

Electric anesthesia is also a medical possibility, both for general anesthesia as well as for local use, where the general consciousness is not disturbed; it may promise much for the future.

Since the advent of cocain many local anesthetics have been introduced for which various claims have been made; some have fulfilled these claims, others have not; some, by virtue of their merits in general surgery or some special field, will probably always be retained in our armamentarium and find a more or less limited use according to their special indications, while many, after having been put through the test of practical clinical application and found wanting, will be dropped and likely soon forgotten.

In spite of the many new agents introduced, and the many advances made in synthetic chemistry, cocain still remains the standard and most universally employed anesthetic, although it should now be entirely superseded by novocain for all general surgical purposes.

In judging the comparative merit of any new claimant for surgical favor in the field of local or regional anesthesia, we must ask ourselves at least three questions:

(1) What are the requirements that we must demand of the ideal local analgesic or anesthetic, utilizing these requirements as the basis or standard of comparison?

(2) What are the claims made for the new anesthetic?

(3) To what extent does experience confirm these claims?

To answer the first question we would require of the ideal local anesthetic:

(1) That it should be efficient in producing a durable, diffusible,

and maximum analgesic effect with a minim of local tissue disturbance.

(2) That it be non-toxic to the organism when absorbed in the doses required to obtain the fullest local effect.

(3) That it must be benign in its local action on the tissues, non-irritating, non-toxic; it should not permanently injure the cellular protoplasm or interfere with the normal repair of the traumatized tissues.

(4) It should be absolutely sterilizable by heat.

(5) It should be soluble.

(6) It should be thoroughly compatible with adrenalin.

(7) It should be commercially accessible and available at a reasonable cost.

After considering the above, and reading the description of the following anesthetics and the critical and comparative review at the end of this chapter, it is found that novocain is the only agent which comes nearest filling all these requirements; and anesthesin, if put to equally rigorous tests for purely topical applications, will be found equally satisfactory in this particular field of usefulness.

PHYSIOLOGIC ACTION OF LOCAL ANESTHETICS

In discussing the physiologic action of the local anesthetics—cocain and its congenors—we will describe in full only cocain, for what applies to cocain is equally applicable to almost the entire group; any differences that exist are slight and vary in degree not in kind.

In discussing the various agents where these differences are of consequence attention will be called to them.

The earliest record I can find of the use of any coca preparations for their anesthetic effects is a letter published in the New York Med. Jour., October 24, 1885, by Dr. W. O. Moore, of New York, who states that for the past ten years Dr. Fauvel (address not given) had been using the fluidextract of coca applied to the pharynx and larynx by a brush or a spray as a local anesthetic of these parts.

Few agents have sprung so rapidly into such general use, and in so short a time after their introduction been so universally tried in all departments of medicine. Being a practically new departure in therapeutics, medical and surgical, it was taken up by specialists in all lines, and was the first step in the introduction of agents which were to fill a long-felt want. The literature of the first year or two following its introduction is teeming with articles on its use, covering a wide range of subjects.

As early as the last half of 1885 the New York Medical Journal contained twenty-eight separate articles and several editorials on its uses; articles in other journals were equally as numerous. It was, as would be expected, already claiming its mortality from injudicious use and the cocain habit was even then reported.

Some of the interesting papers, even at this early time, taken from the above-mentioned list, are "Cocain Anesthesia in Supracondyloid Osteoma and Excision of the Hip-joint" (by Roberts); "Cocain as A Remedy in Seasickness; As an Anesthetic in Fractures and Dislocations; In Hay Fever, Opium Addiction, Sore Nipples, Vaginismus, Whooping-cough; As A Means of Isolation of the Temperature Sense in the Oropharyngeal and Nasal Cavity." In the treatment of facial neuralgia, gynecology, labor, nervous affections, and in the eye and ears, as well as numerous cases of minor surgery, it would be difficult to-day to conceive of a more extended use of the drug; we have improved the technic and manner of its use, but certainly have not extended the field.

COCAIN

Cocain (methyl benzoylecgonin), $C_5Hi_7(CH_3)NCH(OCOCH_5)$-$(CH_2COOCH_3)$.

The alkaloid and hydrochlorate are the only two preparations official in the United States and British Pharmacopeias; the oleate and ointment are mixtures.

Many salts of cocain have at times been put upon the market by the manufacturers in the hope of producing a better preparation than the hydrochlorate, but none have so far fulfilled these claims except for special purposes. Most of these preparations are true salts, some are double salts, and a few are found to be only mixtures.

Cocain aluminum citrate and cocain aluminum sulphate are astringent preparations, and are intended for topical applications; the borate has antiseptic properties, and has been particularly advocated as an eye-wash; its hypodermic use is at times irritating.

Cocain cantharidate has been recommended for hypodermic use in certain forms of nasal catarrh and for tubercular conditions of the upper air-passages and larynx; its use causes a mild inflammation which, through the increased blood-supply to the parts, had been hoped to favor curative processes in these lesions; it is not often used; the carbolate, as mentioned elsewhere, is a mixture; the lactate has been recommended as a sedative application and injection in cystitis; the nitrate has a particular field of usefulness in gonorrheal inflammations and for combination with some of the many silver salts used in this infection; the phosphate is a useful preparation, but is not very soluble and has little to recommend it; cocain saccharate has been suggested for topical applications and for use in throat and mouth operations; the salicylate was at one time advocated for use in asthma; it is now rarely used, its continued employment may lead to a habit; the stearate is a mixture used for topical applications, for suppositories and ointments, but is now rarely used.

The alkaloid was first isolated by Gardeka in 1855, who named it erythroxylin, but renamed slightly later by Niemann, who made a much fuller investigation concerning its action. It began to be used in medicine as early as 1880 in a very limited way, although its dilating effect upon the pupil had long been known. It was not, however, until 1884, when brought forward by Koller, that its true value began to be known, and it came very shortly into general use. This immediate increased demand for the drug far exceeded the limited facilities for its manufacture, and had the effect of markedly increasing the price, which is reported to have risen as high as $3 per grain; as the manufacturing facilities developed this price rapidly fell in a few years to one cent per grain, and has since been further decreased by improvements in the method of manufacture as well as a steadiness of the supply. During the early days of its use the methods of manufacture and purification were very imperfect, and led to its admixture with many impurities, giving rise often to serious accidents when used about the eye and to a misinterpretation of its normal action. The synthetic preparation of the drug has been another means of reducing the cost of manufacture, as well as having led to the discovery of many valuable synergistic drugs which have proved highly valuable.

Tests.—The following tests have been offered as a means of determining its purity:

Maclagan's: Dissolve 1 grain of cocain hydrochlorate in 2 ounces of distilled water, to which add 1 or 2 drops of ammonia solution; after stirring for a few minutes, if free from amorphous cocain, cocain hydrate will separate from the solution in crystalline form and settle at the bottom, leaving the supernatant solution clear and free from opalescence, any cloudiness indicating the presence of amorphous cocain.

Gartier's: Mix 1 drop of a 2 per cent. solution of permanganate of potassium with a solution of cocain hydrochlorate (2 cgm. to 0.5 gm.). The resulting fluid must assume a red color and remain transparent.

To this solution add drop by drop more of the permanganate solution, when there should appear a red precipitate of permanganate of cocain; this should become brown only after heating and without giving off an odor of bitter almonds. If the addition of 1 drop of the permanganate solution produces a brown color or brown precipitate, or when on heating the mixture there is produced an odor of bitter almonds, the preparation is impure and unfit for use.

Physiologic Action.—Cocain exercises a universal action on all living protoplasm, first stimulating and then paralyzing it; this action applies to plant as well as animal protoplasm.

Locally applied cocain acts as a very decided anesthetic, as first brought out by Moreno Y. Maiz, in 1862, and later by Von Anrep, in 1880.

The soluble salts of cocain are absorbed with great rapidity; they pass with the greatest facility through nearly all mucous membranes, and are taken up with an almost equal rapidity from denuded surfaces, but are not absorbed from the intact skin. The above fact explains the large number of cases of serious poisoning which have resulted from its use on mucous surfaces.

Extensive researches, undertaken to study the action of cocain upon the vital manifestations of various kinds of cells of animal life, was made by P. Albertoni. According to the concentration of the solution and the duration of its action, it either stimulates or paralyzes all cells in their functional activities. A 0.25 per cent. solution applied to the palate of a frog stimulates markedly the activity of the ciliated epithelium, so that particles of colored dust are moved along at four times their normal rate, while 2 per cent. solutions so paralyzes this action that it amounts to one-fourth or one-sixth the normal rate of movements. Similar experiments were conducted upon other kind of cells or low animal life, such as grubs, spermatozoids, and the large blood-cells of some animals, as well as the white blood-cells of man, all showed a similar action, being stimulated by weak solutions when acting for a short time, later being paralyzed. Muscle-fiber, when similarly treated, fails to respond either to nerve or electric stimulation. A peculiar action of cocain upon the livers of mice was brought out by the studies of Ehrlich, who fed mice food containing a small quantity of cocain, which killed them after a few days; examination showed their livers increased in volume and looking much like stuffed goose livers. Microscopic examination showed a vacuolar degeneration of the cells with small fragments of protoplasm about the nucleus; the blood-vessels showed fatty degeneration;

the connective tissue was undergoing fatty degeneration with points of coagulation necrosis. No glycogen was found in the entire livers. Its action upon the nerve-tissues cannot, therefore, be strictly regarded as of a specific kind, as it exercises this same action upon protoplasm generally, although its action upon nerve-tissue may be of a more marked degree, as manifested upon the end-organs of sensory nerves or upon the conductivity of their trunks when injected intraneurally, which constitutes one of the most marked and striking properties of cocain, and enables it to claim the high position which it holds as a therapeutic agent.

The well-known vasoconstrictor action of cocain, when brought in contact with the vessel walls by direct application or injection into the tissues, can only be explained by a direct action upon the smooth muscle-fibers within the vessel walls. This action is also seen, but to a less degree, when the drug is given constitutionally, when it is seen to raise the blood-pressure, but in large doses this influence upon the vessels is overshadowed by the greater powers of the drug. In the early days of its use the anesthetic action of the drug was erroneously attributed to the ischemia that its injection caused, as it was known then that ischemic tissues were less sensitive than when in a normal state. It may be possible that the anesthetic influence is slightly affected by this ischemia, but this action must be very slight, and it is also further disproved by the fact that since the introduction of cocain other anesthetic agents have been discovered which exert little or no influence upon the vascularity of the part, and some even producing vasodilation, yet with marked anesthetic action.

If the sequence of the phenomena are closely observed following the local application of cocain (say to the cornea), it will be found that the anesthesia precedes the anemia by a short interval of time.

As demonstrated by Mosso and amply confirmed by others, as well as by daily clinical observation, cocain locally applied suspends the activity of motor nerves, although sensory nerves are first and more decidedly influenced; applied to the nerves of special sense, where these nerves are accessible for experimentation, has caused them to lose their particular function, sight, smell, or taste being lost during the action of this agent. Tumass has been able to demonstrate that it exercises this same influence when applied to the cerebral cortex. The motor areas of dogs were exposed by trephining, then cocainized, using solutions up to 4 per cent. strength; after these applications it was found that the stimulation of these areas barely produced any response; the full effect of this action lasted for fifteen minutes, and required forty-five minutes to entirely disappear.

Alms also experimented by injecting it into the iliac artery of a frog, in this way carrying it to the entire distribution of this vessel in the lower limb, bringing about complete paralysis of the entire limb. This was the first attempt at arterial anesthesia. (See chapter on this subject.)

It is generally stated by all observers that after large doses injected into the general circulation the sensory nerves are finally paralyzed, but that doses not dangerous to life have very little effect upon the general sensibility. This statement may, however, prove only partially correct, as in this connection we would like to call attention to the experiments by Kast and Meltzer, discussed in the opening part of the chapter on Abdominal Surgery, and to its general anesthetic action, as demonstrated by Ritter and Harrison; also to the observation by Ott, that in a certain stage of cocain-poisoning irritation of the central end of the cut sciatic causes no response, while irritation of the distal end excites muscular action.

Central Nervous System.—The higher centers are first stimulated, making ideas flow freer; laughing, singing, or loquacity are also usually produced, associated with a feeling of joy, happiness, or bouyancy, which are the usual causes which encourage addiction to this drug; these sensations are followed by mental hebetude, dullness, or a sense of fatigue. Respiration is always stimulated, large doses producing dyspneic breathing, increasing to tetanic convulsions of the respiratory muscles followed by paralysis in fatal doses.

According to Dodd, very distinct histologic changes can be demonstrated in the nerve-centers after poisoning and that these lesions are most marked in the cerebral cortex. While Verebily and Horvaith have been able to demonstrate nearly similar changes in nerve-tissue following its local action, this, however, as ordinarily used must be of temporary effect, for of the many thousand cases in which cocain has been used there are comparatively very few, and most of these spinal puncture cases, in which there has been any serious results or permanent changes following its use, it is most likely that in many of these cases impure or non-sterile solutions were used or the technic faulty.

The action of cocain upon the heart and vascular system is rather complicated, and many points regarding its action here are far from settled. However, it may be fairly safely stated that small or medium doses stimulate the force and frequency of the heart action and raise the arterial tension by contracting the peripheral arterioles. When a solution of cocain is applied to the eye there occurs first a contraction of the pupil followed by a dilatation in a few minutes. This initial contraction is no doubt reflex, the result of mechanical irritation, or due to the acid reaction of the solution. With medium strength solution (4 per cent.) the maximum dilatation is reached in an hour, and begins to decline by the end of the second hour, requiring from twelve to twenty-four hours to return to normal. The dilated pupil is slightly responsive to light and to accommodation; the dilatation can be increased by atropin and very rapidly overcome by eserin. This mydriasis is due to a peripheral influence, and is the result of stimulation of the sympathetic nerve-endings, for when this nerve is first divided in animals and the injection then made these symptoms do not appear. Cocain is capable of producing a very decided rise in temperature, sometimes to as much as 8° F. in cases of poisoning; as reaction takes place this is followed by a fall before death. Reichert, in a series of experiments, has been able to determine that this rise was due to a stimulation of the thermogenic centers in the caudate nucleus, as well as to motor excitement the result of stimulation of the motor centers. Considerable variation has been encountered by different investigators regarding the renal secretory function; however, it is generally conceded that cocain markedly lessens the elimination of urea, and single large doses have produced an anuria sufficiently prolonged to bring on uremic symptoms.

The secretion of the saliva and perspiration is lessened by its local or constitutional action, due to its influence in constricting the peripheral circulation.

Intestinal peristalsis is increased by moderate doses, large doses paralyzing the intestines and rendering them hyperemic. The ultimate fate of cocain within the body is at present uncertain; when large doses have been used a small quantity, about 5 per cent., has been recovered from the urine, but it is no doubt very largely destroyed in the body and broken up into its molecular constituents.

EUCAIN

The discovery of eucain was the first decided advance in the field of synthetic chemistry to crown the efforts of the many investigators laboring to discover a less toxic agent than cocain.

This, like other anesthetics to be discovered later, is a benzoyl derivative. Alpha-eucain or eucain a was the first discovered. This however, was found to be too irritant and did not meet with much favor. Efforts on the part of synthetic chemists (Vinci, 1897) soon led to the discovery of eucain b, or beta-eucain, which eliminated the irritant qualities and reduced the toxicity. Eucain a was soon entirely displaced and is now no longer manufactured. All the eucain to be obtained is now of the beta kind; this is chemically benzoyltransvinyldiaceton-alkamin and is closely related to tropacocain.

The free base of beta-eucain is almost insoluble in water, but its acid salts (hydrochlorate are fairly soluble 3.5 per cent.). This limited solubility is a decided disadvantage and led to the introduction of eucain lactate, which is soluble to 22 per cent. and slightly less toxic, due to its containing a slightly lesser quantity of eucain, 100 parts, compared to hydrochlorate, 119. The lactate is a white hygroscopic powder of decidedly bitter taste.

The various degrees of solubility of the two salts is given as follows at ordinary temperature:

	Hydrochlorate.	Lactate.
In water	3.5 per cent.	22 per cent.
In alcohol	3.5 "	11 "
In chloroform	15.0 "	20 "
In glycerin	2.0 "	5 "

The solubility of the hydrochlorate is slightly increased by warming, and, as it does not precipitate immediately, increased strengths can be used in warm solutions. Extensive chemical experience with this drug proves that when injected hypodermically for surgical purposes it is practically non-irritant, but produces a slight vasodilatation. Compared with cocain it is slightly weaker in action, 1.5 per cent. solutions equaling in intensity and duration the action of a 1 per cent. solution of cocain.

Regarding its toxicity, a point on which its claims for preference largely depend, investigators are not all of one opinion. Vinci and many others claim it to be three to five times less toxic than cocain, and this would seem to be borne out by the extensive clinical tests to which the drug has been submitted, in which few if any cases of poisoning have been reported. However, the careful investigations of Piquand and Dreyfus (see latter part of this chapter on the comparative study of the different anesthetic agents) give beta-eucain a toxicity very slightly less than cocain. Further points in the action of eucain are that it is slightly slower in action and slightly less diffusible than cocain. Investigations seem to clearly prove that it possesses well-marked but slight antiseptic action, and to possess the particularly desirable quality of being capable of being boiled without effecting its efficiency, and its solutions may be kept for considerable time without suffering deterioration. This agent, while possessing many advantages over cocain, was yet far from proving thoroughly satisfactory to the earlier operators, largely due to the resulting hyperemia, which frequently gave rise to troublesome after-hemorrhage; this was particularly the case in dental surgery. After the introduction of adrenalin in 1900 this disadvantage was practically entirely overcome, and the agent came into more extended and general use.

Following the advent of adrenalin, the advantage of a combination with eucain was quickly recognized by the pioneer workers in the field of local anesthesia, notably Braun, Matas, and Barker, who utilized solutions of eucain and adrenalin for the performance of an extensive range of major surgical procedures, Matas devising an ingenious infiltrating apparatus for edematization of the operative field.

The following solution, recommended by Braun, became very popular:

Beta-eucain	.2
NaCl	.8
Aqua	100.0

This solution, capable of boiling, could always be rendered thoroughly sterile, its keeping qualities adding another advantage. The adrenalin was always added to the solution just before use, estimating the total quantity likely to be used, and adding to this the necessary amount of adrenalin.

Barker's solution was very similar to that of Braun's, but both have the disadvantage of being too weak for satisfactory use for anesthetizing the skin, unless it is thoroughly edematized also for blocking large nerve-trunks; for these last-mentioned purposes it is better to employ solutions slightly stronger (about 0.4 per cent.), but for infiltration of all subcutaneous tissues the Braun solution is found thoroughly satisfactory. It is necessary, however, for a delay of ten or fifteen minutes after the infiltration before beginning the operation, to allow the solution ample time to thoroughly saturate the tissues and exert its maximum anesthetic effect.

In special fields of work eucain has proved highly satisfactory, more particularly in the nose, although here it has not been universally adopted, and it has never seriously threatened cocain in ophthalmology, though possessing some few advantages here.

In the nose the ischemia produced by cocain is at times a disadvantage, whereas, under the use of eucain, this disadvantage does not occur. Instilled into the eye its solution causes mild hyperemia, but does not produce dilatation of the pupil or loss of accommodation, and its use is not followed by the changes in the corneal epithelium sometimes produced by cocain; notwithstanding these advantages, the anesthesia which it produces has not been thoroughly satisfactory, and it has never become very popular with ophthalmologists. This agent, in its time the most satisfactory substitute for cocain for use in general surgery, and marking a decided advance in the progress of local anesthetics, has now been largely superseded by novocain, which possesses all the advantages claimed for eucain with others in addition.

AKOIN

Closely related to holocain is a white crystalline powder of bitter taste. The hydrochlorate is soluble in water to 6 per cent., and freely so in alcohol. It possesses decided antiseptic qualities. It is decomposed by alkalis. Compared with cocain, it is slightly slower and weaker in action and slightly more toxic, and its poisonous action is of longer duration. It, however, possesses the particular quality of producing prolonged anesthesia, sometimes lasting several hours. Its injection is quite irritating, strong solutions decidedly so; 5 per cent. solutions are said to have caused necrosis. As ordinarily recommended, in 0.20 to 0.5 per cent. solutions, its injurious action is not so manifest, but even these weak solutions frequently leave behind a slight painful induration. Possessing as it does the power of producing a prolonged anesthesia, it at one time enjoyed considerable popularity, but since the introduction of adrenalin this advantage is not so apparent. It was particularly combined in weak solutions with other anesthetics, thus utilizing some of its desirable qualities while preventing its primary irritation, and greatly prolonging the postoperative anesthesia. These qualities were particularly desirable in all operations about the anus, hemorrhoids, etc.

HOLOCAIN

Holocain hydrochlorid, a synthetic preparation introduced into medicine in 1897, is derived from the same source as phenacetin, with which it is often adulterated. It is decomposed by alkalis, but stands a moderate degree of boiling. It is moderately soluble in water, and more toxic than cocain. Its action is quite irritant, followed later by anesthesia. Owing to its irritant action it is rarely used for infiltration, but finds its principal field of usefulness in ocular surgery. When instilled into the eye in 1 per cent. solution, the strength usually advised, it produces a moderate degree of burning, followed in about fifteen seconds to one minute by anesthesia, which lasts about ten to twenty minutes. Its particular claims for usefulness here are its decided antiseptic qualities; it does not affect the circulation or produce corneal drying as does cocain, does not produce mydriasis, affect accommodation or intra-ocular pressure; these qualities make it valuable in treating corneal ulcerations and in removing foreign bodies from the eye; in these latter cases as it does not control hemorrhage as does cocain is considered in its favor, as the escaping blood often washes away bacteria which might otherwise gain an entrance into the tissues. Notwithstanding its irritant qualities, its other desirable features, when used in the eye in combination with its dual properties of anesthesia and antisepsis, demands for it a certain place in ophthalmologic surgery.

An investigation undertaken at the Johns Hopkins Hospital to determine its value as an antiseptic arrived at the following conclusions: It exerts a distinct antiseptic influence upon ordinary pus-organisms and the Micrococcus epidermidis albus. No attempt was made to determine the exact point of time in which these organisms lose their vitality when exposed to 1 per cent. solutions, but it is somewhere around twenty-four hours, but these organisms were found to grow on agar containing 0.5 per cent. holocain.

TROPACOCAIN

This agent, benzoyl-tropein, was first isolated from the coca plant of Java by Giesel, and studied physiologically by Chadbourne, who ascribes to it an action identical with cocain, except that it is of much quicker action and of shorter duration than cocain and is about one-half as toxic; it produces no change in the vascularity of the tissues with which it is brought in contact. Toxic symptoms arising from its use are usually of much shorter duration than those produced by cocain. When instilled into the eye in watery solution it produces anesthesia of the cornea in about one-half the time necessary for similar solutions of cocain, but producing no ischemia or paralysis of accommodation and but slight mydriasis; the anesthesia is slightly less intense than that produced by similar strength solutions of cocain.

It has little to commend it for general use, and has consequently not become very popular, but seems to be more suited to spinal analgesia than any other agent so far introduced, as fewer sequelæ or fatalities have followed its use in this field.

STOVAIN

A derivative of the benzoyl group, first introduced by Tourneau as a substitute for cocain, is a white powder easily soluble in water; its solutions stand a limited amount of boiling, but are decomposed when heated to 120° C.; it is said to be unsuited to combination with adrenalin.

The French school by which this drug was introduced have been particularly active in pushing it forward, notably Tuffier and Reclus. It was especially recommended for spinal puncture, in which it was at one time extensively used. After a more extended use its irritating qualities, especially to nerve-tissues, becoming more apparent, it has been less used than formerly. For especial consideration of the changes induced in nerve-tissue, consult chapter on Spinal Analgesia.

A claim advanced for it in spinal analgesia is that it induces a greater relaxation of all the sphincteric outlets than is accomplished by the use of any other agent. It is generally conceded as being slightly less toxic and less powerful than cocain and its anesthesia of slightly less duration; its toxic symptoms when manifest are very similar to those induced by cocain. Its dilute solution, injected into the tissues, causes a slight burning pain, which is soon followed by anesthesia and frequently leaves a postanesthetic inflammatory reaction; strong solutions up to 10 per cent. are very likely to be followed by tissue necrosis. Sinclair reports this occurrence following the use of a 2 per cent. solution. It has been tried in the eye, but has not met with much favor here owing to its irritating qualities. This agent will be discussed more at length in the latter part of this chapter, in the comparative study of the action of the different anesthetics.

ALYPIN

Introduced in 1905 by Impens, is of rather complex chemical formula, a derivative of the benzoyl group, and closely related to stovain; is a white crystalline powder of neutral reaction, easily soluble in water and alcohol, sparingly so in ether, not decomposed by moderate boiling nor precipitated by moderate quantities of sodium bicarbonate. This agent was introduced as a substitute for cocain to overcome some of the unpleasant effects of the latter; in this it has been only partially successful. The results obtained by the investigations of the German school of investigators on the one hand, and the French and English on the other, do not entirely agree in all particulars regarding the toxicity and action of this agent. The

Germans claim it to be non-irritant and less toxic than cocain, while the French and English claim it to be irritant and slightly more toxic than cocain. Our personal observations in the use of this agent rather incline us to lean to the French and English view. For the result of the comparative study of this and other agents, consult the latter part of this chapter. Regarding its anesthetic power it is about equal to cocain, and is especially recommended for ophthalmic, nose, and throat surgery, although it finds certain indications for use in general surgery; thus, Schleich combines it with cocain in his three anesthetic solutions, reducing the cocain in each one-half and adding an equal quantity of alypin; by this combination lessening the toxicity of each as well as enhancing the total anesthetic effect, according to Burgi's contention, explained elsewhere in this volume. While the combination of different anesthetic salts in solution is thoroughly rational and has certain advantages, if such combinations were to be made we would much prefer the use of novocain to alypin. The injection of solutions of alypin as ordinarily used at times causes a slight burning, and is followed by some hyperemia, and in some cases slight inflammation has followed its use; this, however, is less marked than with stovain. Compared with cocain it exercises about an equal anesthetic power, but of slightly less duration; this is probably due to the ischemia induced by cocain retarding absorption, while the hyperemia induced by alypin favors it; this can, however, be overcome by the addition of adrenalin, with which alypin is thoroughly compatible.

Instilled into the eye, its 4 per cent. solution causes a slight burning followed by anesthesia in about twenty-five seconds, and in one minute this anesthesia is sufficiently profound to permit the cureting of corneal ulcers, their cauterization, the removal of foreign bodies, and other superficial operations. Its advantages within the eye are that it does not cause drying of the corneal epithelium, dilatation of the pupil, or changes in accommodation or tension.

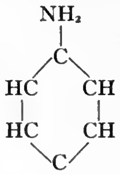
In the nose and throat, but more particularly in the nose, are its advantages sometimes apparent, particularly in the removal of posterior hypertrophies of the turbinates, where the shrinkage induced by cocain is sometimes a decided disadvantage; the same advantages are noticed with polypi; further advantages claimed for it are that its taste is not so bitter as cocain, and it does not cause the same sensation of choking or lump in the throat, which is sometimes annoying to nervous patients. Some operators claim an advantage for it when used without adrenalin for the removal of tonsils, as it does not cause a vasoconstriction; any hemorrhage that will occur takes place at the time of operation and not postoperative.

Prof. Bransford Lewis has especially recommended it for use in the posterior urethra and bladder as a means of anesthesia preparatory to cystoscopy, using for this purpose specially prepared tablets containing $1\frac{1}{8}$ gr. of the drug; these are deposited in the posterior urethra with a special depositor, and, after allowing time for the tablet to be softened by the mucus, the mass is then smeared over the adjacent membrane by a to-and-fro movement of the depositor. He claims that this agent gives thorough satisfaction when used in this way, requiring about five or ten minutes to produce sufficient anesthesia for the introduction of the cystoscope.

Dr. Willy Meyer also recommends it in the genito-urinary tract, but uses instead of the tablet instillation of a 2 per cent. solution. Providing the claims of a lesser toxicity of this agent as compared with cocain had been thoroughly established, it might readily find a more extended use, but from our experience we must regard it as fully as toxic; it, nevertheless, finds a certain field of usefulness for special work, particularly in the eye, nose, and throat. Where silver nitrate is to be applied to mucous surfaces and external parts, alypin nitrate has been introduced by the manufacturers as a substitute for the plain salt, which to some extent neutralizes the effect of silver nitrate through chemical decomposition. This is not the case with alypin nitrate, and its anesthetic effects are not destroyed by the application of silver nitrate; its chemical characters, solubility, and strength of solutions essentially correspond to those of alypin.

NOVOCAIN HYDROCHLORID

With the introduction of this agent the ceaseless efforts and zealous endeavors of the numerous workers in the field of synthetic anesthetics has at last been crowned with a very decided degree of success in obtaining an effective agent absolutely non-irritant and of low toxicity, which qualities are of vital consideration for the general use of a local anesthetic. Some of the many substitutes for cocain already introduced have exhibited advantages in one or the other direction, but none of them have fulfilled all of the prime considerations, particularly those of lack of toxicity and irritating qualities, which in some of these agents has been so marked that their strong solutions produce almost a corrosive action. The absence of irritating qualities in novocain is most marked, even when applied in powder form or concentrated solution to sensitive wounds in the most delicate tissue and on such surfaces as the cornea. Novocain, which is the hydrochlorid of para-aminobenzoyldiethylaminolthanol, is a white crystalline powder of neutral reaction and possesses the formula:



$COO.C_2H_4N(C_2H_5)_2$; HCl, was introduced by Einhorn in 1905. It is soluble in water 1 to 1 and in alcohol in 1 to 30; it melts at 156° C. and can be heated in 120° C. without decomposition. Its solutions possess slight antiseptic properties, and are capable of repeated boilings without apparently affecting their strength, and may be kept for long periods of time (several months), a quality not possessed by any of the other anesthetic agents, without apparently suffering any change in its action.

Like other agents of this group its solutions are precipitated by alkalis and alkaline carbonates, with the exception in favor of novocain that it is not precipitated or its solutions rendered turbid by sodium bicarbonate.

The physiologic investigation of novocain shows that it produces no mydriasis, no disturbances of accommodations, and no increase in intra-ocular pressure. The effect of moderately large doses upon the general system, when absorbed by either the intravenous or subcutaneous route, show almost no perceptible change either upon the circulation or respiration, and practically no changes were observed in the blood-pressure or respiration when studied by the kymograph. Numerous investigations by competent observers regarding its relative toxicity (see latter part of this chapter) all agree in giving it a toxicity from one-fifth to one-seventh of that of cocain, while studies made to determine its relative activity seem to show 1.25 per cent. solutions equal in anesthetic activity to 1 per cent. solutions of cocain, though possessing a slightly shorter duration of action; while, on the other hand, this agent when combined with adrenalin solutions possesses the highly desirable quality of having its action greatly intensified, more so than that of any other similarly used agent, to such an extent that solutions of equal strength equal in activity those of cocain, though slightly slower in action, but often yielding an anesthesia of longer duration than equal strengths of cocain similarly used.

Injected within the tissues, even in strong solution, novocain exerts but little or no influence upon the vasomotors of the part; its injections are without pain and seem to be absolutely free from all irritation; no after-pain, inflammation, hyperemia, or induration has been observed to follow its action. It is further claimed for novocain that where it is necessary to make repeated use of this agent that no danger of the formation of a habit need be anticipated.

The remarkably favorable action obtained by the combination of adrenalin preparations with novocain, as well as its total absence of all irritation, is well shown in the following experiments of Prof. Braun, published in the "Deutsch. Med. Wochenschrift," 1905, No. 42:

"1. Isotonic solution of novocain (0.1 per cent.). Formation of a cutaneous wheal on the forearm. Injection painless. The anesthetic action, like that of tropacocain, was of very short duration, and in from three to five minutes cutaneous sensibility returned. No hyperemia. The wheal vanished without leaving a trace.

"2. Solutions of novocain (0.5 and 1 per cent.). Formation of cutaneous wheals. Injection painless. Duration of wheal anesthesia fifteen minutes. Wheals vanished leaving no trace. No hyperemia.

"3. Solutions of novocain (5 and 10 per cent.). Formation of wheals. Injection of 5 per cent. solution painless; 10 per cent. solution produced very slight irritation. Duration of anesthesia seventeen and twenty-seven minutes, respectively. Very slight hyperemia at site of injection. Wheals vanished. No infiltration or tenderness remained.

"4. Novocain solution (1 per cent.). 1 c.c. injected subcutaneously into forearm in region of superficial radial nerve. Soon after the skin over the injected area showed diminished sensibility. No distinct evidence that the peripheral nerve-twigs were anesthetized.

"5. Novocain solution (0.5 per cent.). Constriction of little finger with rubber tube. Injection of 1 c.c. of solution circularly into the subcutaneous tissue of the first phalanx. After eleven minutes entire finger completely insensible. Rubber tubing removed. In five minutes sensibility had returned. No swelling or sensitiveness remained in finger.

"We have to do, therefore, with a local anesthetic with a strong, yet in comparison with some others, a transitory action, like that of tropacocain. In order to obtain results comparable with those from cocain, it would be necessary to use concentrated solutions and large doses in proportion to the slight toxicity of novocain. However, this necessity is readily and successfully overcome by the addition of suprarenin to the novocain solutions.

"6. Isotonic novocain solution (0.1 per cent.). To 100 c.c. add 5 drops 1 : 1000 suprarenin solution. Formation of cutaneous wheals on the forearm. Injection painless. Very marked anemia. Duration of anesthesia more than an hour. No reaction of any kind.

"7. Novocain solution (1 per cent.), each cubic centimeter of which contained 2 drops of suprarenin solution 1 : 1000. Formation of wheals on forearm. Anesthesia extended far beyond limits of wheals. Duration nearly four hours. Marked suprarenin anemia, upon subsidence of which some after-pain. No other reaction.

"8. 1 c.c. of the same solution injected beneath skin of forearm. The skin over the site of injection, as well as in the course of the sensitive nerves, was anesthetic for two hours. Marked suprarenin action. No reaction.

"9. Novocain solution (0.5 per cent.) with addition of 1 drop of suprarenin solution (1 : 1000) to each cubic centimeter; 1 c.c. injected beneath the skin of the first phalanx of the fourth finger. In ten minutes finger anesthetic and anemic. Sensibility began to return in sixty-five minutes. Another hour elapsed before complete return of sensibility. No after-pain."

The conclusion of Braun's observations are that novocain actually increases the action of adrenalin, while Biberfeld, after studying the same subject, states that novocain is the only local anesthetic which does not arrest or weaken the action of adrenalin. Our own observations on this subject, drawn from a large number of clinical cases, is not thoroughly in accord with those of the above investigations on some few points—viz., we have never observed the same degree of ischemia of the tissues when working with our solution No. 1 (0.25 per cent. novocain) plus 15 to 20 drops of adrenalin (1:1000) to each 3 or 4 ounces of solution, as when using equal quantities of adrenalin with similar solutions of cocain, although the intensity of anesthesia was fully equal to that produced by the cocain solutions and the duration of its anesthesia often longer.

Novocain has not become universally popular for purely topical applications in the nose and throat, although it always succeeds satisfactorily when used for infiltration, especially in combination with adrenalin. It is probable that the failure of some operators to secure satisfactory results from its local application in the concentrated solutions (10 per cent.) usually used for this work is due to the fact that insufficient time has been allowed for its absorption, as it is somewhat slower in action than cocain; but, in view of its much reduced toxicity, its action here should be encouraged, as it is in this particular field that so many toxic cases occur.

Its action in the genito-urinary tract, urethra and bladder, has proved fully as satisfactory as that of any other similarly used agent when a slightly longer time has been allowed for its action.

Novocain nitrate has been introduced for especial use within the urethral tract and elsewhere when silver nitrate and other silver salts are to be used, as it is compatible with combinations of silver. It is particularly recommended for employment with the various silver salts for urethral injections, using the novocain nitrate in 1 to 3 per cent. solutions in combination with such agents as albargin, protargol, etc.

For reference to its other methods of use here, see chapter on General Technic, as well as the chapters on the special subjects.

Thus far the observations made with novocain in ophthalmologic practice rather point to the conclusion that cocain will still remain the anesthetic of choice in this particular field, due largely to the slowness of action of novocain and its inability to penetrate and anesthetize the tissues deeply following topical applications. However, certain advantages possessed by it over cocain are the absence of drying and injury to the superficial corneal epithelium so often noted following the use of cocain. This was studied by Gebb on the cornea of rabbits, holding the eye open by self-retaining speculi and treating the eye with 10 per cent. solutions of novocain; after twenty minutes absolutely no change could be noted in the epithelia, which was in marked contrast to the effects noticed following the similar use of cocain. When dropped into the eye in powder form slight transitory changes were noted which had entirely disappeared after two hours, while cocain similarly employed may be followed by more lasting or serious changes, sometimes terminating in leukoma.

Notwithstanding the advantages possessed by it, due to its comparative lack of irritation, cocain when cautiously and carefully used still remains the agent of choice in this field.

After a rather extended experience, including a large number of cases embracing the entire field of surgery in which this agent has been almost exclusively used, we have failed to note a single case in which there has been any unpleasant local or constitutional action. We, therefore, feel thoroughly justified in unqualifiedly recommending it as the safest, most reliable, and satisfactory of any local anesthetic agent yet introduced.

Novocain base (soluble in oils) has also been put upon the market, and is intended for special uses where oily preparations are to be employed.

CHLORETONE

Chloretone was discovered in 1881 by Willgerodt, and suggested as a substitute by him for chloral in 1884. It was, however, not until 1897 that its active manufacture was undertaken by Hoffman, La Roche & Co.

It is formed by the action of potassium hydroxid upon acetone and chloroform; the result of this action is a white camphoraceous powder, first called aneson or anesin and later renamed chloretone. It is soluble in warm water to 1 per cent., 0.8 per cent. in cold water, quite soluble in oils and glycerin, and very soluble in alcohol, ether, benzin, glacial acetic acid, chloroform, and acetone. It is a very stable chemical compound and is unaffected by heat or light. It is quite compatible in mixtures of bichlorid of mercury, carbolic acid, thymol, etc.

It is particularly an antiseptic, local anesthetic, and hypnotic.

It was expected that a drug possessing such valuable chemical and therapeutic properties would prove highly useful, but in this respect it has not fulfilled the expectations of the profession.

Internally administered, it readily passes into the circulation and is decomposed within the body, as none of it can be recovered from the urine or expired air. In large doses chloretone causes in lower animals a profound sleep, associated with complete and prolonged anesthesia; this occurs without marked effect on respiration, heart action, or blood-pressure. This sleep may sometimes last several days and the animal awake unharmed, but if too large a dose is administered death will occur from asphyxia after two or three days' sleep.

One inconvenience regarding its administration is its insolubility in ordinary menstruums; it is, however, fairly safe and 20 to 40 gr. can be administered to an adult at one time.

When locally applied to denuded areas it first exerts an irritant action, followed in a short time by a very decided degree of anesthesia; injected hypodermically into the tissues it is quite irritating, but is followed by marked anesthesia, the site of the injection remaining for some time as a painful induration. According to Kossa and Vamossy, it possesses greater anesthetic powers than cocain, but is slower in action and less penetrating. They state that a 1 per cent. solution equals in activity a 2.8 per cent. solution of cocain. This remarkable statement has, however, not been confirmed by others. However, its undesirable irritating action condemn it as a useful local anesthetic, nevertheless possessing many desirable qualities; combining marked anesthesia with antisepsis and hypnosis it will always enjoy a fair range of usefulness.

Its anesthetic action is manifested along the gastro-intestinal tract, where it proves a valuable gastric sedative, and, possessing as it does decided antiseptic properties, is quite useful in such conditions as gastric ulcer and gastric irritation, with emesis from other causes, such as seasickness, and as a preventive to nausea incident to general anesthesia; when used for this purpose it should be given in 10- to 15-gr. doses about one hour before anesthesia. It has been stated by Hirschman that in cases so treated very few are nauseated after the anesthetic, and that few, if any, vomit during the anesthesia; its further advantages during this state are due to its hypnotic qualities, which lessens the quantity of the anesthetic used and prolongs the anesthetic sleep. Locally applied, chloretone would suggest itself as applicable to a multitude of surgical conditions, such as ulcers, burns, wounds, hemorrhoids, rectal fissures, insect bites, etc., particularly so owing to the facility with which it lends itself to combination in solutions with other antiseptics as well as in powders; the disappointing feature, however, is its irritating properties, which at times are quite marked, while in other cases this is not so apparent, its anesthetic action quickly setting in. We have used it repeatedly for burns, and in nearly all cases with very happy results; as it is very slightly soluble, it remains in action for some time. It is best used in solution, poured over the dressings as often as the occasion demands, its antiseptic action greatly lessening the surface infection; if the dressings are kept constantly wet the irritant action is rarely complained of, as the anesthetic action is maintained. Its absolute innocuousness, even in large doses, renders its a safe application even for large surfaces; any effect exercised from its absorption will be hypnosis, rather a desirable action, in many cases lessening or entirely removing the need for narcotics. Irritable ulcers and chancroids similarly treated often prove very satisfactory. As a postoperative sedative it may prove useful in circumcision, hemorrhoids following the use of the cautery, and many other conditions, either in solution, ointment, or dry upon the wound; incorporated in gauze, it proves useful in packing irritable wounds; it may also occasionally prove useful as an application to painful cancerous ulcerations.

In nose and throat surgery it finds a field of usefulness in sprays for ulcerated and inflamed conditions or upon packs following operation.

It also serves a use in dentistry, exercising its antiseptic and anesthetic qualities in excavations, alveolar abscess, etc.

It was tried in combination with other anesthetics in spinal analgesia and reported on by Stone, who cites 200 favorable cases, but it is hardly to be recommended here owing to its irritant action.

Owing to this unfortunate quality it has largely been superseded by other agents, notably anesthesin, but its greater solubility and antiseptic properties will always claim for it a certain range of usefulness.

ORTHOFORM

Orthoform, nirvanin, anesthesia, and subcutin were produced largely as the results of the efforts of the synthetic chemists to determine if the complete cocain molecule was necessary to produce anesthesia, as well as to see if by certain changes in this molecule the toxicity could be reduced. Orthoform (old) is a white powder, almost insoluble, and possessing decided anesthetic properties when brought into contact with exposed nerve-endings, such as are found on raw and denuded surfaces, as in wounds, ulcers, gastric vesical, and rectal lesions, etc. When in contact with such surfaces its insolubility renders it active for a long time unless washed away. This agent possesses decided antiseptic properties, which, combined with its anesthetic power, claimed for it an extensive range of usefulness in ointments and powders to burns, ulcerated surfaces, chancroids, etc., for which it came into rather extensive use until its toxic action began to be reported when too extensively used, or in certain cases apparently possessing idosyncrasies.

This led to the introduction by Einhorn, in 1897, of orthoform (new), which is meta-amido-para-oxybenzoic-acid-methylester. In this preparation an attempt was made to eliminate the objectionable toxic qualities of orthoform (old), these efforts were, however, only partially successful, as irritant and toxic symptoms, though, as a rule, less severe and less frequent, began to be reported from the new preparation. One advantage which this agent possesses is the ready facility with which it lends itself to combinations with many other drugs, being thoroughly compatible with, bichlorid of mercury, carbolic acid, iodin, salicylic acid, calomel, and many other preparations.

It also found a rather extended field of usefulness for many internal as well as external conditions, being used for lesions about the nose, throat, and larynx with the same facility as in those of the exposed parts.

Toxic symptoms, which, however, not very frequent, would occasionally develop, were for the most part mild, but occasionally were severe, and brought this agent into disfavor.

The disturbances likely to arise from the use of orthoform manifest themselves as a dermatitis with more or less severe constitutional reaction, and occasionally loss of tissue at the point of application. These symptoms may arise from a few days to several weeks after the powder has been in use, and frequently come on abruptly in cases where the powder had previously given perfect satisfaction; its action in this respect and symptoms are very similar to those occasionally encountered with iodoform.

The symptoms generally begin by more or less burning, smarting, or pain in the wound or at the site of application, a pustular dermatitis develops about the wound and elsewhere over the body associated with itching, elevation of temperature; rapid pulse and prostration may be noted in the severe cases; there is often a sticky discharge of a peculiar branny or doughy odor which takes place from the wound, and this is occasionally accompanied by loss of tissue in the severe cases.

Since the advent of anesthesin, which possesses none of the objectionable features of orthoform, is thoroughly tolerated and non-irritant and practically non-toxic, this agent has now been almost entirely supplanted.

NIRVANIN

Nirvanin, of rather complex chemical formula, is a soluble form of orthoform, introduced by Einhorn and Heinze in 1898, is a white powder, of neutral reaction, easily soluble in water, and possessing antiseptic as well as anesthetic qualities, and is not decomposed by heat. Luxenburger, who investigated this substance, found it to be much less poisonous than cocain and fixed the maximum dose at 8 gr. Its injection causes some burning pain, while no injurious action on the tissues have been reported. It leaves behind a slightly tender hyperemic area. It is about one-tenth as powerful as cocain, and the duration of its action is much shorter. Its feeble action prevents its being used effectively as a topical application to mucous membranes; its irritant action makes it objectionable in the eye. At first it was thought that it would become very popular and largely supersede cocain, but it is now rarely used.

ANESTHESIN

Two notable advances were recorded in the pharmacology of local anesthetics in the introduction of anesthesin for purely topical application and novocain for infiltration. These agents possess so many valuable qualities that they threaten to largely supersede the use of all other agents, particularly in general surgery. Anesthesin is ethyl-para-amido-benzoate, and was introduced in 1890 by Ritsert, to whom we already owed much in the synthesis of local anesthetics. The need for a new substance was felt in the disappointing qualities sometimes exercised by orthoform, which anesthesin was intended to replace; that this want has been well filled is evidenced by the tremendous satisfaction expressed on all sides wherever anesthesin has been used. This agent is a fine, white crystalline powder, melting at 90° C., almost insoluble in cold water, but slightly so in hot water, easily soluble in alcohol, ether, benzin, and fatty oils (in the latter from 2 to 3 per cent.). It is not decomposed by a moderate amount of heat, but is by prolonged boiling, as well as by heating it with alkalis. The particular qualities of this drug are that it is absolutely non-irritating, almost non-poisonous, and possesses decided anesthetic qualities. In animal experimentation by Binz, in which large doses were given to rabbits, it was found to exert no injurious action, very large doses producing a transient methemoglobinemia, but no renal irritation or methemoglobinuria. These facts, with numerous clinical data, in which large doses (30 to 40 gr. daily) have been given internally without noticeable bad effect, would tend to prove that it possesses very mild toxic properties.

Regarding its physiologic activity anesthesin very closely parallels orthoform, but is superior to it in some ways, as it exerts a decided influence on intact mucous surfaces; its insolubility requires a few minutes for it to exert its full influence.

Experiments and numerous clinical observations have proved that anesthesin is tolerated by even the most delicate tissues without the slightest irritation; it can, therefore, be applied quite freely to all kinds of fresh operative wounds, burns, ulcers, chancroids, etc., without producing the least irritation or other unpleasant after-effects.

Internally it is highly useful in all forms of gastralgia, ulcer of the stomach or hyperesthesia, vomiting of pregnancy, etc. In the nose, throat, and larynx it finds a very decided field of usefulness, as insufflations, inhalations, painting as well as in the form of pastils, in tuberculous, syphilitic, and cancerous ulcerations, also in many acute inflammatory conditions. In a series of experiments on patients suffering from tubercular laryngitis conducted by Prof. von Noorden, in which the drug was used in 10 per cent. emulsions, 3 per cent. solutions (water with 45 per cent. alcohol) and by insufflations, all three methods gave relief, but the insufflations proved most satisfactory.

In the auditory canal, for the many inflammatory conditions of these parts, after a preliminary cleansing, the insufflation of the powder or its use in strong oily emulsion often affords very gratifying relief.

The full effect of anesthesin is noted in about ten minutes, and on external surfaces, where it remains undisturbed, this action persists for from several hours to a day.

In genito-urinary surgery it may also prove quite useful when used in emulsion, or as soluble pencils in vesical irritation, due to hyperesthesia, ulcer, tuberculoses, or malignancy or as a palliation in stone, and in similar form within the urethra in combination with other remedies.

In all operations about the rectum it is highly useful, as well as in the palliative treatment of such conditions as ulcers, fistula, painful hemorrhoids, or anal pruritus. Following operations in this region the free use of the preparation as a powder, or 20 per cent. ointment, will relieve almost entirely all postoperative pain. Following the use of the cautery on chancroids or phagadenic ulcers it will allay any after-burning. For irritable and painful chancroids we have found nothing better. A marked illustration of the benefits of this agent were seen in a case of chancroids which, during self-treatment, was severely burned with pure carbolic acid as well as the entire head of the penis; the patient was in great distress, nearly frantic from the pain; all measures which had been tried had failed to give relief. Strong solutions of cocain afforded some benefit, but was too transient and seemed to increase the inflammation, besides producing symptoms of absorption; at this juncture the case was seen by one of us, and pure anesthesin powdered over the parts; relief was complete in about five minutes and lasted for about six hours, when the application was repeated. Under this treatment no further pain was complained of and the wound healed in about the usual time.

Applied in 10 per cent. ointment form to the skin it has proved highly useful in allaying the pain of erysipelas and pruritus from toxic, diabetic, nephritic, and other causes, also in the intense irritations sometimes seen in cases of urticaria.

Solutions of the acid salts of anesthesin had been used for hypodermic use for infiltration with but little success, as during the transformation into acid salts some irritating qualities seem to be developed.

In conclusion, we may say that, after an extended use of this agent in a great variety of conditions, we have never yet been disappointed where sedative topical applications would be expected to give relief.

SUBCUTIN

Subcutin is a soluble anesthesin introduced by Ritsert, and formed by the action of paraphenolsulphuric acid upon anesthesin; it is said to be germicidal and non-toxic. It is obtained as a white crystalline powder of acid reaction, soluble in water up to 1 per cent., and not decomposed by boiling. Its injection is painless, anesthesia taking place at once, but it is stated by some observers to be followed by considerable inflammatory after-effect. It is a much less powerful anesthetic than cocain and of shorter duration. Its irritant action (like anesthesin) when injected makes it little used for infiltration.

PROPÄSIN

A white crystalline powder of neural reaction, almost tasteless and odorless, slightly soluble in water, easily so in alcohol and ether, melting at 74° C. It forms salts with mineral acids and is decomposed after prolonged boiling with alkalis.

It is recommended for use in dermatology and in the gastrointestinal tract. Used as an ointment, 10 to 15 per cent., upon the skin, and after being rubbed in it produces at first a feeling of pricking, followed shortly by anesthesia of prolonged duration; it is recommended as a dressing for ulcers, pruritus, etc.

In the form of pastils it has been suggested for sore throat and internally for gastric ulcers. It is said that after about ten minutes the pain leaves and a numbness sets in which lasts about two hours. The internal dose is 2 or 3 gr. which can be repeated several times daily without any apparent harmful effect.

COMPARATIVE ACTION OF ANESTHETIC AGENTS

The most thorough and careful investigation of the comparative action of the different anesthetic agents and their relative toxicity has been undertaken by Piquand and Dreyfus. Their first investigation was on the toxicity of different mixtures of cocain and stovain, and was undertaken in 1907 and reported to the Society de Biologie. In this investigation rabbits and guinea-pigs were used, and the injections slowly and uniformly made in all cases.

The following are the results of these investigations:

Intravenous Injections in Rabbits

Stovain:

Rabbit, 3 kg. (.150), death with 9 cg. (.5), or 0.0301 per kilo of animal.
Rabbit, 2 kg. (.870), death with 8 cg. (.5), or 0.0299 per kilo of animal.

Cocain:

Rabbit, 2 kg. (.975), death with 4 cg., or 0.0168 per kilo of animal.
Rabbit, 2 kg. (.850), death with 5 cg. (.5), or 0.0192 per kilo of animal.
Rabbit, 3 kg. (.150), death with 6 cg., or 0.019 per kilo of animal.

Stovain (¾), cocain, 1 part to 200 dilution:

Rabbit, 3 kg. (.150), death with 8 cg., or 0.0266 per kilo of animal.
Rabbit, 3 kg. (.150), death with 9 cg., or 0.0285 per kilo of animal.
Rabbit, 2 kg. (.500), death with 7 cg. (.5), or 0.03 per kilo of animal.

Stovocain and cocain, each 1 to 200:

Rabbit, 1 kg. (.900), death with 4 cg. (.25), or 0.025 per kilo of animal.
Rabbit, 1 kg. (.930), death with 6 cg., or 0.031 per kilo of animal.
Rabbit, 1 kg. (.870), death with 5 cg., or 0.026 per kilo of animal.

INTRAPERITONEAL INJECTIONS IN THE GUINEA-PIG

Cocain:

Guinea-pig, 620 grams, death	with 5 cg. (.2),	or 8 cg. (.3)	per kilo of animal.
Guinea-pig, 600 grams, survived	with 4 cg. (.5),	or 7 cg. (.5)	per kilo of animal.
Guinea-pig, 730 grams survived	with 6 cg.,	or 8 cg.	per kilo of animal.

Stovain:

Guinea-pig, 420 grams survived	with 8 cg.,	or 19 cg.	per kilo of animal.
Guinea-pig, 520 grams, survived	with 9 cg.,	or 17 cg.	per kilo of animal.
Guinea-pig, 430 grams, death	with 8 cg. (5),	or 19 cg.	per kilo of animal.

Stovain ($\frac{3}{4}$), cocain, 1 part to 200 dilution:

Guinea-pig, 400 grams, death	with 9 cg.,	or 22 cg. (.5)	per kilo of animal.
Guinea-pig, 700 grams, survived	with 9 cg.,	or 12 cg. (.5)	per kilo of animal.
Guinea-pig, 540 grams, death	with 9 cg. (.2),	or 17 cg.	per kilo of animal.
Guinea-pig, 510 grams, survived	with 7 cg. (.75),	or 15 cg.	per kilo of animal.
Guinea-pig, 480 grams, survived	with 7 cg. (.75),	or 16 cg.	per kilo of animal.

Stovain and cocain, each 1 part to 200:

Guinea-pig, 930 grams, survived	with 12 cg. (.5),	or 13 cg.	per kilo of animal.
Guinea-pig, 700 grams, death	with 10 cg. (.5),	or 15 cg.	per kilo of animal.

It will be seen from a careful perusal of the foregoing that stovain is about three-fourths as toxic as cocain, at least for the smaller animals, and that by using mixtures of the stovain and cocain that much larger total quantities could be used than would have been the case with either agent alone. This last point is of practical interest in bearing out Burgi's contention spoken of elsewhere in this book, and made use of by Schleich, who now combines alypin with cocain in equal quantities in all his local anesthetic solutions.

The following is drawn from investigations by the same authors (Piquand and Dreyfus), and appeared in the "Jour. Phys. et Path. Gen.," for January, 1910:

"Comparing cocain with stovain on peripheral nerves and on the cornea of animals they found that in the same strength and quantities stovain was slower in action and of shorter duration than cocain—twenty minutes as compared to twenty-five.

"Comparing tropococain with alypin in the eye of animals, it was found that with equal quantities of the same strength solution alypin was slightly slower in action and of somewhat longer duration than tropococain—twenty minutes as compared to fifteen. The eye treated with alypin was slightly inflamed for forty-eight hours afterward.

"Comparing cocain with stovain injected intradermally gave about the same comparative results as when used on peripheral nerves or in the cornea. Comparing tropococain with alypin intradermally, tropococain anesthesia (1 per cent.) takes place immediately and persists nineteen to twenty minutes.

"Alypin (1 per cent.) at the end of two to three minutes, and lasted twenty to twenty-two minutes, the skin remaining red and painful for several hours afterward.

"Novocain (1 per cent.) gave immediate complete anesthesia for twenty minutes. Novocain (5 per cent.), with 1 drop of adrenalin solution (1 per cent. per cubic centimeter), gave an immediate anesthesia with anemia that persisted a very long time. At the end of one hour the skin was insensitive to pricking and pinching.

"In clinical use cocain (1:200) in Reclus' solution produced anesthesia after two to three minutes, lasting fifty to sixty minutes; 1 per cent. solution gave an anesthesia lasting eighty to ninety minutes.

"In less concentrated solutions (1:400) anesthesia was obtained in six to seven minutes, but often incomplete, its effect passing off after twenty to thirty minutes; 1:1000 solution, as recommended by Schleich, gave unsatisfactory results.

"Solution 1:200 when kept in prolonged contact with mucous membranes produced anesthesia. Stovain in clinical use in equal strength as cocain was found to be less effective and of shorter duration. M. Billon found 0.75 per cent. solution of stovain equal to 0.5 per cent. solution of cocain.

"Stovain in pure watery solutions was often found to be painful and the development of anesthesia somewhat delayed; in physiologic salt solution its action was more prompt.

"To augment the degree and duration of the action of the stovain solution Billon recommends either the combination with cocain or alcohol:

Alcohol (90 per cent.)	20 c.c.	
Aq. dest.	75 c.c.	(.05)
Stovain		(.50)

Anesthesia produced by this solution is superior to that of stovain in pure watery solutions, but clearly inferior to cocain in 0.5 per cent. solutions.

"Clinical experiments with beta-eucain showed it to be less active and of shorter duration than that produced by cocain.

"In clinical experiments tropococain was found to produce a slightly longer anesthesia than stovain. Novocain was found to possess anesthetic properties superior to stovain and tropococain and almost equal to cocain. In pure watery solution of 5 per cent. it was very slightly painful, but not at all so in normal salt solution—its anesthesia was of short duration, about twenty-five minutes.

"In two patients operated upon in which one-half the field was anesthetized with cocain and the other half with novocain, each 1:200 solution, the following observations were made: The injection of each was painless; in the fields infiltrated with cocain the anesthesia appeared slightly quicker than the half infiltrated with novocain; in one there was no difference in the intensity of the anesthesia; in the other there was a slight difference in favor of cocain; in each the anesthesia was slightly longer in the cocain half of the fields.

"In several patients anesthetized partly with stovain and partly with novocain, each 1:200 solution, the injections of stovain were always slightly painful, while the novocain injections were always painless, more rapid and more complete in action, but the stovain anesthesia was maintained slightly longer.

"Two patients anesthetized partly with novocain and partly with cocain-stovain (in equal parts) each presented a perfect, complete anesthesia, but more durable in the cocain-stovain field.

"A patient, anesthetized one-half the field with novocain and the other half with tropococain 1:200, presented an anesthesia more complete with novocain, but more durable with tropococain."

To augment the durability of novocain anesthesia, Reclus has suggested the following:

"Normal salt solution	100 grams
Novocain	50 centigrams
Adrenalin (1:1000 solution)	25 drops.

With this mixture, in an experience of over 300 cases, anesthesia was immediate, complete, and lasted in general over an hour."

The comparative value of the agents experimented with is given as follows:

(1) Cocain, the most efficient.

(2) Novocain-adrenalin, nearly equal in power to cocain, but more durable.

(3) Novocain, alypin, and coca-stovain in equal parts; these three have an anesthetic power nearly equal but less durable for novocain.

(4) Stovain, tropococain, beta-eucain; these three about equal.

They hold the same general opinion as all experienced observers, namely, that the toxicity of cocain and its substitute depends upon the concentration of the solution and the rapidity with which it is injected and taken into the general circulation. The same dose that will kill an animal when injected intravenously in concentrated solution can be given subcutaneously in dilute solution without noticeable ill effects; or, if injected in concentrated solution and its absorption delayed through constriction, its toxic action is weakened proportionate to the delay.

"(1) By injecting into the vein of a rabbit weighing 2 kg. (.330) a solution of cocain 1:200 in such a way as to control the flow to 5 c.c. per minute, the animal died when it had received 15 cg. of the alkaloid or 6 cg. (.4) per kilogram of weight.

"(2) By increasing the flow to 10 c.c. per minute in a rabbit weighing 9 kg. (.130) death occurred when it had received 9 cg. of the alkaloid or 4 cg. (.2) per kilogram of weight.

"(3) By diminishing the flow to 5 c.c. per two minutes in a rabbit weighing 3 kg. (.200) death occurred when the animal had received 20 cg. of the alkaloid or 9 cg. per kilogram.

"Similar experiences were had with cocain, stovain, and tropococain, and demonstrates the law given by Reclus that the toxicity of the drug depends upon the quantity introduced into the circulation and reaching the central nervous system at the same time.

"By administering the drug in interrupted doses or by delaying its absorption it is possible to administer three or four times the toxic dose without injury.

Toxicity

"All injections were made in the vein on the ear of the rabbit, using solutions of 1:200 strength, with the Roger apparatus, which regulated the flow to 5 c.c. per minute.

1. Cocain:
   Rabbit, 2 kg. (.975), death with 4 cg., or .0168 per kilo of animal.
   Rabbit, 2 kg. (.850), death with 5 cg. (.5), or .0192 per kilo of animal.
   Rabbit, 3 kg. (.150), death with 6 cg., or .019 per kilo of animal.

2. Stovain:
   Rabbit, 3 kg. (.150), death with 9 cg. (.5), or .0301 per kilo of animal.
   Rabbit, 2 kg. (.870), death with 8 cg. (.5), or .0299 per kilo of animal.
   Rabbit, 2 kg. (.300), death with 8 cg. (.7), or .030 per kilo of animal.

3. Stovain-ocain ($\frac{3}{4}$), 1 to 200:
   Rabbit, 3 kg., death with 8 cg., or 0.266 per kilo of animal.
   Rabbit, 3 kg. (.150), death with 9 cg., or .0285 per kilo of animal.
   Rabbit, 2 kg. (.500), death with 7 cg. (.5), or .03 per kilo of animal.

4. Stovain-cocain, each 1 to 200:
   Rabbit, 1 kg. (.700), death with 4 cg. (.25), or .025 per kilo of animal.
   Rabbit, 1 kg. (.930), death with 6 cg., or .031 per kilo of animal.
   Rabbit, 1 kg. (.870), death with 5 cg., or .026 per kilo of animal.

5. Beta-eucain:
Rabbit, 2 kg. (.900), death with 5 cg. (.5), or .0187 per kilo of animal.
Rabbit, 2 kg. (.800), death with 5 cg. (.5), or .0196 per kilo of animal.

6. Tropococain:
Rabbit, 2 kg. (.900), death with 5 cg. (.8), or .02 per kilo of animal.
Rabbit, 3 kg. (.100), death with 6 cg., or .019 per kilo of animal.
Rabbit, 2 kg. (.800), death with 6 cg. (.1), or .022 per kilo of animal.

7. Alypin:
Rabbit, 2 kg. (.600), death with 4 cg. (.5), or .0155 per kilo of animal.
Rabbit, 2 kg. (.850), death with 5 cg. , or .0178 per kilo of animal.
Rabbit, 3 kg. (.050), death with 5 cg. (.5), or .0182 per kilo of animal.

8. Novocain:
Rabbit, 2 kg. (.330), death with 15 cg., or .064 per kilo of animal.
Rabbit, 2 kg. (.328), death with 15 cg. (.5), or .066 per kilo of animal.
Rabbit, 2 kg. (.380), death with 14 cg. (.5), or .06 per kilo of animal.

9. Novocain (1 to 200) and 1 drop of adrenalin solution (1:1000) per 2 c.c.:
Rabbit, 2 kg. (.150), death with 20 c.c. of the sol., or 4 cg. (.6) of novocain per kilo of animal.
Rabbit, 1 kg. (.950), death with 17 c.c. of the sol., or 4 cg. (.5) of novocain per kilo of animal.
Rabbit, 2 kg. (.250), death with 25 c.c. of the sol., or 5 cg. (.1) of novocain per kilo of animal.
Rabbit, 2 kg. (.100), death with 20 c.c. of the sol., or 4 cg. (.7) of novocain per kilo of animal.

10. From the above the following relative averages of toxicity were obtained:
1 cg. (.7) per kilo of animal for alypin.
1 cg. (.83) per kilo of animal for cocain.
1 cg. (.9) per kilo of animal for beta-eucain.
2 cg. per kilo of animal for tropococain.
2 cg. (.7) per kilo of animal for stovain and cocain equal parts.
2 cg. (.83) per kilo of animal for stovain and cocain (¾ parts).
3 cg. per kilo of animal for stovain.
4 cg. (.6) per kilo of animal for novocain-adrenalin.
6 cg. (.3) per kilo of animal for novocain.

Intraperitoneal Toxicity in the Guinea-pig

1. Cocain, 1 per cent.:
Guinea-pig, 620 grams, survived with 5 cg. (.2), or 8 cg. (.3) per kilo of animal.
Guinea-pig, 600 grams, survived with 4 cg. (.5), or 7 cg. (.5) per kilo of animal.
Guinea-pig, 730 grams, survived with 6 cg., or 8 cg. per kilo of animal.

2. Stovain, 1 per cent.:
Guinea-pig, 420 grams, survived with 8 cg., or 19 cg. per kilo of animal.
Guinea-pig, 520 grams, survived with 8 cg., or 17 cg. per kilo of animal.
Guinea-pig, 430 grams, death with 8 cg., or 19 cg. per kilo of animal.

3. Stovain and cocain (¾), 1 per cent.:
Guinea-pig, 700 grams, survived with 9 cg., or 12 cg. (.5) per kilo of animal.
Guinea-pig, 540 grams, death with 9 cg. (.2), or 17 cg. per kilo of animal.
Guinea-pig, 510 grams, survived with 7 cg. (.75), or 15 cg. per kilo of animal.
Guinea-pig, 480 grams, survived with 7 cg. (.75), or 16 cg. per kilo of animal.

4. Stovain and cocain, each 1 per cent.:
Guinea-pig, 930 grams, survived with 12 cg. (.5), or 13 cg. per kilo of animal.
Guinea-pig, 700 grams, death with 10 cg. (.5), or 15 cg. per kilo of animal.
Guinea-pig, 700 grams, death with 10 cg. (.5), or 15 cg. per kilo of animal.
Guinea-pig, 570 grams, survived with 7 cg. (.5), or 13 cg. per kilo of animal.

5. Novocain, 1 per cent.:
Guinea-pig, 595 grams, with 19 cg. per kilo showed no trouble.
Guinea-pig, 357 grams, with 20 cg. per kilo showed no trouble.
Guinea-pig, 362 grams, with 30 cg. per kilo showed no trouble.
Guinea-pig, 372 grams, with 40 cg. per kilo showed no trouble.
Guinea-pig, 550 grams, with 50 cg. per kilo became very ill.
Guinea-pig, 350 grams, with 60 cg. per kilo, death.
Guinea-pig, 510 grams, with 50 cg. per kilo, death.

6. Novocain-adrenalin (1 per cent.) with 1 drop of adrenalin (1:1000) per 2 c.c.:
Guinea-pig, 360 grams, with 30 cg. per kilo showed no trouble.
Guinea-pig, 375 grams, with 40 cg. per kilo showed no trouble.
Guinea-pig, 420 grams, with 45 cg. per kilo became ill.
Guinea-pig, 500 grams, with 50 cg. per kilo, death.

"From the above experiments the following comparisons were drawn for the relative toxicity of intraperitoneal injections:

8 cg. (.15)	per kilo of animal for cocain.
14 cg.	per kilo of animal for cocain-stovain ($\frac{3}{1}$).
16 cg. (.5)	per kilo of animal for cocain-stovain ($\frac{3}{4}$).
19 cg.	per kilo of animal for stovain.
50 cg.	per kilo of animal for novocain.
50 cg.	per kilo of animal for novocain-adrenalin, 25 drops.

"Novocain was almost three times less toxic than stovain and six times less toxic than cocain. What was particularly important was that novocain-adrenalin was notably more toxic than novocain alone only in intravenous injection, but was not more toxic in intraperitoneal injection.

"Subcutaneous injections on various animals show that novocain-adrenalin is not appreciably more toxic than novocain alone.

"*Action on the Tissues.*—Cocain when injected into the tissues causes no pain or inflammation and is absorbed without leaving behind any trace of its action. When instilled into the eye it causes no pain or alteration in the cornea. It has a marked vasoconstrictor action.

"Concentrated solutions when instilled into the eye cause a momentary burning pain. This is more marked with some preparations than with others, and is probably due to slight differences in the method of manufacture.

"Stovain when instilled into the eye causes a marked sensation, as of a foreign body, lacrimation, and photophobia, the vessels becoming injected with moderate contraction of the pupil. Injected intradermally and subcutaneously it provokes pain lasting two to three minutes.

"The lacrimation, photophobia, and congestion produced by the instillation of stovain in the eye, and when injected into the tissues the pain and vasodilatation indicated an irritation due to its acid reaction."

German authors, particularly Braun, insist upon this irritant action of stovain and cite 4 cases, observed by Sinclair, in which gangrene of the tissues followed the use of a 2 per cent. solution. But Reclus, in an experience of over 3000 cases with stovain in 1.5 per cent. solution, did not see a single such accident, and when used on the dog and rabbit in 10 and 15 per cent. solutions did not see a trace of gangrene. Clinically, it produced a slight irritation of moderate duration.

"(3) Beta-eucain, injected subcutaneously, causes a sharp pain which lasts several minutes. Instilled into the eye it causes lacrimation, photophobia, and a persistent redness. These phenomena of irritation are notably more marked and more durable than with stovain.

"(4) Tropococain, when injected into the tissues, is not irritating, and has no effect upon the vessels. Instilled into the eye of the rabbit it causes a slight lacrimation and redness of the conjunctiva.

"(5) Alypin is extremely irritant; intradermal injection of 1 per cent. solution are painful, and accompanied by marked redness and vasodilatation. Following the injections the tissues remain painful and infiltrated for a long time. Five per cent. solutions are extremely painful, and may be followed by gangrene. Instilled into the eye in 5 per cent. solutions causes pain, lacrimation, photophobia, redness of the conjunctiva, and transient paralysis of accommodation.

"(6) Novocain does not appear at all irritant; with injections of 0.5 or 1 per cent. there is no vasoconstriction or vasodilatation and leaves no after-effect upon the tissues. Injections of 10 per cent. are slightly irritant and produce slight congestion of the tissues; this rapidly disappears and does not leave behind any appreciable lesion. Applied to the mucous membranes on tampons it produces a rapid anesthesia without any disturbing effects upon the tissues. When instilled into the eye it causes no disturbance; if a little of the pure drug is dropped on the cornea it causes a slight irritation of short duration; if pure cocain is dropped on the cornea it produces pronounced disturbances.

"(7) Novocain and adrenalin (1:200 with 1 drop of adrenalin solution 1:1000 to each 2 c.c.) do not appear to be more irritating than novocain alone, and cause no disturbance either at the time of the injection or afterward. With the adrenalin it produces prolonged anesthesia and a pronounced vasoconstriction, lasting for several hours. These conclusions were drawn from an experience of over 300 cases. In this series there was, however, 3 cases of gangrene, which occurred during a change of staff, and it is presumed was due to some error in the technic of sterilization or preparation of the fluid, as no similar cases had been reported except 2 cases by Strohe ("Deutsche Zeit. f. Chir.," T. x, C. T. x, p. 264), but in these 2 cases the quantity of adrenalin was very large.

"From the above observations the following conclusions were drawn. Cocain is the most powerful of all local anesthetics, but its high toxicity renders it dangerous; a safe dose should not exceed 14 to 15 cg. in 1:200 solution, care being taken to maintain the recumbent position during and after its use.

"Six cases of death occurred from the use of cocain, in one the dose was 28 cg. in 2 per cent. solution.

"Beta-eucain appears to present no advantage over cocain; it is equally as toxic, much less anesthetic, and more irritant.

"Alypin should be proscribed in view of its toxicity and irritating qualities.

"Stovain presents considerable advantage over cocain; it is two times less toxic, and a safe dose is placed at 30 cg. of a 1:200 solution, but this dose was exceeded several times, reaching as high as 37 cg. without observing any trouble. Precautions are notably less important than with cocain.

"The irritant action following its use and its weaker anesthetic power can be largely overcome by using it in normal salt solution and in slightly greater strength.

"Tropococain. Little clinical experience was had with this alkaloid, but it appears to be a good anesthetic. Judging from the experimental results, its toxicity and anesthetic value are very close to that obtained with stovain-cocain.

"Novocain. This appears at the present time the most commendable of local anesthetics; its feeble toxicity permits large doses to be used without inconvenience; it has considerable anesthetic power, is non-irritant, and not a vasodilator. The only inconvenience is that its action is comparatively a little shorter than cocain, but this can be overcome by the addition of adrenalin, which produces a prolonged anesthesia of slightly more marked degree without increasing its toxicity. The solution that has given the best results is the following, recommended by Reclus:

Normal salt solution	100 c.c.
Novocain	50 cg.
Adrenalin (1:1000 solution)	25 drops."

The above most interesting report, which covers almost the entire range of local anesthetics as employed to-day, will bear the careful study of those interested in working out any problems in connection with the action of local anesthetics.

Some interesting points worth noting are the increased toxicity shown when novocain was administered intravenously with adrenalin. The value of this observation is lessened, as other agents were not similarly used for a comparative study, and leaves us to draw the only likely conclusion that the increased toxicity was due to the action of the adrenalin *per se*, and not to the fact that it was in combination with novocain.

Another interesting point is that beta-eucain is given a toxicity equal to cocain; that is, however, entirely against all clinical experience, which has seemed to show that it possessed a much lower toxicity.

Their observations regarding the irritant action and toxicity of alypin are decidedly at variance with the German school, but in this respect our own clinical observations are more nearly in line with the above.

After a consideration of the above it is seen that novocain possesses advantages unequaled by any other local anesthetic, being absolutely non-irritant and six to seven times less toxic than cocain, and, when in combination with adrenalin, producing an anesthesia that for intensity and duration equals that obtained by any other agent, claims sufficient to give it first place in all surgical considerations, which, combined with the fact that it forms stable solutions capable of repeated boilings without deterioration, make it, at least for the present time, the ideal local anesthetic.

The above subject was similarly, though less thoroughly, studied by the Therapeutic Committee of the British Medical Association, who arrived at nearly similar conclusions, and as a result of their studies, have fixed the following scale of toxicity, taking cocain as the standard of comparison and having it represent 1:

Alypin	1.25
Cocain	1.00
Nirvanin	0.714
Stovain	0.625
Tropococain	0.500
Novocain	0.490
Beta-eucain lactate	0.414

ANESTHETIC PROPERTIES OF QUININ SALTS

To Dr. Henry Thibault, of Scott, Arkansas, is due the credit of having discovered the anesthetic properties of this drug. Prior to Dr. Thibault's discovery and announcement the only record of the sedative action of quinin is a report by Dr. Fulton, who used it as a local application to the nose in hay fever ("Jour. Amer. Med. Assoc.," July 20, 1904).

It is interesting to note that though the hydrochlorid of quinin and urea, which was first discovered by Driguine in 1881, and extensively used all over the world as the most soluble salt of quinin and the best adapted to hypodermic use in the malarial infections, was not recognized as a local anesthetic until 1907, when Dr. Thibault first called attention to this property, which it possesses in common with other salts of quinin, notably the bisulphate. In this the analogy of historic experience is not unlike that of cocain.

Dr. Thibault informs me that he discovered the anesthetic properties of the agent while administering it hypodermically to himself for malaria in June, 1905, by taking a second injection six hours after the first in the same place. His experiments and surgical use of it quickly followed, which he reported in the "Journal of the Arkansas Medical Society," September 15, 1907.

We know that quinin is an antiseptic, antiperiodic, antiphlogistic, antimiasmatic, a diminisher of reflex action, a proplasmic poison, emmenagogue, and oxytoxic; we have now to add its anesthetic properties and swell the list of its already many uses.

I used it in an experimental study several years ago in 33 cases, which included inguinal hernia, varicocele, circumcision, hemorrhoids, anal fissure, fistula in ano, superficial abscesses, ulcers of leg, epithelioma of face, galactocele of breast, and removal of sebaceous cysts—a fair range of cases and sufficient to arrive at some conclusions regarding its merits as a local anesthetic. I will give the report of my observations made at that time.

The first case of any consequence was a large perirectal abscess and fistula in ano, with multiple perirectal sinuses. It was a trying case for any form of local anesthesia, and was intended to put the method to a decided test and develop certain technical details which I had found necessary from my experience in the office.

The patient, Burnell, aged sixty-seven, was operated from Ward 69, Delgado Memorial, December 2, 1909. No preliminary morphin or sedatives were used. A 1 per cent. aqueous solution of quinin and urea hydrochlorid was selected. The injection was commenced in healthy tissue and advanced toward the inflamed area. The initial injection caused some burning and pain, which lasted about five minutes. By advancing slowly into the surrounding parts practically no discomfort was caused, no more than was to be expected from the manipulation of the yet unanesthetized parts. If the infiltration was advanced too rapidly it produced a return of the burning pain in the freshly invaded area, but when slowly done this did not occur. Also, if the needle was entered too near the margin of the infiltrated area, without waiting for anesthesia to be established, it caused pain, but if a long needle was used and entered some distance back in the anesthetized area and advanced gradually by distending the tissues, no pain was produced. The infiltration process lasted fifteen minutes, and by the time it was complete the area first injected showed profound anesthesia; those last injected showed sensation to both touch and pain.

But by operating in the order of the infiltration, by the time the area last infiltrated was reached, anesthesia was well established. The infiltration was about as thorough as would have been obtained with any other local anesthetic. Several injections were made deep into the tissues behind and to the side of the anus to meet the branches of the pudic nerve as they came down from the spine of the ischium. In all, 4 ounces of a 1 per cent. solution was used, 19.2 gr. of quinin salt. The anesthesia produced was everywhere profound. The anus was dilated, the sinuses slit up freely and curetted, and pieces of tissue removed.

There was no apparent effect on the circulation *in situ;* there was considerable bleeding and hemostats and ligatures were used. The wound was finally well cleaned and packed freely.

At no time did the patient suffer any discomfort beyond the burning pain following the first injection.

At the completion of the operation no infiltration of the tissues was apparent; they presented the same appearance as would have been expected after a general anesthetic. No peripheral zone of hyperesthesia could be detected.

After his return to the ward observations were made at intervals during the afternoon for return of sensibility, and he was instructed to note the time at which he noticed any painful sensations in the wound. He reported next day that there had been no painful sensations, but a feeling of deadness about the operated parts. The only after-effect, either local or general, was a slight ringing in the ears for several hours.

The wound was then examined and the pack removed. Infiltration of the tissues was now very apparent. They looked and felt much thickened and presented a pale, edemic, greyish appearance. Two striking points were noticed. The removal of the pack caused no pain and was followed by very little oozing of blood. This was in marked contrast to what would have been expected in removing a pack within twenty-four hours from a wound of this kind. The wound was dressed daily for the purpose of making observations, and very little change noticed from day to day. About the third day the tissues in the wound became sensitive to the prick of an instrument or the grasp of a dressing-forceps, but up to the sixth day the removal of the pack caused no pain. The tissues were slow in losing the pale, edemic appearance, and some infiltration was still noticed eight days afterward. The progress of healing seemed much retarded.

Three weeks later, when the patient left the ward, there was still quite a wound, which he was instructed to care for. He returned at intervals for observation and it was about six weeks before healing was complete.

Through the kindness of Dr. Matas, I was permitted to operate, December 7, 1909, on a galactocele of the breast of sixteen years' duration in Mrs. M., aged thirty-eight, Ward 70, Dengado Memorial.

The operation was performed in the general amphitheater, and as the patient was quite nervous, a preliminary injection of morphin, $\frac{1}{6}$ gr., and scopolamin, $\frac{1}{150}$ gr., was given a short time before; 1 per cent. quinin and urea in sterile water was used.

The first injection caused some little burning pain. The tissues around the cyst and at the base of the gland were well infiltrated. A large incision at the base of the gland, under its dependent portion, was then made and the breast turned up; bleeding was very free; the cyst was dissected out and its ramifications entirely removed. Aside from a little nervousness on the part of the patient, she made no complaint and the procedure was satisfactory.

Six ounces of the solution was used, 28.8 gr. of the quinin salt. The wound healed by first intention without much apparent infiltration and in about the usual time.

On January 3 I attempted to operate on an old ulcer of the leg, the result of a compound fracture. It was my intention to curet the base of the ulcer, liberate its edges, and draw them together.

The patient, Mr. B., aged fifty-three, a railroad conductor. A 1 per cent. quinin and urea solution was used. Infiltration was very difficult, as the tissues everywhere were much thickened and bound down to the underlying bones. After much effort at infiltration, in which about 3 ounces of the solution was used and a delay of twenty minutes for anesthesia to become established, it was finally abandoned, as the tissues seemed as sensitive as at first. Cocain was then used, anesthesia secured, and the operation performed.

Inguinal hernia: Davis, aged thirty-three, Ward 69. Left oblique inguinal hernia, duration, four years; operation, January 14, 1910, 1 per cent. quinin and urea.

No complaint was made at any time by the patient and anesthesia was very satisfactory; 7 ounces of solution were used, as the hernia was very large. By the time the superficial injection of the skin was completed anesthesia was established. The field was very vascular. No hyperesthesia was noted and no induration was seen at the completion of the operation. The dressings were not disturbed for one week, as the wound had remained perfectly comfortable and the patient had no temperature.

When the dressings were changed the wound presented a brawny induration, extending over the entire area of infiltration; the tissues were much thickened and felt leathery. A few superficial stitches were loosened without any pain and fresh dressings applied. These were changed in two days. Some serous exudate was found. The wound remained much the same in appearance. About the tenth day suppuration became more apparent, and finally extended down to the aponeurosis of the external oblique, a portion of which sloughed away. Healing was very slow. The patient remained in the ward over one month and became restless and left before healing was complete. I do not know what effect the infection will have upon the final result. I asked the patient to return for later observation, but he did not do so.

Epithelioma of right cheek: Mr. C., aged fifty-one, carpenter. Growth was as large as a quarter and had existed for three years. Operation in office, January 5, 1910; $\frac{1}{4}$ of 1 per cent. quinin and urea was attempted, but proved insufficient after fifteen minutes' delay. The strength was gradually increased until 1 per cent. was used, which produced profound anesthesia. The growth was removed by a wide incision and good approximation of the wound secured with silk sutures. A suitable dressing was applied and changed in two days, when much induration of the wound was noticed. Infection became apparent by the fifth day. The wound was three weeks in healing and left quite a scar.

Many other minor operations were performed before and since these detailed cases, including circumcisions, hemorrhoids, rectal fissures, fistulas, varicocele, buboes, etc., most of which were done in the office. From 0.25 to 1 per cent. in sterile water or salt solution was used. The weaker solutions proved effective in loose cellular tissues, like the scrotum or skin of the penis, and their use was always followed by less induration and less danger of slough than the stronger solutions. I did not find that the addition of normal salt solution influenced the results to any marked extent. About the rectum the 1 per cent. solution was always found necessary, and succeeded well in all but one case, when it was abandoned and cocain used.

The after-effects, when used about the rectum, are in marked contrast to that following the use of cocain solution. When the quinin solution was used in the removal of hemorrhoids, practically no after-discomfort was complained of, the anesthesia lasting until healing was well under way, while similar operations performed with a cocain solution are always followed by much burning and pain after the anesthesia dies out. Particularly about this region is a preliminary injection of a syringe full of Schleich solution, to prevent the burning sensation following the first injection of the quinin solution, advisable. As some infection always follows operations on these parts, I have not found that the quinin solution added to the suppuration sufficiently to be objectionable, but judgment must be used in selecting the operation for its use or embarrassing results may follow.

I would not care to undertake a resection of the bowel or extensive Whitehead operation with quinin as the anesthetic, but if a local anesthetic was to be used would much prefer a novocain solution.

In circumcisions the 0.25 per cent. solution has some points to commend it. The pain and discomfort associated with the trying erections which follow this operation are absent when quinin is used and no discomfort is experienced when changing the dressings.

In seven circumcisions, performed in this way, I have had fairly good results, and much time and annoyance was saved myself and the patient, and I have not found that healing was interfered with to any great extent. The wound was generally well in about ten days.

However, I noticed in several of the cases that the infiltrated skin often had a dark ecchymotic appearance afterward, which, at times, took on a threatening aspect. I have accordingly discontinued its use in these parts for fear of possible serious consequences.

I have used it in the bladder in 15 and 20 per cent. solutions, but did not obtain very satisfactory results. Used topically in the rectum in the above strengths it has given fair results. A very thorough study of its action and surgical uses was undertaken by Drs. Hertzler, Brewster, and Rogers, and reported in the "Journal of the American

Medical Association," October 23, 1909. I quote the following from their report:

"Hertzler undertook to determine experimentally the cause of the induration. Experiments performed on rabbits showed that the thickening was not due to cellular infiltration at all, as was supposed on clinical grounds, but was due to a pure fibrinous exudate free from cells. This exudate was proved to be fibrin by Mallory's and Weigert's stain. The reaction appears, therefore, to be purely chemical in nature. The exudation of the fibrin begins to appear within a few minutes. In a general way it determined the amount of exudate depending on the strength of the solution used; the attempt was made, therefore, to determine a strength of solution which would not cause this exudation of fibrin. In 0.5 per cent. solutions the exudate is less than with 1 per cent., and with only 0.25 per cent. solutions only traces can be discovered. To what extent this fibrinous exudate is subsequently converted into fibrous tissue has not yet been definitely determined, but apparently nearly all is absorbed.

"In order to determine the subjective sensations of the injection, and to determine the question of a possible zone of hyperesthesia about the anesthetized zone, one of us (Hertzler) studied the effect by the injections in the skin of his leg. Injections of 1, 0.5, 0.25, and 0.167 per cent. solutions and an injection of plain water as controls were used in each series. The 1 and 0.5 per cent. solutions gave immediate and complete anesthesia without a particle of pain during its introduction. Within a few minutes there was a distinct induration. With the 0.25 per cent. solution, anesthesia was not complete for a few minutes, but was then as complete as after the use of the stronger solutions. The 0.167 per cent. solution gave delayed anesthesia, but after a few minutes was complete. In neither of these weaker solutions was induration noted on palpation. The water-control caused intense pain on injection, and the anesthesia, at no time perfect, lasted but a few minutes. There was a zone of hyperesthesia, 1 or 2 inches in width, about the area injected. Curiously enough the hyperesthesia seemed to be for touch and not for pain.

"The duration of the anesthesia in the 1 and 0.5 per cent. solutions was perfect for four or five days, and sensation in the 0.5 per cent. strength was not restored to any great extent for ten days, and in the 1 per cent. solution sensation was not completely restored after two weeks. At no time was there the least pain, though the induration about the 1 and 0.5 per cent. solutions was yet marked at one and two weeks, respectively.

"The above observations were made with the solution of the quinin in water. When physiologic salt solution was used as the solvent, the induration was little or not at all marked, but the duration of the anesthesia was much lessened. Hypotonic and hypertonic solutions also were used without notable variation.

"The result of this experimentation indicated that the delayed skin union above noted was due to fibrinous exudate. This was present in the 1 and 0.5 per cent. solutions, but not in the 0.25 per cent. solution to any notable degree. The 0.25 per cent. solution seemed, then, on laboratory grounds, to be the strength most desirable for anesthesia in the class of work where speedy primary union of the skin is desirable, and where duration of anesthesia beyond several hours is not required, and clinical experience seems to bear out the laboratory determinations.

"Any operations ordinarily done with cocain can be done with quinin. The technic of its use is the same. As in the use of cocain, only those tissues known to be sensitive should be injected. In clean tissue the 0.25 per cent. solution seems to be strong enough to produce anesthesia, lasting several hours. In regions where primary union is not necessary, particularly in tissue, the seat of inflammatory reaction, the stronger solutions are more satisfactory. In the opening of the abscesses, for instance, and operations for anal fistulas, hemorrhoids, etc., the stronger solutions are the ones of choice. In regions where the operation is attended by hemorrhage, too, notably tonsillectomy, tubinectomy, etc., the 1 per cent. solution or stronger (3 per cent., Brown) is the solution of choice. The stronger solution is desired here because of the hemostatic effect exercised by the fibrinous exudate. The exudate being fibrin in the strict chemical sense, the usual natural processes of hemostasis are anticipated. The coagulum occurs, it is true, *about* and not *in* the vessels, and their occlusion, therefore, results from the pressure from without. The important point, however, is that the effect lasts from seven to fourteen days, a time abundantly sufficient to allow healing by granulation to become well advanced. This is in marked contrast to the ephemeral influence of cocain and adrenalin, which act only by causing a contraction of the muscular walls of the blood-vessels.

"We have done the following operations, among others, under quinin anesthesia: Drainage of the gall-bladder, drainage of appendiceal abscesses, exploratory laparotomies, hernias, castrations, varicocele and hydrocele operations, etc., and the removal of all sorts of tumors ordinarily undertaken under cocain.

"We desire particularly to emphasize the value of this anesthetic in two operations. In operations about the anus it is for us the anesthetic of choice. In both fistulas and hemorrhoids any of the radical operations can be performed with the same thoroughness as under a general anesthetic. The advantage consists in that the duration of the anesthetic is from seven to ten days, which does away entirely with the after-pain ordinarily attending these operations. In tonsillectomy the results have been equally satisfactory. For this operation a large amount of the solution is injected about the tonsil, between it and the faucial pillars. This forms an artificial edema about the tonsil which much facilitates its removal. An unlimited amount of solution may be used with impunity, so that a satisfactory anesthesia can be easily secured. Because of its safety, both tonsils may be operated on at one sitting. The absence of after-pain is as desirable here as following an operation about the anus.

"As a local application about the eye we have no experience, but turbinectomies and septal spur operations have been done with a fair degree of satisfaction when the drug was used as a topical application. For local application the strength must be from 10 to 20 per cent., as correctly stated by Thibault. When the solution is injected beneath the mucosa, however, anesthesia is perfect and hemorrhage slight.

"In the bladder, as a preliminary to cystoscopy, the result has been very satisfactory. A solution of from 10 to 20 per cent. is used and allowed to remain from twenty to thirty minutes. The only objection to this solution is the difficulty of removing the precipitated flocculi from the bladder after the anesthesia is complete. These flocculi work no further mischief than to obscure the vision."

Quinin and urea hydrochlorid has been recommended in the treatment of neuralgia. We have had but a limited experience with it in this field, and that has not been satisfactory. The following is from a recent article by Dr. Matas:

"I have had occasion to try both the bichlorid of urea and quinin and the bisulphat in the treatment of trigeminal neuralgia, and as a preliminary to the extirpation of the second and third divisions of the trigeminus, associated with the alcohol injections into these nerves at their exit from the base of the skull (Schlosser's method). My experience has brought out most forcibly the objections above stated:

"In the case of an aged gentleman, Judge H., aged seventy-three years, who consulted me two months ago for a most violent tic douloureux of the infra-orbital and inferior maxillary divisions of the trigeminus, I felt especially anxious to avoid any extensive operation which might require a general anesthetic, because he was a corpulent man with a dilated heart, chronic asthma, and emphysematous lung. I decided in this case to try, as on many previous occasions, the effect of a deep, massive infiltration of the nerve-trunks at the base of the skull, and thus obtain a regional anesthesia, as a preliminary to the excision of the nerves after injection of the nerve-trunks with alcohol. I used a solution of quinin bisulphate (1 per cent.) with adrenalin solution (1 : 1000), 20 minims of the adrenalin to 5 ounces of quinin solution. With my special infiltration apparatus I edematized the sphenomaxillary and zygomatic fossæ by introducing the needle of the pump into these regions through the sigmoid notch of the lower jaw. The anesthetic effect on the peripheral distribution of the nerves was pronounced in half an hour, but in a few hours I was much worried by the persistence of the edematous swelling of the entire cheek and face on the corresponding side and extreme induration of the infiltrated parts. The paroxysms of pain, which subsided for a day, gradually returned to their original violence, the hard swelling of the cheek persisting for nearly two weeks. I then decided to reinject the nerves with my regular beta-eucain (0.2 per cent.) and adrenalin solution. With this infiltration the anesthesia was so complete that I was able to resect both nerves painlessly. The inferior maxillary was exposed above the origin of the inferior dental by deepening the sigmoid notch and following the nerves toward the foramen ovale (Victor Horsley's method). The infra-orbital nerve was exposed and followed through the orbit to the sphenopalatine fossa by a simplified Carnochan method. Both nerve-trunks were injected interstitially with alcohol as near the point of exit as possible from the skull, and then torn away by twisting with forceps, the peripheral distribution being extracted by Thiersch's method. The relief obtained by this procedure was complete and satisfactory.

"In this case I learned, first, that the anesthetic effect of the quinin solution was not as pronounced as when beta-eucain was used; and, second, that the long-lasting hard swelling after the quinin, even when used in combination with adrenalin, was not a negligible after-effect."

The intra-abdominal use of the drug was tried by Dr. Thibault, and reported in the "Journal of the American Medical Association" in the article which I quote below. In view of the non-toxicity of the drug, and the consequent freedom with which it can be used, its action here should be borne in mind, as it may prove of advantage under certain conditions.

The following report of an experience with the bimuriate of quinin and urea hydrochlorid may prove of some value to surgeons doing abdominal work, especially in cases in which general anesthesia is undesirable:

"*History.*—Strangulation of an old inguinal hernia occurred March 10, in a negress aged sixty-four, who had, in addition, inoperable cancer of the uterus and rectum. The circulation was poor. There were arrythmia, edema, considerable arterial sclerosis, beginning dilatation of the heart; slight cough, some preliminary secretion, and a parenchymatous nephritis.

"*Operation.*—Immediate operation was necessary, and both physicians called in consultation thought that general anesthesia would almost certainly prove fatal. The operation was done under local anesthesia, induced by injecting 0.25 per cent. solution of quinin and urea hydrochlorid. The tissues above the canal were moderately infiltrated with the solution and there was no pain until after the canal was laid open, when the peritoneum was found to be quite sensitive. About 2 drams of the warmed solution was poured into the canal and in a few minutes there was perfect anesthesia of the parietal peritoneum and the operation was finished without the patient at any subsequent time feeling any pain, although considerable adhesions were broken up. There was no local reaction in the peritoneum, union was primary, and there was no shock. The fluid poured into the canal gradually escaped into the abdomen as the adhesions were broken up. There was no pain after the operation and nothing to indicate that any peritoneal irritation had taken place.

"While it is dangerous to draw conclusions from a single case, this report is at least worth attention, and suggests that the solution might be poured into the abdomen and more extensive operations done without pain or injury to the patient, as the presence of the solution seems to render the handling of the abdominal viscera painless."

Judging quinin by the standard set for any new local anesthetic, and comparing the many claims made for it with our clinical experience, we find that (1) compared with cocain, novocain, and beta-eucain, its local anesthetic effect is not as rapidly obtained. This is especially true of its topical application to mucous membranes. On the other hand, when the anesthesia is obtained, it is of very much longer duration, the after-pain in some operations being thus avoided, a great advantage in nasal and rectal work when painful dressings must be removed shortly after the operation. (2) The local anesthetic effect is not only slower in its appearance, five to fifteen minutes, but is less diffused. It spreads over a more restricted area than with cocain and other local anesthetics. (3) Quinin acts as a vasodilator and favors capillary oozing. (4) It produces a secondary indurative reaction in the tissues, due to a fibrinous exudate, which appears a few minutes after injection and in a general way is dependent upon the concentration of the solution.

While from the point of view of repair this excess of fibrinous reaction is a disadvantage, since it tends to interfere with the healing of wounds, it is also an advantage in producing a secondary and permanent hemostatic effect by producing a perivascular compression, which may be utilized profitably in some operations associated with much secondary oozing. This may be the case in rhinologic work and in hemorrhoidal operations, where, in addition to long anesthesia, a permanent hemostasis is desirable.

The primary vasodilator effect and interference with healing, with long persistence of hard swelling when the more effective quinin solutions are used, is a serious drawback in aseptic operations where quick primary healing is desirable, and will militate against the general acceptance of quinin as a routine anesthetic, its non-toxicity notwithstanding. It is possible that by combining the quinin and urea hydrochlorid with adrenalin solution the objectionable oozing due to the primary vasodilator effect may be overcome; but it would appear that by this combination the vasoconstrictor effect of the adrenalin is diminished and the ischemia is not obtained, as is the case when some of the cocain substitutes are combined with adrenalin (Gaudier). Neither does this combination appear to have a very marked influence in diminishing the objectionable fibrinous exudation of quinin in my experience.

The practice of combining two or more drugs in solutions weaker than any one could have been effectively used alone has lately met with much favor, thereby often retaining the good points of each while being able to eliminate objectionable effects. Schleich, in this way, has combined alypin with cocain in the formulæ for his solutions which he recommends at present. It may be possible to combine quinin in this way, thereby retaining some of its desirable qualities.

In conclusion, it is only fair to state that whatever may be the objections to the routine use of the quinin as a local anesthetic in surgical practice, we must admit that there is always place for a reliable anesthetic as quinin has proved to be, which is absolutely free from toxicity. (Brewer has injected 100 gr. of the bichlorid of urea and quinin intravenously in the course of six hours in a case of pernicious malarial infection without ill effects.)

This non-toxicity, coupled with the extraordinary duration of the anesthesia (one to six days), will always keep this remarkable drug in the mind of every surgeon who is constantly facing the problem of local anesthesia in its multitudinous phases in the daily routine of surgical practice. Furthermore, in view of the remarkable properties which quinin possesses, as above stated, it is to be hoped that every effort will be made to overcome the objections which we have previously noticed by combining its salts with other agents that will modify or neutralize its undesirable reaction in the tissues.

In discovering this unknown and most valuable property in a long-familiar drug, Dr. Thibault has contributed a valuable addition to the surgeon's resources in annulling pain and has proved himself an unusually keen and perspicuous observer.

While the study of the local action of this drug is highly interesting, we do not feel, in the present stage of its development, that we can recommend its use for any but a limited number of rectal operations; possibly the surgeon specialist may select it for certain nose and throat work.

An interesting point upon which we have been unable to secure any information is its surgical use as an anesthetic in those said to possess an idiosyncrasy to the drug. In the large number of cases already reported no such observations have been made.

While this book is going through the press there appears in the literature an article by Dr. F. W. Parham, on Quinin and Tetanus ("New Orleans Med. and Surg. Jour.," October, 1913), in which this valuable drug is incriminated as an exciting cause of tetanus. This arraignment is so convincing that I record it here as a caution against its unguarded use, particularly as there appears the tendency to extend the field of usefulness of quinin as an anesthetic. At least one fatal case of this dread disease has occurred recently in New Orleans in which quinin seemed to have been the exciting cause.

In all cases so far in which tetanus has followed the quinin was in concentrated solution, and usually administered for malaria, but as the determining factor seems to have been the area of necrosis which the injection produced this would seem possible in the solutions ordinarily used for purposes of anesthesia, 0.25 to 1 per cent., which at times has been found to produce necrosis, as in some of the cases reported in the preceding pages. As this mere statement of facts may fail of its purpose without the production of further proof or argument, I copy the following taken from Dr. Parham's article, which is a quotation from Major S. P. James, January, 1911, number of Paludism, in which he summarizes the work of Sir David Semple on this subject:

"Cases of tetanus sometimes occur after the hypodermic or intramuscular administration of quinin, and it may now be regarded as proved that such cases are not always due to a contaminated needle or solution, but sometimes occur in circumstances in which the sterility of the apparatus used, of the fluid injected, and of the patient's skin at the site of injection is assured. The results of the present investigation indicate the probable cause of such cases, the danger attending the hypodermic or intramuscular administration of quinin, and the procedure by which that danger may be avoided.

"The author's explanation of the occurrence of tetanus when no tetanus spores have been injected with the quinin solution rests upon the following findings: (1) Many people in good health harbor tetanus spores in their bodies, either in healed wounds or in the intestinal canal. Hidden away in the tissues the spores remain alive and retain their virulence, but, for one reason or another, they do not grow into toxin-producing bacilli. It appears that such tetanus-spore carriers may be quite common, for, as regards the intestinal canal carrier, Colonel Semple found the spores in the feces of four out of every ten persons examined. The frequency of 'healed-wound carriers' is not known, but probably is considerable, for it is reasonable to suppose that the majority of people have suffered slight injuries accompanied by the introduction of tetanus spores, but not followed by tetanus, and that at least some of these people harbor in the healed tissues a few spores which have not been destroyed by the phagocytes, and which, from the absence of anerobic conditions, or from some other cause, do not grow into toxin-producing bacilli. In the thirteenth series of experiments described by Colonel Semple, eight guinea-pigs were inoculated in the hind leg with spores entirely free from toxin ('washed tetanus spores'). The animals remained healthy. At periods varying from five weeks to seven months after inoculation the guinea-pigs were killed, and small pieces of the subcutaneous tissue at the site of inoculation were removed aseptically, placed in tubes of broth, and incubated. In all the eight experiments true tetanus bacilli, which were found to be virulent, were recovered. These results prove that living tetanus spores can remain in the tissues for at least seven months without being destroyed by the phagocytes and without causing tetanus; and it is reasonable to suppose that a similar condition obtains in persons who have suffered an injury accompanied by the introduction of tetanus spores, but not followed by tetanus; most of the spores are followed by phagocytosis, but some of them escape and become hidden away in the tissues, where they remain for months or years after the wound has healed. (2) The second finding is that these tetanus-spore carriers are in danger of suffering from tetanus: (*a*) on the occurrence of circumstances (such as great fatigue or exposure to extremes of heat and cold) which lower their normal power of keeping at bay the germs which they harbor; (*b*) when the site where the spores are lodged becomes converted into a medium which, from being anerobic and from a failure of phagocytosis, is favorable for the growth of the spores into toxin-producing bacilli; (*c*) when a focus of dead tissues forms in a part of the body at a distance from the site where the spores are lodged.

"For our present purposes the third of these conditions is the most important, and in regard to it Colonel Semple has proved, especially by his series of experiments numbered III, VII, XVI, and XVII, that the 'latent' or 'dormant' tetanus spores are sometimes conveyed from the site where they were harmless to a site (such as that of a quinin injection) where they can develop abundantly and produce sufficient toxin to cause tetanus. (3) The third finding is that the results of injecting quinin hypodermically or intramuscularly are, (*a*) local destruction of tissue, and in most cases the formation of a slough which includes the true skin, the subcutaneous tissue, and the deep fasciæ; this means the formation of a subcutaneous necrotic area which is an anerobic medium very favorable to the growth of tetanus spores; (*b*) the paralysis of the leukocytes so that their phagocytic action is hindered.

"If we have interpreted Colonel Semple's paper rightly, the explanation of the occurrence of tetanus after an uncontaminated and aseptic hypodermic or intramuscular injection of quinin, is, on the basis of the above findings, not difficult. Suppose the malaria patient to be a tetanus-spore carrier, the spores being situated in the intestinal canal, and suppose we inject the quinin solution into the patient's buttock, and by so doing produce there a local subcutaneous patch of dead tissue, leukocytes from all parts will crowd to the injected area, and it may happen that some of them contain tetanus spores gathered from the alimentary canal as a result of an abrasion of the mucous membrane. The spores that have been conveyed to the necrotic patch will find the conditions there very suitable for development into toxin-producing bacilli, and tetanus will ensue. Similar events might happen if the tetanus-spore carrier was a person in whom the 'latent' or 'dormant' spores were situated in the site of an old wound on any part of the body.

"If we accept this explanation, it is easy to understand why, even in tetanus-spore carriers, injections of non-irritating drugs, such as morphin, cocain or digitalin, are not followed by tetanus. These solutions are quickly absorbed and no local destruction of tissue results, so that the person remains free from a focus suitable for the germination and growth of the spores; and as regards those drugs, even if tetanus spores were injected along with the solution, it is probable that, the activity of the leukocytes being unimpaired, all the spores would be destroyed at the site of the injection.

"From this brief sketch it will be clear that there is considerable danger in administering quinin hypodermically or intramuscularly, even with the strictest aseptic care. For this reason it is fortunate that Colonel Semple has been able to prove, by his nineteenth series of experiments, that tetanus antitoxin is a trustworthy prophylactic against tetanus when it is necessary to administer quinin by those methods. When the drug has to be administered hypodermically or intramuscularly, an injection of antitetanic serum should be given immediately before, or immediately after, the quinin injection. Colonel Semple recommends an injection of 10 to 15 c.c. of the serum into the loose subcutaneous tissues of the side of the abdomen, and states that this amount would confer upon the patient a passive immunity to tetanus for two or three weeks. If this procedure is adopted, the hypodermic and intramuscular administration of quinin can, so far as the danger of tetanus is concerned, be carried out with safety."

ANESTHETIC PROPERTIES OF MAGNESIUM SALTS

The anesthetic properties of magnesium salts were discovered through the experiments of Dr. S. J. Meltzer, of New York. He had reasoned that the phenomena of life results from the interaction of excitation and inhibition. There are four principal inorganic constituents of the body—sodium, potassium, calcium, and magnesium. Of these, the first three have been shown to possess a stimulatory effect on muscle and nerve. It, therefore, remained for magnesium to exert an antagonistic or inhibitory effect. The theory was accordingly put to test. The application of magnesium sulphate to nerve-trunks was found to block conductivity and abolish excitability. The intracerebral injection of magnesium sulphate was next tried, and found to induce a state of general inhibition; subcutaneouly, it produced deep narcosis and complete muscular relaxation; intravenously, it produced the same effect, also arresting intestinal peristalsis. Both the subcutaneous and intravenous injections produced complete muscular relaxation in tetanus, lasting often as long as twenty-four hours. These experiments were tested by many and found to be correct, but when locally applied to an open wound it did not seem to exert any sedative action.

Guthrie and Ryan, in testing the action of magnesium salts, came to the conclusion that they produce a general muscular paralysis, and in this state the animals were unable to respond to sensory stimulation, and when general anesthesia was produced it was due to the paralysis extending to the respiratory muscles, and the degree of anesthesia depended upon the degree of asphyxiation.

This contention was later disproved by Meltzer, and as confirmed by the intraspinal injection of magnesium sulphate on human subjects who were operated upon in a thoroughly conscious state with undisturbed respiration, but completely anesthetic below the point of injection. It leaves no doubt regarding the anesthetic properties of magnesium sulphate.

(For the intraspinal injection, see section on this subject.)

The intracerebral injection of magnesium chlorid has been tried on laboratory animals and found to produce complete muscular and sensory paralysis, and has been suggested as a means of anesthesia for laboratory use.

Notwithstanding the undoubted paralyzing effects of magnesium salts in tetanus, where it has been tried and found to control the convulsions, its depressing effect was too great and no reduction was accomplished in the mortality, the high temperature continuing and the patient dying from exhaustion or as a result of the action of the toxins of the disease.

Local applications of solutions of magnesium sulphate have been found to give relief when used for neuralgias, headache, pleurisy, pericarditis, and various abdominal pains. This sedative action is by no means constant and often fails, but it is a simple method and worthy of trial where opiates and other sedatives are to be avoided. This sedation is not accompanied by any local anesthesia, but seems to be through reflex action.

CHAPTER VI

TOXICOLOGY

SINCE the introduction of Schleich's infiltration anesthesia, and the knowledge that effective operative analgesia of the tissues could be obtained by infiltration and saturation with solutions even as weak as 1:20,000, caused an abandonment of the use of the strong solutions (5, 10, or even 20 per cent.) that were in common use in the early days of cocain anesthesia, with their tremendous array of fatalities or alarming symptoms which were reported from every quarter, and served largely to discredit the use of this agent or limit it to very restricted fields. At the present time, with the improvement in our methods and the addition of adrenalin and other aids and the use of solutions not exceeding 0.25 or 0.20 per cent. for ordinary filtration, or 0.5 to 1 per cent. for nerve-blocking (only a few drops being necessary), have greatly lessened or almost entirely eliminated the toxic action of this drug in general surgery to such an extent that men of large experience in its use have not had a single case of the toxic action of this drug.

In our own experience we have fortunately not had a case of poisoning from cocain or its allied drugs to deal with, but have occasionally seen these cases, and they will continue to occur in the hands of those inexperienced in its use and its dangers who uncautiously use strong solutions. In the practice of dentists and surgical specialists (eye, ear, nose, and throat), who make use of solutions stronger than those now used by the general surgeon, cases of poisoning are frequently occurring.

The solutions used in this line of work are often 1 per cent. for infiltration, and for topical application 10, 20, and 30 per cent., or even stronger, and should be used with great caution, as prevention is better than cure, applying only small quantities at a time and not to over-saturate tampons or allow the solution to drop to other parts or to run from the point of the application to be absorbed elsewhere, and always safeguarding these applications with adrenalin.

The poisonous effects of cocain and its allied drugs and other agents used for their local anesthetic action may be either local or constitutional. As illustrations of local irritating action may be mentioned the inflammation occasionally seen to follow the use of alypin and stovain in strong solutions, and the action of stovain on nerve-tissue, notably in spinal puncture; also the local necrotic action of quinin and urea, or the local destructive and inflammatory action of carbolic acid. The prolonged freezing by ethyl chlorid will produce coagulation with destruction of tissue. All these local effects are discussed in the chapters with the action of these different agents; here we propose to discuss the general or constitutional action.

In speaking of this toxic action cocain will be taken as the type, for what applies to cocain is equally applicable to all of its congeners, with perhaps very slight or inconsequential differences in some few cases.

Cocain is recognized as a universal protoplasmic poison effecting all protoplasm, animal and vegetable alike. When gradually absorbed in toxic doses, acting first as an excitant, paralysis follows after a more or less brief period of excitement. When injected into the circulation in toxic doses the stage of excitement is so short as to escape observation, paralysis taking place almost immediately.

It must be remembered that the local anesthetic action of cocain is the result of a local paralysis of the parts affected; all tissues are similarly effécted by its use, nerves of special sense, motor nerves, muscle-fiber as well as sensory nerves, and white blood-corpuscles loose their ameboid movements when in contact with its solutions; and its constitutional or central action is the result of this paralysis upon the higher nerve-centers.

This paralysis is the result of a definite chemical combination, and the longer the solution remains in contact with the tissues at the point of injection the more pronounced becomes this chemical combination, and consequently the more pronounced the anesthesia (paralysis).

These facts should guide us in its use: first, to keep within the limits of safety; secondly, to use means to retain it at the point of injection or application; and, finally, should toxic symptoms arise, to apply at once such measures (constriction) if possible as will check or delay further absorption, as well as such other measures as have been suggested elsewhere to combat this toxic action.

The soluble salts of cocain are absorbed with great rapidity. They have the power of passing with great facility through nearly all mucous membranes, so that their absorption is almost immediate when topically employed on such surfaces as the nose, throat, mouth, urethra, eye, and rectum, consequently the greater number of cases of poisoning have resulted from their use in this way.

The ultimate fate of cocain after absorption into the body is somewhat in doubt; it is believed that when slowly absorbed to be entirely broken up by the body-cells (Moreno y Maiz); when more rapidly absorbed very small quantities (5 per cent.) have been recovered from the urine.

It is believed that cocain once fixed by the body-cells (in combination with them) is not liberated from these combinations as cocain, but as constituent products, ecgonin, etc.; Glasenap believes he has isolated ecgonin from the urine. These derivatives of cocain are slightly anesthetic and slightly toxic, but much less so than cocain. As a result of the preceding statements it can be said that cocain exerts its full anesthetic or toxic action but once, and if exhausted locally there will be no constitutional reaction.

It can be further stated that that portion of the cocain which is absorbed and acts upon the general system producing toxic symptoms is the excess over that fixed by the tissues locally, consequently that much in excess of the amount needed to thoroughly saturate and combine with the tissue-cells producing in them complete paralysis; in considering this statement it must, however, be borne in mind that on very actively absorbing surfaces and in very vascular tissues, where no aids are used to retard absorption, such as constriction or adrenalin, that much of the drug is rapidly taken up and transported by the veins and lymphatics to the central nervous system before but a very limited quantity of it has had time to be fixed by the tissues and act locally. This and other statements are borne out by the clinical experiences in the cases of poisoning by comparatively small doses in comparison to the amount used under other conditions without ill effects. Mattison reports a case by Knabe where 12 drops of a 4 per cent. solution given hypodermically to a young girl of eleven years caused death in less than one minute. Garland reports a death following the application of 20 drops of a 5 per cent. solution to the gums. Hundreds of such cases have been reported, and many cases of idiosyncrasy showing poisonous symptoms from remarkably small doses; these, however, have all been in strong solutions, 1 per cent. and over, and only serve to emphasize the caution given that when using such agents to keep well within the safe limits and use only the weakest dilutions compatible with efficiency; the toxic action will vary in direct ratio to the strength of the solution and the rapidity of absorption.

Three-quarters of a grain of cocain is given as a safe average dose, but this varies within wide limits; less than this amount may produce poisonous symptoms if too rapidly thrown into the circulation in susceptible individuals, while many times this amount can be given when well diluted, distributed over a large area, and safeguarded by measures to retard absorption.

Patients who once have been poisoned by cocain often show a marked susceptibility to remarkably small doses; this fact should be borne in mind when dealing with patients who give such a history.

The power of the tissue-cells to combine with and destroy cocain is not limited to this agent alone, but is true of many other poisons, animal as well as vegetable; we may mention strychnin and snake venom, particularly in the case of snake-bite upon an extremity; all are familiar with the action of a constrictor proximal to the point of bite, thus retaining *in situ* the snake venom, allowing it to exhaust its force upon the tissues locally which intensifies its local action, often leading to extensive necrosis but saving the general system.

The same is true of cocain, many times the toxic dose can be injected into the tissues locally if retained *in situ* by the use of a constrictor or adrenalin, but particularly in this case with a constrictor, and largely diluted so as to freely diffuse it and bring it into contact with a larger number of tissue-cells, when if retained sufficiently long the strength of the drug is exhausted and little or no constitutional effect will be noted when liberated into the general system; in the case of excessive doses this should be gradually done by the intermittent relaxation of the constrictor.

The relative toxic effects of the drug when liberated into the system by various routes has frequently been the subject of study by many investigations.

Petrow found in animal experimentation that the toxic dose was two to three times greater when using a constrictor, which, however, was not allowed to remain on very long (time not given), while the lethal dose was seven to ten times greater than that needed without a constrictor.

V. Oppel, in experimenting along the same lines, found that the lethal dose of cocain when injected into the arteries is eight to ten times greater than the intravenous, while subcutaneous injections are two to three times less dangerous than the arterial and fifteen to twenty times less dangerous than intravenous injections. Other observers, in working along the same lines, have arrived at nearly similar conclusions.

In considering the above statement, it is readily understood how the intra-arterial injections are more dangerous than subcutaneous when it is realized that, even though the solution is being carried away from the centers, it does not leave the lumen of the vessels, and the time required for the circuit is comparatively short when measured by the time necessary for cocain solutions to combine with the tissues, besides the entire volume is delivered at once into the general circulation with the returning blood. The subcutaneous injections are weakened by the action of the tissue-cells outside of the vessels, and is slowly and gradually taken up to be liberated into the general circulation slowly over a considerably longer period of time.

The age and condition of the patient is also an active factor in considering the toxicology of these drugs; childhood and early youth, due to the highly sensitive and impressionable nervous system, as well as the influence which psychic impressions may play, are relatively much more susceptible to the toxic influence of these drugs than are adults; on the other hand, old age, where so often general anesthetics may be contra-indicated, is particularly favorable to all local anesthetic procedures. This question of age is considered more thoroughly under Indications and Contra-indications, as well as other conditions of the patient which may operate for or against the toxic action of these drugs. While $\frac{3}{4}$ gr. of cocain is given as the maximum safe dose that can be absorbed into the circulation at any one time, still this dose may be many times exceeded with perfect safety when largely diluted, diffused over a large area, and slowly absorbed; the danger of toxicity depends entirely upon the strength of the solution and rapidity of absorption; we have repeatedly used, 8, 10, or 12 ounces of Schleich's solution No. 1, containing 0.96 gr. of cocain to the ounce, or our solution No. 1, containing 1.2 gr. of novocain to the ounce, when performing very large and extensive operations under infiltration anesthesia, without once ever having seen any toxic effects; 32 ounces of solution No. 1, containing 38.4 gr. of novocain, was used in doing an extensive lipectomy without any disturbance. Of course, in these procedures some of the solution escapes from the tissues through the incisions, and the total quantity absorbed is in this way somewhat reduced. The precaution mentioned elsewhere, of keeping the patient recumbent with head low for several hours after operation where large doses of the drug have been used, may again be emphasized here; also when operating upon an extremity under similar conditions to intermittently relax the constrictor rather than removing it entirely at once upon the completion of the operation.

Cocain produces a veritable general analgesia as a final stage in all severe intoxications, but only when the life of the animal is seriously threatened; this is not only of interest to the physiologist, but to the surgeon as well. (See General Anesthesia with Cocain.)

The local action of cocain, aside from its anesthetic action, is that of a vasoconstrictor, producing a decided degree of anemia; it is believed that its central toxic action is ushered in by similar phenomena—anemia of the cerebrum and vital nerve-centers, producing at first a brief period of excitement or irritation, followed by paralysis; these symptoms may be of mild degree and slow to develop, passing off without serious results, or appear suddenly and end in a fatal termination within a few moments, depending upon the size of the dose and the rapidity of absorption.

Many operators have tried to prevent or lessen this central toxic action by adding to the cocain solution various drugs to combat this central vasoconstriction, or by using a combination of anesthetic drugs have hoped to be able to reduce the quantity of cocain needed to a point well below the toxic dose, even when large quantities of the solution was necessary. Thus, Stuver advised a mixture consisting of one part of cocain to two parts of antipyrin; Gluck advised carbolic acid and Parker resorcin. To combat the vasoconstriction, Thomas and Guitton have recommended the addition of nitroglycerin. All these combinations are objectionable from many points, some of them being irritant and others fully as toxic or depressing. What is wanted is to simplify rather than complicate the mixtures. The use of vasodilators having a local action is especially to be avoided, for many reasons the local anemia is desired and we try to intensify it by the use of such aids as adrenalin or by the use of cold; this local anemia, besides increasing its local action, lessens or prevents its central or constitutional action by prolonging the sojourn of the drug in the tissues, where its action is weakened or entirely exhausted.

It is also quite doubtful that such drugs are of any value in combating the toxic effects; what is better is to keep well within the limits of safety, and, should toxic symptoms occur, to meet them by other more effective means.

The symptoms of mild intoxication may be evident in loquacity, laughing, or singing, later slight nausea, vertigo, faintness, thoracic oppression; as the severity of the symptoms increase, the pulse which at first is stimulated becomes rapid and weak, respiration may be oppressed or quite rapid, great mental excitement and anxiety may occur, the patient becoming very restless with twitching or trembling of the muscles, these symptoms indicating the threatening onset of convulsions; at times the stage of excitement may manifest itself by maniacal delirium, the patient becoming violent and uncontrollable; convulsions with unconsciousness may now supervene and be followed by death. During the onset of symptoms the pupils are usually dilated, but may at times be contracted. The order and character of symptoms may vary greatly in different individuals, the stage of excitement may be absent, unconsciousness coming on at once, followed by convulsions. In some cases where the toxic dose is very large, or the patient is particularly susceptible, death may occur almost immediately from cardiac inhibition.

The onset of mild symptoms, such as loquacity or faintness, are usually controlled by having the patient maintain the horizontal position or by lowering the head of the table; this position should be continued for half an hour or longer following the disappearance of all symptoms. The use of drugs to combat poisonous symptoms must be largely symptomatic. If syncopy occurs, or the heart becomes weakened, digitalis should be used, preferably given by hypodermic, while ammonia or amyl nitrite are given by inhalation. For nervous excitement or convulsions H. C. Wood recommends chloroform by inhalations, but it would appear that ether should be better, particularly if it be proved that the central action is associated with the same vasoconstriction and anemia that takes place in its local field of action; inhalations of ether, due to the tremendous congestion which it produces in these parts, should prove of great value, besides stimulating both heart and respiration and controlling the convulsions; nitrous oxid would be equally as valuable; amyl nitrite, while producing the same congesting effect, would not exert the same controlling influence upon the convulsions.

Regarding the use of ether a very interesting report has lately been published in the "Journal American Medical Association" by Dr. J. E. Engstadt, which we quote in part as follows:

"In the first few cases I was called on to treat, strychnin and morphin in combination were used with a marked benefit. But, as cases kept multiplying, I found the action of these drugs too slow, and I decided that there must be something to counteract the poison more rapidly when life was in extreme danger. It was necessary to find a remedy that could be administered at any time and be instantaneous in its action. I soon found ether to be the required drug. This was administered as ordinarily given to produce surgical narcosis. Ether stimulates the vasomotor system, is a tonic to the heart muscles, stimulates the action of the respiratory centers of the brain and of the pneumogastric nerve, and increases the pulmonary circulation in the first stages. While cocain inhibits the action of the heart, especially on the right side, it has also a marked inhibitory action on the respiratory centers of the brain. Death may occur from feeble respiratory movements of the so-called Cheyne-Stokes type or asphyxia.

"To me ether has proved extremely valuable. It has saved what seemed hopeless cases. It stimulates the heart and the respiratory system almost instantly. The pulse becomes fuller at once and of normal tension. The marked mental excitement is allayed as the patient goes under the influence of the ether and the effect of the poison rapidly disappears. The individual regains consciousness as soon as the effect of the small amount of ether has disappeared."

To get the best results, the anesthetic is administered only to the degree of mild surgical narcosis, or, at times, even less than this. A mask should be employed and the ether given by the drop method. This is all-important. Given by the old method, the ether would only add to the danger of asyphxia by excluding air from the venous-blood engorged lungs.

It is quite interesting to compare the sedative and controlling influence of ether upon the symptoms of cocain intoxication, as reported by Engstadt, with the sedative effects of a hypodermic of cocain upon animals coming out of ether narcosis (although not operated upon), as reported by Kast and Meltzer in the chapter on Abdominal Operations.

It was thought for some time that adrenalin lessens the toxic action of cocain upon the central nervous system, but upon later investigation this has been found to be in error, and that after the cocain once enters the general circulation the use of adrenalin may increase its toxic action; this may be understood when it is considered that both produce vasoconstriction. Adrenalin greatly lessens the likelihood of development of toxic symptoms by retaining the cocain in the field of injection, and greatly intensifying and prolonging its action there, where it is largely exhausted by action upon the tissues, but after it has once entered the general circulation the adrenalin may prove a distinct disadvantage.

The observations of J. M. Berry on this subject are particularly interesting. He concludes his remarks as follows: "In the use of adrenalin-cocain care should be exercised not to inject a toxic dose of the latter, for not only does the adrenalin fail to protect the body against the toxic doses of cocain, but it seems to enhance the toxic action."

Thriss found, by experiments on cats, that cocain and adrenalin, when injected into the lumbar sac, had the same toxic effect as when cocain was used alone. Miles and Muhlberg, in a series of experiments upon animals for the study of the comparative value of adrenalin and other substances upon vasomotor depression artificially produced, conclude that "adrenalin subcutaneously is indicated on theoretic ground for the vasomotor collapse following cocain or chloroform poisoning, etc." Here, however, it is to be used to combat a symptom, and not in any sense as an antidote.

Braun, in his book on local anesthesia, and elsewhere in the "Archiv. f. klin. Chir.," vol. lxix, does not concur in these views, but believes that adrenalin lessens the central toxic action; on the other hand, Petrow found that adrenalin did not seem to exert any great influence upon the toxic action.

Morphin, while highly valuable as a preliminary injection to all major operations with local anesthesia for the purpose of preventing psychic influence, and is a constituent of Schleich's solution, has probably no value at all as an antidote, and should rarely be used, or only cautiously, for this purpose. Vaillard condemns the use of morphin. He concludes: (1) There is no antidote to cocain-poisoning. (2) Authorities do not favor the use of narcotics in this condition. (3) There is no evidence to show that morphin has any neutralizing effect to warrant its use as an antidote in a case where an overdose of cocain has been taken, and, under such circumstances, it is not merely of doubtful benefit, but may prove positively dangerous. (4) The administration of morphin in a case reported did not prevent death, but may have exerted a modifying effect upon the terminal convulsions.

The use of intravenous salt injections, as recommended for all poisons, may be tried for cocain when time permits. The diluting effects of a pint or quart of normal salt solution should have a favorable influence in weakening the toxic strength of the drug, as well as stimulating the heart and favoring more rapid elimination.

Carlo Bozzo found that the minimum fatal dose of cocain for dogs, injected hypodermically, was 0.025 gram per kilo, without infusion, but when infusion was resorted to the minimum fatal dose rose to 0.03 per kilo; he concludes that besides favoring rapid elimination it retards the absorption of further quantities of the drug, owing to the fulness of the blood-vessels.

The development of toxic symptoms from the use of cocain may be considerably delayed, or, after apparent recovery, the patient may again sink into a state of syncopy or collapse. As an illustration of this condition, the author was called to see a case of convulsions in a young man twenty-four years old, and obtained the following history: Two hours previously he had had two molar teeth extracted by the use of local injections of cocain; it was necessary for the dentist to make repeated injections before securing the necessary anesthesia; the extractions were finally painless; following the procedure there was slight nausea and some vertigo, for which he was given a drink of whisky, when he appeared to recover, and was able to go home in the street cars a distance of about twenty city blocks; after arriving at home he felt uneasy and restless and sat in a chair in his gallery; he was found sometime later by his family, still in the chair, but in a state of convulsion; when the writer arrived he had had several such seizures, at intervals of about fifteen or twenty minutes, becoming quite uncontrollable and violent just before their onset; as I had learned the nature of the case I went prepared. The patient was frantic upon my arrival, requiring the combined efforts of several of the family to hold him; his pupils were widely dilated, face very pale, studded with large drops of perspiration, and his expression one of terror; the respirations were rapid and shallow, the pulse small, feeble, and rapid. We at once threw the patient across the bed, where he was held while I administered ether by the drop method to the point of superficial anesthesia; with the beginning of the ether administration there was an immediate change, the respirations deepened, the pulse slowed and became fuller, the color returning to the face, the muscles which had been tense soon relaxed; the entire picture was changed, the patient presenting the usual appearance of one under light ether narcosis; this was kept up for about fifteen or twenty minutes and gradually suspended. The feet and hips were then elevated upon pillows until the head was quite dependent; this position was maintained while the patient came from under the influence of the ether and for sometime afterward. I remained with him for about one-half hour after he appeared normal to make sure that there would be no return of the symptoms, but beyond a feeling of exhaustion there was no further disturbance. Next day he appeared quite normal; later examination of his kidneys and other organs failed to show anything abnormal.

J. K. Pedley reports a case related by Dr. B. Christensen, in which a young woman aged twenty-eight had the root of a tooth extracted under novocain anesthesia and died several hours later: "At 1.45 P. M. I injected about $1\frac{3}{4}$ c.c. of a little less than a 2 per cent. solution of novocian-suprarenin (Tab. B. Containing novocain, 0.1 gram, suprarenin, 0.00045 gram), but as the anesthesia was insufficient ten minutes later I injected some more, in all about 3 c.c. The patient felt rather unwell afterward and was advised to remain in the office and lie down.

"From 4 to 4.30 she was sitting up and chatting; at 5.30 she had so much improved the doctor left her; at 6.30 his wife noticed her and she seemed to be in a natural sleep; shortly later noticed her breathing rather deeply and on examination found her almost pulseless; gave camphor by needle.

"At 7 P. M. doctor returned and performed artificial respiration, at 8 P. M. was removed to the hospital, and died one hour later, without regaining consciousness, with symptoms of edema of lungs."

Cases of this kind could be reported in great number, but the above will suffice for an illustration.

To recapitulate: With the onset of the first symptoms immediately place the patient in a recumbent position and lower the head; if the operation has been upon an extremity apply a constrictor proximal to the field; give ammonia or amyl nitrite by inhalation; if the case seems severe, lightly narcotize with ether by the drop method; use digitalis or oil of camphor by needle if the heart is weak; in severe cases use infusions of normal salt solutions if convenient; should the respiration cease artificial respiration should be resorted to and persisted in as long as the pulse or heart is perceptible or even longer, as there may be a chance of resuscitation. Legrand reports a case where it was necessary to continue artificial respiration for five hours before the function became normal. In such cases, where the facilities are at hand, use the Meltzer-Auer intratracheal intubation with forced respiration.

Some of the earlier cases of poisoning may have resulted from the presence of certain impurities in the preparation used, and this may even occur now, though not so likely, as the methods of manufacture and safeguards placed around it have so far improved as to reduce this likelihood to a minimum.

Some of these impurities have never been determined, but a few have been isolated and positively identified; two of these, which in the past have been most likely to occur, are isatropylcocain and cinnamylcocain, both highly toxic; as these impurities act in different ways, some of the peculiar toxic symptoms reported may be accounted for in this way.

CHAPTER VII

ADRENALIN

Adrenalin, the therapeutic constrictor, known under several names as suprarenin, paranephrin, epirenin, eudrenal, and epinephrin, but probably better known in this country as adrenalin, the name proposed for it by Takamine (and the synthetic preparations of arterenol, homorenon, and suprarenin synthetic), are powerful local and constitutional vasoconstrictors, and, except the latter, obtained as an extract from the suprarenal glands of animals.

The introduction within the last ten years of this highly valuable and wonderful agent has proved a great boon to many departments of surgery, and has given a decided impetus to all local anesthetic procedures. Next to the possession of safe local anesthetics and the Schleich infiltration method (with dilute solutions), there is no single agent or factor which has fostered and encouraged the development of local anesthesia, and enabled surgeons to enlarge the field and broaden the scope of all purely local procedures.

This has been made possible by the unique power this agent exercises of producing vasoconstriction, and retaining within the tissues the dilute anesthetics which both intensifies and prolongs their action for a period of time usually well beyond that required for the performance of any ordinary operation, and that without injury to the tissues.

To Prof. Heinrich Braun, of Zwickau, Germany, from whom we have quoted quite liberally in this volume, is largely due the credit of first introducing, developing, and perfecting the use of this agent in local anesthesia. Already a staunch advocate of local anesthesia, in which field he has been a constant worker, he was quick to see the advantages of a combination with adrenalin and early advocated its use, and it is largely due to his efforts in this direction that adrenalin became so popular an adjunct in all local anesthetic solutions so shortly after its introduction.

Adrenalin has become almost indispensable to the surgical specialists, particularly in the nose and throat, where it is in constant daily use, both for purposes of examination as well as for operations; in examinations it greatly facilitates the procedure when swabbed or sprayed on turgid and congested mucous passages, causing them to shrink and permit free access and inspection of the deeper parts. Nearly all operations upon these parts are greatly facilitated and simplified by its use, which renders the field almost entirely bloodless, thus greatly expediting the work, which enables the operator to undertake many operations in the office without assistance under local anesthesia and without the loss of any blood, which formerly were done only in institutions under general anesthesia, with considerable loss of blood and a much more complicated and tedious technic.

The history of the early work which led to the discovery of adrenalin is not without interest, but only brief mention will be made of it here in expressing our gratitude to those who have given us this valuable agent. Early anatomists observed that the juice of the medullary substance of the suprarenals darkened upon exposure to light and air; they called this substance *atra bibis*. It was not, however, until the nineteenth century that the color change was understood. Vulpian in 1856 noticed that this juice, when brought into contact with ferric chlorid and iodin, turned emerald green and then rose carmin. These reactions were characteristic of this organ, and led to the opinion that the gland contained a physiologic substance.

Pellacani, as early as 1879, performed a very interesting series of experiments in Foa's laboratory by injecting an extract of the fresh glands into various animals. Mattei later repeated Pellacani's experiments, and came to the conclusion that his results were those of septicemia rather than from any special active principle of the gland.

In 1883 Foa and Pellacani again took up the study and published some interesting results, and it would seem, after reading the original papers of these early writers, that more credit should be given them, for they certainly describe symptoms of poisoning which are now recognized as characteristic of adrenalin.

Other investigators followed up this line of work: Krukenberg (1885), Marino-Zuco (1888), Guarnieri and Marino-Zuco (1888).

The synthetic preparation of this agent began to be foreshadowed as early as 1893 by the work of Dr. Zierzgowski, who should be given credit for pioneer work in this line.

Gluzinski (1895), Moore (1895), Dubois (1896), and Vincent (1897) were other workers with these glands. In 1896 Fränkel suggested sphygmogenin as a name for the active principle of the gland; this was, however, later shown to be a mixture.

The work that had been done by the earlier investigators prepared the way for that which was to follow; the subsequent investigations began to yield better results in isolating the active principle of these glands. Dreyer had also been able to isolate the active principle of the suprarenals in the veins coming from these glands.

Batelle (1902) claimed to have obtained a purer adrenalin than that produced by Takamine's method.

In the meantime enough data had accumulated to attempt the synthetic preparation, although, as has been mentioned, Dzierzgowski in 1893 had done creditable work in this line. Stolz succeeded in producing the so-called dl-product, which was found to be somewhat different from the natural base. This was found by Flacher to be due to dextro and levo components which he was able to separate, and found that the levo-adrenalin was identical with that obtained from the glands. The action of this principle began now to be extensively studied, and Cybulskilgo pointed out that concentrated doses were much more poisonous than when diluted; and Gluzinski determined that intravenous doses were more toxic than subcutaneous. The physiologic investigators began now to become more numerous, and the literature of this subject is filled with the names of prominent investigators.

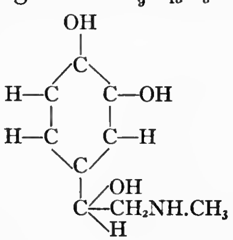
In 1895 Oliver and Schäfer, and Szymonowicz and Cybulski, working independently, discovered the action of certain suprarenal bodies upon the circulation.

Abel in 1897, working along the same lines, was able to isolate a body which he called epinephrin.

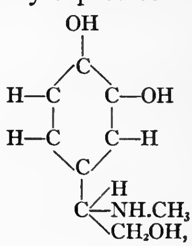
In 1900 Von Furth described suprarenin, and in 1901 Takamine and Aldrich isolated a principle which Takamine called adrenalin. It is probable that these two last substances are identical, while epinephrin seems to be different both chemically and physiologically. Abel regards adrenalin as an epinephrin hydrate.

Investigations regarding the relative merits of the synthetic preparations (dl-adrenalin, known commercially as arterenol, and the ethyl-amino-aceto-catechol, known as homorenon) conclude that the former is about two-thirds as active as the natural product and the latter about one-eightieth as strong.

The chemical formula of adrenalin, as analyzed by Stolz, Aldrich, and others, is given as $C_9H_{13}O_3N$ and graphically expressed—



or



the former of which is generally accepted as correct. Following the analysis, adrenalin has been synthetically prepared; these synthetic preparations have, however, until lately found little favor in this country, but have become popular abroad.

Adrenalin is easily affected by light, which decomposes it; it is, therefore, always best kept in the dark and in dark-colored bottles. When decomposing it first becomes faintly rose colored, then of a brownish-red color and turbid; when in this condition it should never be used, as it may be irritating or even poisonous; only absolutely clear and colorless solutions should be used.

That part of the physiologic action of adrenalin which concerns us here is limited to its action upon the circulation in any given operative area when locally used. For a consideration of its highly interesting action in other spheres of its influence, particularly its constitutional effect in its many clinical uses, the reader is referred to the various articles which deal with this subject. (See especially Crile, Boston Med. and Surg. Jour., March 5, 1903, and Amer. Jour. Med. Sciences, April, 1909; Miles and Mühlberg, Cleveland Med. Jour., Dec., 1902; also Winters, Lancet, June, 1905, and others.)

Only such clinical illustrations will be mentioned here as will serve to emphasize its great power as a vasoconstrictor, and, under certain conditions, a stimulant to all smooth muscle-fibers.

The action of adrenalin in constricting the blood-vessels is both local and constitutional; the latter effect is quite general throughout the body; its local effect is best studied when injected locally in dilute solutions, when it produces a high degree of anemia of marked duration; that portion of the drug absorbed exercises a constitutional effect. Lehman found that by injecting solutions of adrenalin into the liver of experimental animals he was enabled to excise large sections of this organ without loss of blood; this marked anemia lasted thirty to forty minutes and was not followed by secondary hemorrhage. This vasoconstrictor action does not seem to depend upon any influence upon the vasomotor nerves, but is no doubt due to direct action upon the smooth muscle-fibers in the vessel walls, as shown by the following experiments. Crile was able to keep the heart of a decapitated dog acting for over ten hours by the action of adrenalin and saline solution upon the heart and blood-vessels, and in sufficient dosage to be able to produce a marked rise in blood-pressure even when the vasomotor center was proved to have been exhausted (complete shock); the same result was produced when the center was cocainized or had previously been destroyed; it also occurred after the division of both vagi and both accelerantes when the animal was under the influence of curare. It was also noted during these experiments that adrenalin was capable of constricting the blood-vessels after the circulation had ceased.

Animals killed by asphyxia, and apparently dead for periods up to fifteen minutes, were restored to conscious life again by artificial respiration and the simultaneous injection into the jugular vein of adrenalin and salt solution.

The circulation and respiration of dogs electrocuted by a shock of 2300 volts of an alternating current were again re-established by injecting adrenalin solution into the circulation.

During these experiments it was determined that adrenalin was rapidly oxidized by the solid tissues of the body as well as by the blood.

Animal experimentation conducted by writers under slightly different conditions showed similar results.

From these and similar experiments it is concluded that the action is a direct one exercised upon the smooth muscle-fibers in the vessel walls; all smooth muscle-fibers seem influenced in a similar way, though not always to the same degree (Jacoby and Schäfer). It is found to exert a marked influence upon the uterine muscles, as illustrated in a case of Cesarean section operated on by Bogdanovics, in which, after the delivery of the child, the uterus was found flabby and inert. The uterine wound was first closed and 1 c.c. of a 1:10,000 solution of adrenalin injected into the uterine walls at four different points; this at once excited muscular action and the contracted uterus became as hard as stone.

The blood-vessels of the different organs are not all influenced to the same degree; the action on the vessels of the skin is most marked, less so in the gastro-intestinal tract and bladder, and hardly at all in the vessels of the lungs (Langley). The urine of animals injected with large doses of adrenalin is capable when injected into other animals of raising the blood-pressure; but it would seem that this agent is very largely destroyed in the body, very little of it being excreted. Ott and Harris, Meltzer and Auer found that by mixing strychnin with adrenalin before injection into frogs the toxic action is both delayed and diminished; this observation is of great practical value in local anesthesia, as will be presently pointed out.

A similar favorable action of adrenalin has been noted in the treatment of snake-bite in 3 cases recently reported by Drs. Hooker, Menger, and Ferguson, all occcurring in the state of Texas.

In 2 cases the snake was a rattler, in the other case a moccasin. All bites were upon the extremities, and occurred from one to two hours before treatment. Various procedures were resorted to—scarification or incisions into the wound, injections of permanganate, with the use of a constrictor reported in 1 case—but all were treated with adrenalin in addition, injected into the tissues near the site of the bite. All cases recovered in a short time without any notable local or constitutional after-effect; the adrenalin was largely given the credit for their favorable termination. It is probable that in these cases the adrenalin, through its vasoconstriction, retains the snake venom in the parts locally until it is largely oxidized or destroyed by action upon it of the tissues.

Dr. K. C. Bose, of Calcutta, gives his experiences in the treatment of enlarged spleens, where he claims invariably satisfactory results. Tremendous enlargements have yielded to 5-drop doses three times a day, continued for a period of several weeks. Interesting and somewhat similar experience was reported by Dr. Tarry, of Long Beach, Miss. Another practical clinical application of adrenalin, which illustrates in a striking way its local action upon the vascularity or congestion of a part, is readily seen in urethral stricture, particularly of the deep urethra; tight strictures of these parts, when it seems almost impossible to pass even a filiform, if first treated with adrenalin (about 5 to 10 drops of a 1:5000 solution), deposited in the urethra with an urethral instillator just in front of the structure and allowed to remain about ten minutes, will often so relieve the congestion of the parts, which is always a contributing factor in strictures, as to fairly easily permit the passage of a moderate-sized instrument. Further clinical applications could be enumerated in great numbers, but the above will suffice to illustrate its highly valuable local action as a vasoconstrictor.

Before, however, concluding these illustrations a few remarks may be made regarding its highly beneficial and useful action in certain rectal conditions, notably hemorrhoids. In this condition, when the parts are badly swollen and congested, which increases their irritability, marked relief may be obtained subjectively and objectively by the use of adrenalin, either alone or combined with other indicated agents in ointment form, which relieves the congestion, causing the parts to shrink and assume a more normal aspect.

In all operations upon these parts when they are badly congested and bleed freely, either under general or local anesthesia, the injection of adrenalin solution is always of decided benefit; under general anesthesia the injection of a few syringefuls of a solution of 10 drops to the ounce distributed in the field will prove of decided aid.

Hurter and Richards, as well as others, have demonstrated that this agent in large doses or when repeatedly used will produce a glycosuria.

Vincent claims that this agent is a muscle poison, death resulting from the use of large doses by paralysis of respiration with small weak pulse, which follows a short period of high blood-pressure.

The dose of adrenalin should be carefully considered, as large doses are very dangerous; the greater the concentration the greater the toxic action. In very dilute solutions a much larger quantity can be safely given; the toxic dose is naturally much smaller when given intravenously than when subcutaneously administered.

Batelle, Bouchard, and Claude give the toxic intravenous dose for rabbits as 0.0001 to 0.0002 gram per kilo, while the subcutaneous toxic dose is 0.002 to 0.02 per kilo. Batelle states that the toxic dose subcutaneously is forty times greater than the intravenous.

The degree of action of this drug depends entirely upon the strength of the solution. While a decided influence is obtained by remarkably weak dilutions, the use of stronger solutions will absolutely obliterate the lumen of vessels the size of the palmar digital arteries and even larger, so that not a drop of blood will escape from their cut ends while the adrenalin remains in action.

It is, however, never necessary for our purposes to use strong solutions, as a very decided influence is produced by very dilute solutions. Moore and Purinton found that the blood-pressure of dogs was noticeably increased by doses as small as 0.000,000,245 to 0.000,024 gram of the extract per kilo of dog weight.

In animals experimented upon with toxic doses, after a short initial rise of blood-pressure, there is a collapse of the vasomotor system with small rapid and feeble pulse, paralysis of the extremities, tonic and clonic spasms, opisthotonus, mydriasis, rapid respiration, edema of the lungs, anemia of the abdominal organs, and death usually from paralysis of respiration.

Its continuous injection in small doses produces in animals experimented upon calcareous degeneration of the heart, aorta, and great vessels with glycosuria.

The experiments carried out by Braun with adrenalin upon himself during 1902 are given in his "Die Lokal Anesthesie," and are as follows: He injected under the skin of his forearm adrenalin solution 1:1000 in increasing doses; with a little over $\frac{1}{2}$ c.c. constitutional symptoms were noticeable. He states: "Five minutes after injection I had a feeling of oppression in the breast, cardiac palpitation with quickened and deepened respirations; the number of heart-beats rose from 64 to 94 per minute. I was compelled to lie down, although after one and a half minutes the symptoms disappeared; there was no glycosuria. When I diluted the adrenalin solution with ten times the quantity of normal salt solution, I was able to increase the quantity injected to 1 c.c. before any effect was observed."

The pronounced effect exercised by adrenalin in delaying the absorption, and consequently the constitutional action and excretion of any substances or drugs injected into the tissues in combination with it, is best studied when the adrenalin is used with some agent

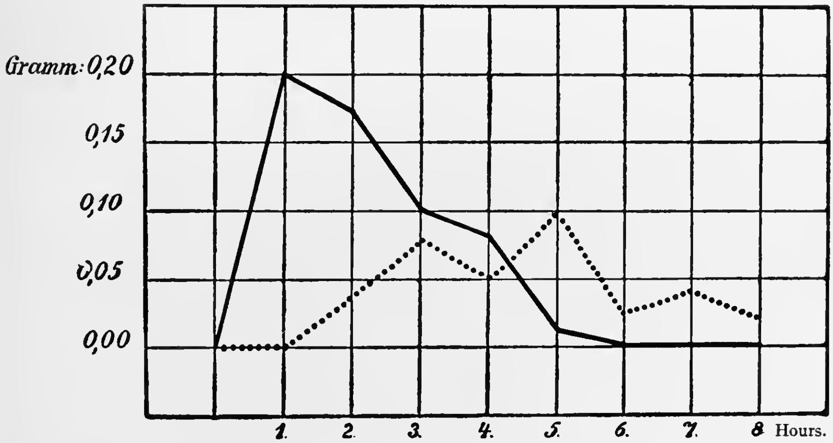


Fig. 2.—The influence of adrenalin on the excretion of milk-sugar in the urine following its subcutaneous injection: ▬▬ without, ... with adrenalin, after Klapp (Braun).

little or not at all affected by its passage through the system. This action is strikingly illustrated by the following experiment of Klapp with the use of milk-sugar, first carried out as a control experiment without adrenalin, and later repeated under identical conditions with the addition of adrenalin.

A dog was injected subcutaneously in the region of the back with 10 c.c. of a 6½ per cent. milk-sugar solution, and the excretion of the sugar through the urine studied from hour to hour. Three days later the same quantity of the same solution, with the addition of 2 drops of adrenalin 1:1000, was similarly injected and the excretion by the kidneys studied in the same way.

A study of Fig. 2 will give in a schematic way the results of this experiment. It will be seen at a glance that the maximum excretion of sugar without adrenalin, as indicated by the heavy line, begins immediately after the injection and reaches its maximum intensity within the first hour, when it rapidly falls off and entirely ceases after the sixth hour, by which time a total of 0.569 gram had been recovered from the urine.

The dotted line indicates the absorption and excretion of the sugar under the local influence of adrenalin, and presents a striking and interesting contrast to the former in the following points: During the first hour, in which the maximum is excreted without adrenalin, absolutely none was recovered when the adrenalin was used, the excretion not beginning until the commencement of the second hour; from this time it slowly increases, reaching its maximum at the end of the fifth hour, and that at this maximum point of excretion the amount was one-half that recovered during the interval of maximum excretion without the use of adrenalin; further, that the excretion is prolonged over a very much longer period, as traces were still found in the urine at the end of the eighth hour, when the observations were discontinued, after a total of 0.343 gram had been recovered.

In the strengths ordinarily employed its use is not followed by any after-reaction; there is not hyperemia, but the tissues gradually resume their normal vascularity, and there seems to be no retarding or injurious action upon the healing of wounds; when slightly more than the dose to be recommended has been used, it has seemed to the writer that there was more after-pain in the wound than would have been the case under other conditions associated with a reactionary hyperemia.

As ordinarily used by the author for infiltration, the dose should never exceed 5 drops of a 1:1000 solution to the ounce of the anesthetic fluid, and less than this, 2 or 3 drops, will be found amply sufficient.

It is well in all large operations to estimate about the total quantity of the anesthetic solution likely to be needed—say, for a rather large hernia, 4 to 6 ounces may be required; this is measured off and put in a convenient receptacle, and to this total quantity about 15 or 20 drops of the adrenalin solution (1:1000) is added; in this way we know exactly how much is being used and the safe dose need not be exceeded; we obtain by these weak dilutions all that can be accomplished by stronger doses, and without noticeable constitutional action or other ill effects. As the action of adrenalin is immediate it is not necessary to wait to obtain this influence, but a delay of five to ten minutes is usually necessary after the infiltration to obtain the full anesthetic effect of the drug used. When the incision is made the first effect noticed will be the anemia of the parts, practically no blood being lost except from the mouths of divided vessels. When adrenalin is used in the above-mentioned strength this anemia lasts approximately one hour; this is influenced to a considerable extent by the normal vascularity of the part; it is consequently of shorter duration about the face and in abnormally vascular parts; in these parts the maximum dose, 5 drops to the ounce of anesthetic solution, may be found necessary.

The advantages of this anemia are the greater facility and freedom with which delicate dissections may be performed in a comparatively bloodless field. Aside from the hemostasis, the most notable gain derived from the use of adrenalin is its power to retain the anesthetic agent within the tissues for a considerable length of time, from three-quarters of an hour to an hour and a half in the strength above mentioned (not over 5 drops to the ounce of solution); when stronger solutions are used this anemia and prolongation of the anesthetic action of the agent used may be considerably extended—as long as three or four hours in some cases.

This retention within the tissues intensifies the anesthetic action and lessens the likelihood of repeated injections being necessary in a prolonged operation, thus avoiding the trauma of repeated infiltrations upon the tissues, and eliminating the possible toxic action of such repeated infiltrations, as well as lessening the likelihood of any toxic action developing from the solution injected by retaining it in the tissues for such a long period of time that its activity is largely weakened or destroyed, and when absorption does occur it is so gradual that no constitutional effects are to be noted. This permits the use of much more extensive infiltrations than would otherwise be safe without the addition of adrenalin; in this way we have repeatedly made use of 8, 10, 12, or more ounces of Schleich solution No. 1, or our solution No. 1, in extensive operations without once having seen any toxic effects arising from the large quantity used. Of course, in all operations under infiltration a certain variable quantity of the solution infiltrated escapes through the incisions, which to some extent lessens the total amount of the drug finally absorbed.

Ordinarily, in operations upon the peripheral parts of the extremities under local anesthesia, with the addition of adrenalin, the constrictor may often be dispensed with, except for hemostatic control of the larger vessels, as in amputations, when it should always be used.

When used in these operations it should always be applied after the infiltration or nerve blocking has been completed; in the case of the latter procedure it may be necessary to apply it below the point of the nerve injection, but in case of infiltrations it should always be applied proximal to the field of infiltration. When used in this way with adrenalin it intensifies both the action of the adrenalin as well as that of the local anesthetic used (the anesthesia is probably also contributed to by the fact that anemic tissues are always less sensitive than vascular), and prolongs indefinitely the local anesthetic action of the agent used as well as the adrenalin; this prolongation of the action of these agents in this way is only limited by the time that the constrictor may safely be allowed to remain in position (from one to two hours, depending upon the age of the patient and condition of the parts locally). A very important point in the technic in operating in any field with the use of adrenalin is to make ample provision for hemostasis after the effects of the adrenalin have subsided; bleeding points which barely permit a capillary ooze at the time of operation may, after the vasoconstriction subsides, give rise to a rather free hemorrhage; for this reason, it is absolutely necessary to secure and ligate all visible bleeding points, and leave no dead spaces for the accumulation of hematomas; this may be accomplished by approximating the different planes of tissues, as in a herniotomy, by anchoring the overlying plane to the one beneath by occasionally passing the suture down and catching a bite in the plane beneath, thus uniting the various layers at the suture line and preventing a possible space for the accumulation of ooze. In operating upon very loose tissues, as the scrotum, it is very essential to finish the operation by a firm supporting dressing, held snugly in place by a well-fitting suspensory. In operations within the nasal cavity, and in such wounds as are left open, postoperative bleeding should be guarded against by the proper use of packs.

All the agents in use as local anesthetics are not equally effected by adrenalin; this degree of influence varies with the different agents.

Beta-eucain is affected to a less extent than cocain and the same with stovain, while with tropococain it has little or no effect. Novocain is decidedly affected, its action being greatly intensified and prolonged by its addition.

Other effects noticed by these combinations are that when used with cocain, which has a slight vasoconstrictor effect, that the resulting anemia is slightly more marked than with such agents as novocain (Fig. 3).

Large operative fields can be rendered completely bloodless by its use; here it is not necessary to thoroughly saturate the entire field with the solution, but to make the injections in a peripheral or circumferential manner around the field, as with the Hackenbruch plan for local anesthesia, or only in the directions from which the circulation enters, thus constricting all vessels which enters the operative area; this use of the agent may often be of value when operating upon very vascular areas even under general anesthesia.

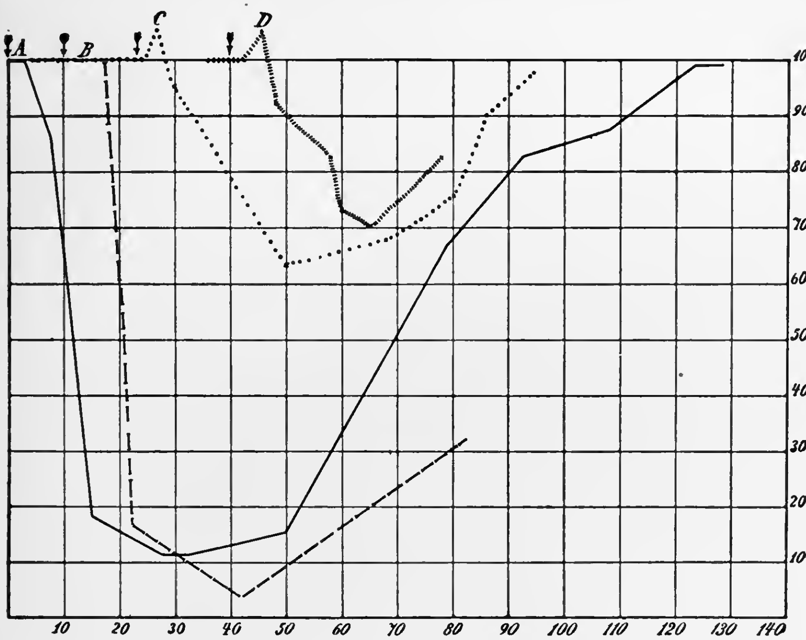


Fig. 3.—Illustrating diagrammatically the action of adrenalin in combination with different anesthetics (after Läwen): *A*, Adrenalin; *B*, adrenalin with cocain; *C*, adrenalin with eucain; *D*, adrenalin with tropococain (Braun).

To obtain this perfect anemia in operating upon the extremities, unless at the extreme distal parts, it will be necessary to make the injections on the distal as well as the proximal side of the field, to influence, on the one hand, the veins; on the other, the arteries as they enter the field.

The synthetic preparations, such as arterenin, homorenon, and suprarenin synthetic, are found to be identically the same in formula and action as adrenalin. Braun found that homorenon was about fifty times less toxic and fifty times less active than adrenalin, and does not cause any injury or irritation to the tissues.

The synthetic preparations of adrenalin have until recently been little used in this country, surgeons preferring the natural product, which had so far proved best and has answered all requirements; all that the synthetic chemists have attempted is to imitate adrenalin, none have surpassed it. The comparison of these synthetic preparations with adrenalin has been undertaken by some observers, thus, Biberfeld states that synthetic suprarenin is identical both by qualitative and quantitative test with the natural preparation, while arterenin seemed slightly weaker, at least in rabbits, the toxic dose being two or three times greater. Braun, who has experimented with both solutions, finds them in 1:1000 dilutions about equal to the natural preparations; both preparations possess certain qualities in common with the natural preparation; they must be kept in slightly acid solutions (HCl); they have but a limited stability, and must not be used when cloudy or discolored. Regarding the synthetic preparations of homorenon Braun has much to say in favor of it; it is quite soluble and stable and presents identical pharmacologic qualities with adrenalin, but about fifty times weaker in action and fifty times less toxic. A 5 per cent. homorenon solution is, therefore, equal to a 1:1000 solution of adrenalin, and produces a vasoconstriction equal to that of corresponding strength. When used intracutaneously and subcutaneously it produces no irritation or after-reaction.

That ideal synthetic preparations of the adrenal glands will eventually be obtained which will entirely replace the animal extracts is to be expected, as has been the case with local anesthetics, novocain representing the greatest and latest achievement in this line.

The animal extracts have many disadvantages, principally their lack of stability, inconstancy of action, the inability to properly sterilize them by heat, and their cost, which, when considered with their poor-keeping qualities, makes this cost relatively greater.

The latest achievements in synthetic adrenalin is suprarenin synthetic; this agent has now been very thoroughly tested, and seems to meet all requirements and demands made upon it. In 1:1000 solution, as ordinarily used, its rapidity, intensity, and duration of action compare very favorably with the natural product, some observers claiming for the synthetic product slight advantages.

It is further capable of a fair degree of sterilization by heat (boiling from three to five minutes); it is more stable in keeping qualities and is cheaper.

While the writer has had but a limited experience with this preparation the reports from others are rather encouraging, and it gives promise of fulfilling all requirements exacted of it, and will, if further experience justifies these claims, largely, if not entirely, replace the organic preparations.

The following experiments, reported by Braun in his book on local anesthesia, should be compared with similar experiments made by the same author with similar solutions, but without the addition of adrenalin, and quoted on page 87. (See chapter on Local Anesthetics.)

"(1) To 100 c.c. of a 1 per cent. alypin solution 5 drops of adrenalin (1:1000) were added. With this solution an intradermal wheal is formed; the injection is painful. No hyperemia occurs, but the adrenalin anemia develops to full extent. The white wheal lies within an area covered with large white blotches. The anesthesia lasts for about two hours, when the sensibility gradually returns. An hyperemic infiltrate remains at the point of injection until next day.

"(2) 0.5 per cent. solution, with the addition of 0.8 per cent. sodium chlorid.; 1 c.c. of this solution, to which has been added 1 drop of 1:1000 adrenalin, is injected in a circular manner into the subcutaneous tissue at the base of the fourth finger.

"The injection is painful; after ten minutes the entire finger as far as the tip is entirely anesthetic. After two hours the sensibility begins to gradually return, and after three hours is completely normal.

"The base of the finger remains red, infiltrated, and painful for several days; 0.5 per cent. cocain or eucain solution with the same addition does not produce this final phenomena.

"(3) 1 per cent. isotonic novocain solution and 5 drops of adrenalin solution (1:1000) to each 100 c.c. The formation of cutaneous wheals on the forearm by intradermal injections were painless and produced a very pronounced anemia. The duration of the anesthesia lasted longer than an hour and left no reaction.

"(4) 1 per cent. novocain solution with 2 drops of 1:1000 adrenalin to each cubic centimeter. Formation of wheals on the forearm; injection painless. The anesthesia, which extended considerably beyond the limits of the wheal, lasted about four hours. The action of the adrenalin is very marked.

"After subsidence of the adrenalin anemia some after-pain results at the site of injection. No other reaction.

"(5) $\frac{1}{2}$ c.c. of the same novocain-adrenalin solution was injected subcutaneously in the forearm. The skin over the point of injection, as well as the distribution of the sensory nerves which passed through the injected area, was insensitive to pain for from two and a half to three hours. Pronounced adrenalin influence. No reaction.

"(6) 0.5 per cent. novocain solution with the addition of 1 drop of adrenalin (1:1000) to each cubic centimeter; 1 c.c. of this mixture was injected subcutaneously in a circular manner around the base of the fourth finger. After ten minutes the entire finger is anemic and insensitive.

"After sixty-five minutes sensation begins to return in the finger-tip, requiring a full hour for the complete return of sensation. There was no after-pain or swelling."

In conclusion, a few words regarding the dose of adrenalin: 10 minims is about the safe maximum dose which should be thrown into the circulation of a normal healthy adult at any one time, but as the dose varies with the concentration this amount may be exceeded when largely diluted and distributed over a large area, as in infiltration, from which it will be slowly taken up. The dose should vary according to the age and condition of the patient, childhood, old age, arteriosclerotics, and those suffering from lesions of the vascular system, high blood-pressure, Graves' disease, etc., are more susceptible to its influence. The dose in these cases should be lessened accordingly.

CHAPTER VIII

PRINCIPLES OF TECHNIC

GENERAL CONSIDERATIONS

In considering in its broadest sense the advisability or utility of performing major operations under purely local methods of anesthesia, as opposed to the use of cerebral anesthetics, one must consider primarily the risk to the life of the patient.

Notwithstanding the many advances that have been made in the administration of general anesthetics, particularly in the administration of ether by the open method, the risk from general anesthetics remains relatively high. Many well-appointed institutions, where the anesthetics are given by professional anesthetists, are able to present large series of cases, 10,000 to 15,000, without a death, but these are exceptional illustrations, and cannot be accepted as representing the average conditions which prevail in the great majority of institutions, or which occur during the administration of anesthetics outside of institutions.

We had been led to believe that due to our improved methods and the diffusion of knowledge regarding the administration of anesthetics the mortality, both primarily at the time of the administration and secondarily due to the renal, pulmonary, and other complications directly traceable to the anesthetics, had been very materially lessened of late. This has been largely dissipated by the report of Neuber to the Surgical Congress of 1909, in which he shows that the mortality remains about what it was many years ago. Many of the more recent statistics published represent results in large surgical centers, where the administration of anesthetics is largely in the hands of experts and cannot be accepted as representing the general results. Neuber collected many thousands of cases (previously published and unpublished), and was able to show that the deaths from chloroform average 1 to 2060 and those from ether 1 to 5930, thus raising the mortality to about where it stood a decade ago.

"In view of the preceding fact, is it not proper that while we are seeking by every means suggested by reason, ingenuity, and experience to minimize the dangers of these necessary evils—general anesthetics—that we also continue to develop and perfect the various methods of local and regional anesthesia, which permit us to accomplish the same results without peril to the organism or injury to the part involved? If this great desideratum can be realized in a constantly increasing number of surgical conditions by a skilful and judicious application of cocain and its succedanea, why not resort to these methods oftener whenever they can be advantageously applied and thus help to eliminate, or at least diminish, one of the greatest sources of anxiety in surgical practice?" (Matas).

Admitting that local methods of anesthesia possess certain disadvantages to the operator, in view of the increased time required and the greater attention often necessary to bestow upon the patient, such methods of operating will always be unpopular in very large clinics, where a large number of cases are operated daily; still the advantages to the patient are often so great as to make local methods of operating the method of choice in many cases.

To the great majority of operators, whose patients are brought into the operating-room before being anesthetized while the operator waits the completion of anesthesia, this loss of time is unnecessary with local anesthesia, as the operator may begin the anesthetizing process at once, and with many of the commoner performed operations the actual time spent in the operating-room is no greater than under general anesthesia.

We must also face the broad proposition of whether or not it is desirable that the patient retain consciousness during the performance of the operation. Obviously, if we took the view that such consciousness was wholly undesirable, except in minor operations, it would be a serious objection to local anesthesia, but such is not the case, particularly where small doses of morphin and scopolamin are used beforehand, as we advocate in all major procedures, which allays anxiety and uneasiness. There are many patients who dread more than anything else the loss of consciousness, and many who have once had a general anesthetic do not care to repeat the experience.

The great majority of our cases operated under local anesthesia come to us especially for this purpose, and many operators are able to attract a large clientele by the skilful development of purely local methods and prefer local anesthesia for all suitable cases. Köhler almost invariably uses it for the removal of the thyroid gland. Certain other desiderata are, however, essential, besides a knowledge of the purely technical procedures; these are, first of all, a thorough knowledge of the nerve-supply of the part; local anesthesia makes of the surgeon especially a nerve anatomist; other essentials are gentleness and patience on the part of the operator; rough handling and gross dissections, often indulged in under general anesthesia, should be avoided here.

"We are also convinced that an unfounded and unjustifiable skepticism still prevails among many excellent, skilful, and otherwise progressive surgeons, who, having neither the inclination nor the patience needed to acquire the latest, most advanced, and efficient methods of local anesthesia, or still confusing the imperfect and dangerous methods of the past with the safe and efficient methods of the present, still doubt and cling to general narcosis as the only means of abolishing pain in their operations. Others, again, who have not familiarized themselves with the more recent applications of regional anesthesia in major surgery will occasionally perform minor or superficial operations, such as the removal of a wart or the opening of an abscess, but will smile with incredulity if in a case requiring the amputation of a limb some one suggests the propriety of using cocain as the anesthetic. There is still a lingering tendency on the part of many surgeons, and especially the more conservatively inclined of the past generation, to regard those who practice local anesthesia in major surgery in the light of experimentalists or enthusiasts, and to class them, as a whole, among the impractical class of surgeons. To dispel this illusion, and to demonstrate that the value and efficiency of cocain and its allies are not restricted to the purely minor or superficial cases that occur in surgical practice, but that they are still of greater service in dealing with many of the gravest and most critical emergencies of surgery, in which the rôle of the anesthetic is of paramount importance, will be the object of our endeavor in this volume" (Matas).

We must also consider that had the discovery of local anesthesia preceded instead of followed that of general anesthesia, it would certainly have now been established on a firmer foundation and its principles more generally understood, instead of having to contest with general anesthesia to displace it in certain cases from its firmly entrenched position.

SOLUTIONS AND THEIR METHODS OF USE

The following quotations are from the report of Prof. Matas on "Local and Regional Anesthesia," Louisiana State Medical Society, April, 1900:

"To the student of American surgical history it will be a source of pleasure to recall the fact that probably the first clinical demonstration of the value of cocain, when used by the subcutaneous method for purposes of surgical anesthesia, was made by American investigators. Beginning with the earlier experiences of Hepburn (November 15, 1884), of Hall and Halsted (December 6, 1884), and of J. Leonard Corning (1885–86), it is gratifying to note that the essential and fundamental principles upon which rests the most effective technic in cocain anesthesia had been foreshadowed, and in some particulars completely elaborated, by these early pioneer efforts of American surgeons."

Before attempting a further discussion of the subject, it will be well to present a brief statement of the discoveries which have exercised the most potent influence in widening and perfecting the methods of local and regional anesthesia.

(1) "The discovery that anesthesia of the skin or derm proper by intradermal infiltration with cocain or similar analgesic agents, as distinguished from the hypodermal method, is the key to success in local anesthesia, *i. e.*, the anesthesia of the field of operation. This fundamental fact seems to have suggested itself at the same time to several observers, but the names of W. S. Halsted (1884), J. L. Corning (1885), Reclus and Ich Wall (1886), and Schleich (1890) are the first and most prominent that occur in the literature on the subject, though Halsted was the first to insist upon the importance of the intradermal method and to demonstrate by a large clinical experience its great practical importance."

(2) "The discovery that the tissues are sensitive to the anesthetic action of extremely dilute solutions of cocain and other analgesics (1:20,000 parts, Schleich, Heinze), and that these can be used effectively in exceedingly weak and positively non-toxic doses.

"Corning showed the effectiveness of solutions (warm) of $\frac{1}{3}$ of 1 per cent. cocain in 1885. Reclus rendered great service by his forcible and constant pleading in favor of solutions not stronger than 1 per cent., which he used as early as 1885; but to Schleich belongs the great credit of reducing the strength of the surgical solutions to $\frac{1}{5}$, $\frac{1}{10}$, and $\frac{1}{100}$ of 1 per cent. His experiments began in 1888, but their value was not fully recognized until the publication of his great work, 'Schmerzlose Operationen,' in 1896."

(3) "The discovery by Schleich (1888) that the thorough edematization of the tissues with standard isotonic solutions of sodium chlorid (0.2 per cent., Schleich; 0.8 per cent., Heinze) at a low temperature is in itself, as a process, an anesthetic agent. The experimental

evidence on this point began with the observations of Potain (1869), Dieulafoy (1870), Lebroue (1870), and with Liebreich's researches on the anesthetic properties of pure water. Halsted independently called attention to the same property of distilled water when infiltrated into the derm, and also called attention to the efficacy of very dilute solutions of cocain as early as 1884. While saline infiltration is not to be ranked as a surgically practical anesthetic, it is a most powerful adjuvant to local anesthesia by increasing the effectiveness of extremely dilute solutions of cocain in many ways that will be referred to later.

(4) "The very important discovery made by Dr. J. Leonard Corning, of New York (1885), that the action of cocain can be indefinitely prolonged as long as the circulation of the anesthetized area is arrested by elastic constriction or other mechanical devices. This is Corning's great discovery, undoubtedly the most important of his many original suggestions, unless it be his discovery of the spinal subarachnoid method of cocainization, in which his name will always be coupled with that of Bier. The value of circulation stasis in prolonging and intensifying the effect of cocainization occurred separately to Mayo Robson, of Leeds, in 1886, Chandelux, of Lyons, 1885, and to Kummer, of Geneva, 1889, but it is Corning who first suggested and popularized it by his numerous practical demonstrations and contributions on the subject."

(5) "The discovery that the infiltration of the sectional area of a nerve-trunk in any part of its course with cocain or similar analgesics is followed by a sensory paralysis of its entire peripheral distribution, thus causing a complete anesthesia of all the parts that it supplies. The infiltration of the nerves in this manner immediately 'blocks' the way to all afferent or sensorial impressions up to the point where the injection or 'blockade' exists. This procedure is equivalent to a complete section of all the centripetal fibers of the nerve, only that the effects are transitory as long as the circulation is not controlled. This discovery, which is now recognized as a law in cocain technic, is the foundation of the regional, as distinguished from the purely local, methods of anesthesia. The first demonstration of its surgical value we owe to Hall and Halsted's clinical experiments in 1884, undertaken almost immediately after Koller's announcement. It was also demonstrated by Barrenechea, of Santiago, Chili, 1885; and to some extent recognized, but not utilized, as we now understand it, by J. Leonard Corning in 1885. It was more fully established as a physiologic fact by U. Mosso (1886) and by François Franck (1892).

"In German clinics it was probably first practised by Kochs in 1886, who was inspired by the researches of Mosso (1886) and Feinberg (1885), but it was popularized by Oberst, of Halle (1886), and his pupils, who still refer to it as 'Oberst's' method, and by Braun, of Leipsic, a little later. Up to 1897 the principle was utilized only in an indirect manner, *i. e.*, by paraneural subcutaneous injections and in small operations. The application of this principle by direct injection into the nerves exposed by dissection was first made systematically by Dr. George W. Crile, of Cleveland, Ohio, who amputated a leg painlessly after injecting the sciatic and anterior crural nerves on May 18, 1897, and by myself (Matas), independently (January, 1898), in amputating the hand, after a preliminary cocainization of the ulnar, median, and musculospiral nerves at the bend of the elbow. The same principle was most admirably utilized by Dr. Cushing and others in Dr. Halsted's clinic (Johns Hopkins Hospital) about the same time (1907) for the radical cure of inguinal hernia. Dr. Young, of the same institution, had also previously utilized this method in securing anesthesia of the thigh for Thiersch grafting, which he did by injecting the external cutaneous nerve under Poupart's ligament."

(6) "The greater appreciation in recent years of the physiologic fact that all the tissues and organs of the body, with the notable exception of the papillary layer of the skin and the nerves, are, in normal conditions, practically devoid of sensibility, and that if the sensation of the derm and of the nerves that supply a given region is subdued by an artificial anesthetic, the sensibility of the tissues can be practically disregarded from the operative point of view. On the other hand, the importance of psychic pain in the course of operations is not to be underestimated; and, as this cannot be controlled by purely local anesthetic agents, it remains a serious obstacle, which in major surgery frequently compels a recourse to general or cerebral anesthetics in spite of the total abolition of sensation in the field of operation. The evidence on this point can be traced to numerous and even ancient sources, but its great significance in the practice of local anesthesia has been most forcibly presented by Dr. O. Bloch, of Copenhagen. (See 'Bibliotek for Laeger,' Copenhagen, 1898; 'Revue de Chir.,' Paris, January 10, 1900; also H. Lilienthal, 'Ann. of Surg.,' 1898, vol. xxvii.

"As a result of the practical applications of the principles embodied in these discoveries or generalizations, the technic of local and regional anesthesia has been gradually evolved into a method, or a variety of methods, which for efficiency and safety far outstrip the most sanguine expectations of the early advocates of local anesthesia. Not only all the exigencies of minor surgery are met with success by the new methods, but they are applicable with still greater force in a constantly increasing number of grave, critical, and major conditions which, a few years ago, would have been regarded as absolutely impracticable without the aid of general anesthetics.

"Before proceeding to consider the field of application of the new technic, and the advantages that can be gained by its more frequent and systematic application in general surgical practice, let us first define and classify these methods in order that their indications and limitations may be the better understood."

CLASSIFICATION OF THE METHODS OF LOCAL AND REGIONAL ANESTHESIA IN WHICH COCAIN AND THE OTHER ALLIED ANALGESIC DRUGS ARE UTILIZED AS THE ACTIVE AGENTS

"It should be first clearly understood that the artificial anesthesia of any given tissue or organ of the body is entirely dependent for its production upon the suppression of all sensorial (irritant) impressions made upon that region through the agency of the nervous system. This suppression can be effected by: (1) Paralyzing the peripheral nerve-endings or terminal organs of sensation, as in the papillary layer of the skin; or (2) by 'blocking' or obstructing the path of all sensorial impressions in the nerve-trunks, including the sensory roots in the spinal cord that connect the field of operation with the sensorium."

Before considering the different methods of local anesthesia, we must bear in mind that it is an operative analgesia that is aimed at, and not an anesthesia in the true meaning of this term; it is a paralysis of the pain-conducting fibers, and not those which conduct purely tactile sensations, consequently the patient is always able to feel the contact of instruments, fingers, etc., in the operative area, but pain is absent. True anesthesia can be secured, but it is necessary to use much stronger solutions, as the tactile conducting nerve-fibers are much more resistant to the influence of the weaker solutions; for this purpose it is accordingly necessary to use solutions of from 2 to 5 per cent. strength, which are clearly unnecessary for surgical purposes where a perfect analgesia can be secured by solutions of from 0.25 per cent. and often weaker.

"Schleich, who is the father of the infiltration method, was first to call attention to the value of salt in preventing the pain produced by plain water infiltration, and, while many of his conclusions have been more or less contradicted by the experimental studies of Custer, Heinze, and Braun, the fact remains that his first appreciation of the remarkable sensitiveness of the tissues to such weak dilution of cocain as 1:20,000 revolutionized the technic of local anesthesia and gave new impetus to this mode of practice. According to Schleich, the edematization of the tissues with a salt solution (0.2 per cent.) at a lower temperature than the body heat is the essential condition required for the production of local anesthesia. The small quantity of the analgesic drug that he adds to his solutions ($\frac{1}{5}$, $\frac{1}{10}$, $\frac{1}{100}$ of 1 per cent. cocain) is simply intended, he claims, to suppress the abnormal hyperesthesia of pathologic tissues. When dealing with normal tissues he believes that a plain 0.2 per cent. salt solution is sufficient to anesthetize, provided the tissues are thoroughly edematized. The *modus operandi* of the simple infiltration method, as he admits, does not depend solely upon the injection of a hypotonic salt solution; there are other factors which enter more powerfully into the causation of the anesthesia. These are: (1) The ischemia of the tissues and partial stasis caused by the great pressure exercised by the injected fluid on the capillaries and blood-vessels; (2) the compression of the terminal nerve elements themselves from the same cause; (3) the lower temperature of the infiltrated area caused by using cold solutions, or by cooling these after their injection into the parts. These purely physical conditions are undoubtedly of great importance in favoring and intensifying the action of the analgesic drug, and upon the thoroughness with which they are brought to play largely depends the success of the infiltration method as it is practiced by Schleich. That Schleich has underestimated the importance of the paralyzing effects of the cocain which enters into the composition of his solution cannot be doubted. Heinze and Braun contend, as a result of numerous experiments, that Schleich's solutions owe their entire analgesic effect to the cocain they contain, and my personal experience has convinced me that if the cocain were excluded from them they would cease to be of value as practical surgical anesthetics. On the other hand, we must recognize that without the process of edematization the weak solutions of cocain which Schleich has taught us to use so effectively would become practically worthless.

"From the preceding discussion, it is evident that there are two efficient factors concerned in the production of infiltration anesthesia which must be clearly differentiated from one another. One is the physical effect of the infiltration from pressure, differences of temperature, etc. (Schleich); the other is the chemical action of the drug employed (cocain, etc.) to paralyze the sensitive structures. According to the preponderance of the physical or the chemical factors we may classify the practice of local anesthesia by infiltration into two distinct methods: (1) Schleich's method, with a very weak cocain solution, which depends upon the infiltration itself as the effective agent and lays the greatest possible stress upon its physical action; and (2) the method of Corning, Reclus, and the earlier German anesthetizers (Wölfler, Landerer, etc.), in which the tissues are injected, layer by layer, with stronger solutions (1 to 4 per cent. cocain), and which depends for its efficiency almost exclusively upon the diffusion of the chemical analgesics dissolved in the solutions.

"The preference given in the selection of these methods will be determined by certain conditions, which will be referred to in dealing with the topographic application of the technic in the various regions of the body. In a general way, Schleich's method of infiltration is indicated in all operations in which the circulation cannot be controlled and in which the major part of the infiltrating solution must be allowed to remain in the tissues. In this, as in all other methods of local anesthesia, it is most important to remember that the derm proper, and especially its papillary layer, must be first edematized by intracuticular infiltration before beginning the infiltration of the deeper planes; the same rule applies to the mucous surfaces. This is a *sine qua non* in local anesthesia which cannot be repeated too often."

The original solutions, as advocated by Schleich, are the following:

No. 1		No. 2		No. 3	
Cocain mur........	0.2	Cocain mur.......	0.1	Cocain mur......	0.01
NaCl.............	0.2	NaCl.............	0.2	NaCl............	0.2
Morphin sulph.....	0.02	Morphin sulph.....	0.02	Morphin sulph....	0.005
Aquæ destil........	100.	Aquæ destil.......	100.	Aquæ destil......	100.

Solution No. 1 was intended for the skin, sensitive and inflamed tissues.

Solution No. 2, for less sensitive tissues, such as the subcutaneous planes.

Solution No. 3, for massive infiltration of the deeper tissues, which possess very little sensibility.

The idea in the addition of morphin was that it exercised some slight local anesthetic influence and exerted its constitutional effect by the time the anesthesia was passing off, thus relieving the after-pain in the wound. The idea of depending upon the anesthetic influence of such weak solutions of NaCl is objected to, as mentioned elsewhere in this book, and the addition of morphin to the anesthetic solutions for its constitutional effect is inadvisable; our aim should be rather to simplify the solution, and when morphin is to be used to give a definite dose some time before operation, as we advocate in the combination of morphin and scopolamin.

Recently, Schleich has modified the formula of his solutions to the extent of reducing the quantity of cocain in each one-half and adding an equal quantity of alypin, otherwise the solutions are the same as originally advocated.

While the admixture of different anesthetic salts in solution should, according to Burgi's views (discussed in the chapter on Scopolamin-morphin Injections), exert a more decided influence than when a total equivalent quantity of any one agent is used, as well as retaining the good points of each, while being sufficiently weak in each constituent to prevent any unpleasant results that may arise from the use in too large quantities of that particular constituent. This fact has recently been made use of by Schleich in combining alypin with cocain in his solutions. The advantages in the use of novocain are so great and its toxicity so low, permitting so much more of it to be used, and the clinical results so entirely satisfactory that we have not found it necessary to resort to any combinations, but, if such were done, novocain would be used as one of the constituents.

Schleich is opposed to the use of adrenalin for general use, but approved of it for the extraction of teeth and on mucous surfaces.

The views of Braun, Heinze, and other prominent advocates of local anesthesia are opposed to those of Schleich in the use of solutions of such low freezing-point, heterotonic solutions, claiming that solutions of such low specific gravity injure the tissues, preferring to depend exclusively upon the chemical influence of the solution rather than upon any physical influence for their anesthesia, and consequently utilize only normal salt solutions as their solvent medium. On theoretic and physiologic grounds this would seem to be correct (see chapter on Osmosis), but from a very extensive personal clinical experience, extending over many years, and the accumulation of thousands of cases throughout the surgical world, it would appear that these fears have not been borne out on clinical grounds. Our own reasons for discarding the use of the Schleich solutions has been due to the many advantages presented by the use of some of the newer anesthetics, notably novocain, which we will discuss later.

Following the introduction of eucain, Braun advocated the following solution:

Eucain B	0.2
NaCl	0.8
Aquæ destil.	100.

to which adrenalin was added. This was a very serviceable solution, and is discussed under Eucain.

Later Braun suggested the following solutions, which are those recommended in his book on "Local Anesthesia":

Solution No. 1.

Cocain hydrochlorate	0.1
or Novocain	0.25
Normal salt solution	100.
Adrenalin solution	(1 : 1000)
or Homorenon solution (4 per cent.)	5 drops

Solution No. 2

Cocain hydrochlorate	0.1
or Novocain	0.25
Normal salt solution	50.
Adrenalin solution	(1 : 1000)
or Homorenon solution (4 per cent.)	5 drops

Solution No. 2 diluted one-half with normal salt solution gives solution No. 1.

Solution No. 3

Cocain hydrochlorate	0.05
or Novocain	0.1
Normal salt solution	10.
Adrenalin solution	(1 : 1000)
or Homorenon solution (4 per cent.)	5 drops

Solution No. 4

Cocain hydrochlorate	0.05
or Novocain	0.1
Normal salt solution	5.
Adrenalin solution	(1 : 1000)
or Homorenon solution (4 per cent.)	5 drops

Solution No. 4 diluted one-half with normal salt solution gives solution No. 3.

Solution No. 1 is the one recommended for general use, while in more sensitive or inflamed tissues solution No. 2 may be used. Solutions No. 3 and No. 4 are intended for such purposes as nerve-blocking, or for use in highly inflamed or sensitive tissues, and for use in special regions (nose, throat, teeth, etc.).

The above solutions serve an extensive range of usefulness, and are found equal to the demands of any condition except the purely topical applications, as used in the eye, nose, and throat, and for such special work.

In selecting solutions for practical clinical purposes we have tried to simplify to the minimum the number of solutions used, and have found it advisable to reduce the content of sodium chlorid as advocated in the Braun solutions, in this respect adopting a medium between that recommended by Schleich and the Braun formula; in this way securing a certain degree of purely physical action from the infiltration, at the same time having the content of sodium chlorid sufficiently high to prevent any possible objection being found to it on purely physiologic grounds, and at the same time to forestall the possibility, however remote, of any injury resulting in highly sensitive tissues as the result of too pronounced imbibition by the tissue-cells. Consequently, after an extensive trial in several hundred major operations we suggest the following as used by us:

Solution No. 1

Novocain..............................	0.25 (¼ per cent.)
Normal salt solution (one-half)..........	100.0 (.45 per cent. NaCl)

The above solution is the one recommended for general use, and in the great majority of cases will be found amply sufficient for all purposes. It has been utilized by us for the performance of major operations about the body generally, as well as in such highly sensitive regions as the face and anus; it is amply sufficient for the skin, and, owing to the mild toxicity of the novocain, can be used for massive infiltration of the deeper parts as well; it is found equally effective for the blocking of medium-sized nerves, even as large as those of the brachial plexus, and can be used on the sciatic, but for the latter, as well as occasionally for the former, Solution No. 2 may be found more desirable.

Solution No. 2

This solution is intended for use in more sensitive parts, such as the nose, throat, mouth (teeth), for intraneural injections (brachial plexus, sciatic), and for paraneural injections, about the branches of the trigeminus, pudic, etc., when reaching these nerves in their deep positions with long needles. The solution can be made in 0.5 to 2 per cent. strength, according to the apparent needs of the particular case, and is as follows:

Novocain..........................	0.5, 1 or 2 (½ to 2 per cent.)
Normal salt solution (one-half).......	100.0 (.45 per cent. NaCl)

This solution will, however, be found rarely needed, except in special fields of work, as above mentioned.

The advantages of novocain, and the reasons for discarding the Schleich solutions which we had so long used, is the lessened toxicity of novocain (one-fifth to one-seventh that of cocain), its perfect toleration by the tissues, and its ability to stand thorough sterilization by heating, as it can be repeatedly boiled without suffering deterioration; these and other advantages mentioned in the discussion of novocain place it, for the present at least, at the highest pinnacle of success of the synthetic chemist's art.

The probability of the discovery of an anesthetic agent absolutely devoid of toxicity or irritating qualities would seem very unlikely; however, later advances may be able to still further reduce the toxicity.

In the preparation of solutions for purely topical applications, 5, 10, 20 per cent. and stronger, it is inadvisable to add sodium chlorid; the concentration of these solutions places their freezing-point considerably above that of blood-serum (they are hypertonic).

Regarding the addition of adrenalin considerable care should be exercised, as this is an agent not free from danger itself, and many unpleasant symptoms arising during the course of an operation attributed to the anesthetic agent are in reality due to the adrenalin. It is well to estimate the total quantity of solution likely to be needed for an operation, allowing slightly an excess, and to this total quantity, which has been previously sterilized, add the adrenalin from a sterile bottle and with a sterile dropper, using not over 10 drops to a 3-ounce mixture, or 20 drops to a 4- or 6-ounce mixture, which will be found amply sufficient for all ordinary uses; by confining one's-self within these limits of safety no unpleasant symptoms will arise. Additional precautions may be necessary in using adrenalin upon those with very high blood-pressure and in patients suffering from Graves' disease, where the vascular system is very easily excited. Aside from the unpleasant constitutional effects which adrenalin may exercise at the time of its use, when used too strong it is likely to be followed by pain in the wound, and its injudicious use in strong solution has been followed by gangrene.

It will often be found convenient for office use, and for those doing a limited amount of surgery to procure the novocain in tablet form of definite strength, with or without sodium chlorid and always without adrenalin; these tablets are then added to the necessary amount of water and the whole sterilized, when the adrenalin is then added.

The disadvantage in the tablets already containing adrenalin is that its keeping quality in this condition is very questionable unless quite fresh, and more particularly as in the sterilizing process the adrenalin is largely destroyed.

The idea of adding other agents, antiseptics, etc., to the solutions is to be avoided, as these substances often exert a hemolytic influence or otherwise prove irritant to the tissues; the possible contamination of the solutions by alkalis (so often used in the sterilization of instruments) is particularly to be avoided, being both destructive to the anesthetic agent and when sufficiently strong exerting decided hemolytic influence. Notwithstanding this knowledge, Bignon at one time claimed that cocain in alkaline solution was more effective than in other media, alkalinizing the solution with sodium carbonate, making a milky-like mixture. Braun tested the efficiency of such solutions, and found them inferior in duration, intensity, and diffusion power to the ordinary method of preparation, which gives a solution nearly neutral in reaction.

More recently 3 per cent. solutions of sodium phosphate have been recommended for use with novocain as a substitute for the sodium chlorid usually employed; it was claimed for this combination that it produced a more profound and prolonged anesthesia. After a rather extended trial in our clinics we failed to note any advantages, and have accordingly returned to NaCl. It may be said, however, that the combination is well tolerated by the tissues as no unfavorable reaction was noted, and the anesthesia, while good, had nothing to commend it over the sodium chlorid solution.

The use of highly concentrated solution of cocain is so general with surgeon specialists, particularly in the nose and throat, that a few remarks regarding the action of such solution may not prove out of place here, and should be considered in connection with information given in the chapter on Osmosis.

The employment of such strong solutions as are sometimes used is only possible in such highly vascular (high nutrition) tissues as in the nose and throat and in superficial wounds, which heal largely by granulation and can be kept freely irrigated; if used elsewhere, the hydroscopic action of these solutions would so desiccate the tissue-cells as to be likely to produce serious consequences (the injection into the skin of a 10 per cent. solution of cocain is painful and leaves behind an inflamed indurated area).

The views of the specialist on this point is so ably put forth by

Dr. John Leshure ("New York Med. Jour." of February 6, 1909) that I quote his arguments at length:

"The marked absorptive power possessed by mucous membranes render them peculiarly susceptible to the action of drugs applied directly to their surface.

"In the case of cocain used for the purpose of inducing local anesthesia a certain amount of absorption is desirable, that is, it is necessary that the drug should reach the level of the nerve-endings, but it is undesirable that it should enter the large venous and lymphatic radicles, which are placed at a deeper level, since, by way of these vessels, general absorption takes place, and toxic symptoms of greater or lesser degree are likely to occur.

"Both cocain and adrenalin have the power of contracting superficial and deep vessels, but the degree and rapidity of this contraction appears to be proportionate to the strength of drug solution used.

"This is particularly true of the deep vessels, and it is necessary to apply strong solution of cocain and adrenalin to contract these deeper structures promptly, for the solutions are rapidly diluted by the copious mucous secretions and osmosis through the vessel walls can then take place readily. We wish to bring the drug to the vessel wall, but not through it, and to influence the vasomotor fibers which surround the vessel.

"Fluids of high density, such as the cocain solution to be mentioned, are not readily taken up by the blood-vessels, and by the time they are sufficiently diluted to be so taken up the local circulation has been blocked off by the drug.

"By a strong cocain-adrenalin solution is meant one made by dissolving 1 gram of cocain hydrochlorid (flaky crystals) in 1 c.c. of a 1:1000 solution of adrenalin chlorid. This solution contains about 55 per cent. of cocain by volume, and has a specific gravity of 1.110.

"The following table gives the specific gravity of some commonly used solutions of cocain:

2 per cent.	= sp. gr. 1.004
4 per cent.	= sp. gr. 1.008
10 per cent.	= sp. gr. 1.020
20 per cent.	= sp. gr. 1.040
25 per cent.	= sp. gr. 1.050
55 per cent.	= sp. gr. 1.110

"Certain laws governing the absorption of aqueous drug solutions are: (1) A fluid passes through a membrane with a rapidity inversely proportional to the density of the fluid. (2) The rate of absorption varies directly with the fulness and density of the blood-vessels and lymphatics. (3) The slower the movement of the blood and lymph-streams the slower will be the rate of absorption of the fluid.

"These well recognized laws of physiology explain the local retention in the tissues of the strong cocain-adrenalin solution and the lasting anesthesia and ischemia following its use.

"As the specific gravity of blood-serum is from 1.025 to 1.032, reference to law (1) shows that other things being equal the strong cocain solution, having a specific gravity of 1.110, will pass through the mucous membrane of the nose slowly as compared with the weaker solutions (4 to 20 per cent.).

"The sequence of events resulting from the application of the strong cocain-adrenalin solution to the mucous membrane of the nose seems to be as follows:

"A prompt, powerful stimulus is transmitted to the vasoconstrictor fibers surrounding the more deeply placed arterioles. The latter then strongly contract, slowing the local blood-stream. At the same time the caliber of the venous and lymphatic radicles is narrowed, and the proximal pressure having been reduced venous stasis occurs, as is evidenced by the deep redness of the membrane.

"General absorption is thus blocked off, and, the membrane contracting, the nerve-endings and nerve-trunks are brought nearer to the periphery, and consequently more directly under the influence of the local anesthetic.

"All this time the cocain solution is becoming less dense, being diluted by the mucous membrane secretion, and a certain amount of absorption is taking place into the nerve-trunks through the axis cylinder, since this latter structure is non-medullated near its distal end.

"Areas quite remote from the point of application often are complained of by the patient as being anesthetic, *e. g.*, the teeth. The passage of the drug up the axis cylinder to a ganglion, distributing fibers to neighboring regions, may explain this phenomenon.

"It has been recently demonstrated that toxic substances may reach the central nervous system by way of the axis cylinder, also that absorption may take place at the nodes of Ranvier, there being a defective insulation of the axis cylinder at these nodes.

"In operating nerve-trunks as well as nerve-endings are sure to be wounded, and the former must be rendered absolutely anesthetic to insure the patient immunity from pain.

"The physiologic action of the strong cocain-adrenalin solution can be practically demonstrated, so far as its effect upon the blood-vessels is concerned, using tadpoles as the subjects of investigation.

"When from 30 to 35 mm. in length these animals have a thin, membranous, lateral outgrowth from the caudal appendage. This is highly vascular, and each half is supplied by branches from the aorta and central vein of the corresponding side, which pass down the thick central stem. The point of practical importance is that there is no direct communication between the blood-vessels of the two sides.

"It is possible, therefore, to compare the results obtained by simultaneously applying drug solutions of different strength to corresponding portions of the structure referred to, which resembles in many respects a mucous membrane. The animal is first curarized by placing it in a small dish, containing about 15 ounces of water, in which $\frac{1}{15}$ gr. of curarin sulphate has been dissolved. In from fifteen to twenty minutes the muscular system is paralyzed, and the tadpole will lie quietly upon the microscopic stage. The small vessels can be satisfactorily studied with a two-thirds objective and a 1-inch eye-piece. A mechanical stage contributes greatly to the ease of examination. A small drop of the strong cocain-adrenalin solution (55 per cent. strength) is placed upon the membranous structure near the tail of the tadpole, and a drop of the same size of a 4 per cent. solution of cocain in 1:1000 adrenalin is placed at a corresponding point on the opposite side of the caudal appendage. Slowing of the blood-stream and venous stasis occurs at a much earlier period on the side with the first-named solution than on that treated with the weaker solution. In about twenty seconds the circulation in the smaller vessels has practically ceased. The tadpole, being a gill breather at this stage of its existence, cannot be kept alive more than five or six minutes out of water, but control tests made with un-cocainized animals showed that death occurred as early in these individuals as when cocain was used.

"The fact would seem to prove that general absorption could hardly have taken place, since cocain is a powerful cardiac paralyzant, and would have caused death promptly had it entered the general circulation."

The above from Leshure deserves careful consideration, and explains admirably the action of highly concentrated solution when brought in contact with the tissues; such solutions are swabbed on mucous surfaces, as the nose and throat, and are not intended to be injected into the tissues. Strong solutions should never be used when it is possible to accomplish the purpose with the weaker dilutions, but if they must be used, as seems necessary in nose and throat work, which in many ways is a distinct departure from the method of use of local anesthetics for general surgical purposes, then we must have a rational explanation for the action of such solutions, founded on sound physiologic grounds and amply borne out by clinical experience. Such an explanation, I believe, is given above.

The safe use of such strong solutions requires great skill, and is acquired only after long practice and experience and is not to be lightly undertaken by the novice.

The idea of using other than watery solutions of the anesthetics (as in oils) as has been advocated at various times, and on purely theoretic grounds might seem to have some claims, has been found upon practical tests to be unsatisfactory and possessing many disadvantages. Water solutions, which are taken up by both veins and lymphatics, are absorbed comparatively rapidly, while oily solutions are absorbed exclusively by the lymphatics, which always act much slower, besides the oil globules choke the lymphatics and further delay the process; this prolonged retention in the tissues should intensify the local effect of the anesthetic as well as permitting it to be almost entirely exhausted locally, thus diminishing the likelihood of constitutional effects.

These solutions have been tested by Braun and found impractical; the oily solutions are unsatisfactory to use, diffuse very poorly, exert a weaker anesthetic influence, and frequently prove irritating to the tissue.

For the sterilization of cocain solutions, where it is desirable to use this salt, the solution will stand heating almost to the boiling-point, and will not suffer any appreciable loss of strength, but repeated heatings render them inert.

Mikulicz has suggested the following method: He dissolves a definite quantity of cocain in alcohol, allows the alcohol to evaporate, and dissolves the precipitate in sterile water or salt solution.

Solutions of cocain should not be kept for more than a few days as it very rapidly deteriorates, but should be frequently made fresh.

THE ARMAMENTARIUM

It is not at all necessary to have a complicated outfit for the application of the various methods of local anesthesia; all that is necessary is to have a supply of suitable syringes, preferably two or more of each, so should one become defective or be broken the work is not interrupted. The syringe should preferably be all glass, with glass plungers, and have no washers; the needles should slip on the ground ends; needles which screw on and require washers are objectionable; the screwing on process takes time, the washers frequently

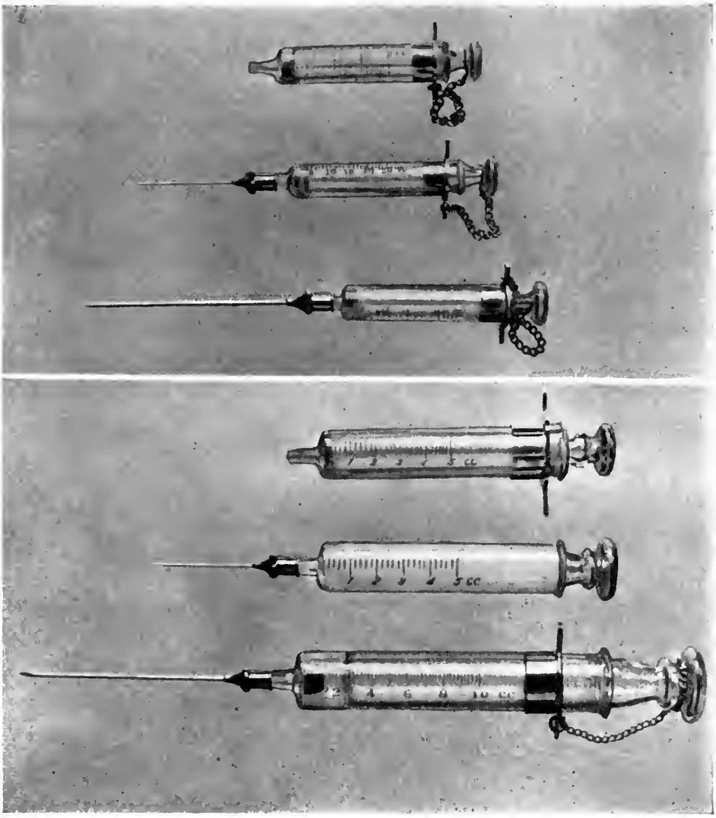
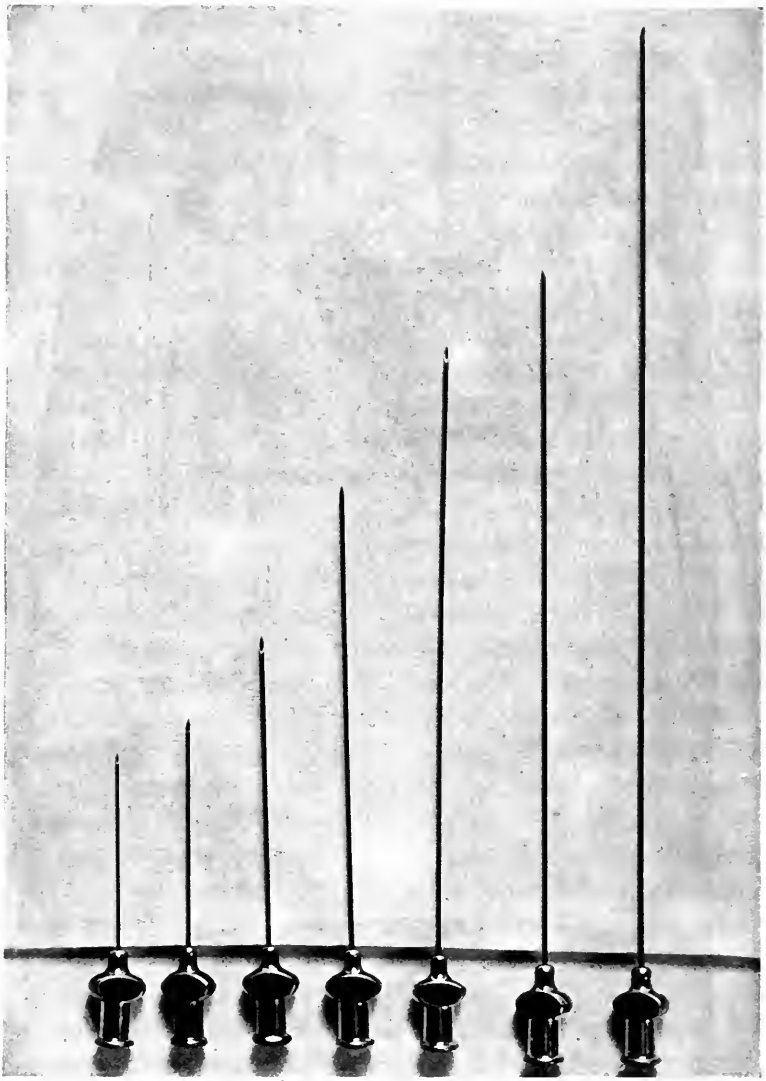


Fig. 4.—This illustration is reduced to about one-third size: the large syringe is the plain ground glass of the Luer or phylocogen (P. D. & Co.) type, 10 c.c. size; the small syringe is of the same type and is the ordinary hypodermic of 25 to 30 m. capacity (P. D. & Co. Glaseptic). The illustrations are intended to show the absence of all washers or threads upon syringe and needle; they both have the same size beveled glass tip to fit the needles and each fits the large or small needle as occasion requires.

give trouble, leak, and are otherwise undesirable. The simplest outfit compatible with efficiency is the best.

In selecting such syringes the best makes will be found the cheapest in the end; care should be exercised in selecting them to be sure that the plungers work easily and do not jam; the points which fit the needles should be tapering and not pointed too acutely, otherwise the needle will not fit securely and may fly off under pressure from the syringe; the needles should be as fine as compatible with efficiency. The idea of needles which slip on and off readily without having to



Diameter.......	.5	.5	.6	.7	.7	.7	.9 mm.
Length.........	25	30	35	60	80	90	125 mm.

Fig. 5.—Assortment of needles (after Braun).

unscrew them is of decided practical value as well as facilitating the refinements of technic. It is well in selecting syringes to have the different sizes fit the same needles, as this interchangeability will often be found of great practical advantage (Figs. 4 and 5).

(1) The syringe is more readily and quickly filled when the needle is off. When this process has to be frequently repeated much time is saved.

(2) Where several syringefuls are to be deposited in the same position the needle is allowed to remain *in situ* in the tissues; simply slip off the syringe, which is refilled and again attached, thus avoiding the necessity of making repeated skin punctures, which is an unnecessary trauma. This method is particularly of advantage in infiltrating the subcutaneous tissues, we will say, over a hernia; here the long needle, after one puncture in the skin, is advanced in the subcutaneous tissues, and several syringefuls deposited at different points or diffused generally as may seem advisable.

Two sizes of syringes are recommended, the small ordinary hypodermic size and a fairly large syringe, which will hold at least 10 c.c. with long needles (about 3 inches); such syringes stand boiling well and are otherwise surgically satisfactory. When through using a syringe the plunger should always be removed, wiped, and kept out of the barrel; if allowed to remain in the barrel, it may become jammed and only be removed after much difficulty.

For massive infiltration, and where the use of large quantities of solution are necessary, the Matas infiltration apparatus will be found highly serviceable, as it permits the easy infiltration of large areas within a few minutes.

Most of the more commonly used formulas (Schleich, Braun, etc.) of the various local anesthetics can be obtained on the market in convenient tablet form, which when dissolved in a stated quantity of water will give the desired solution. These tablets are usually sterilized and some contain adrenalin; this last ingredient is inadvisable in tablet form, as its keeping qualities are very poor.

More recently manufacturers have put upon the market sterile tablets in sterile containers consisting of novocain, NaCl, and the synthetic adrenalins (notably suprarenin synthetic), which is the best, in graded strength of novocain and suprarenin, but with a uniform strength of NaCl, so that their solution in sterile water yields standard solutions.

The tablets are highly useful for office use and for the extemporaneous preparations of small quantities of solution. The objection to tablets containing the animal extract adrenalin does not hold good here, as the synthetic preparations have been proved to possess greater keeping qualities, and, especially with suprarenin synthetic, capable of a moderate amount of sterilization (boiling for from three to five minutes).

The sterilization of these tablets can be depended upon when obtained from reliable manufacturers, but it is impossible to keep them sterile when the container is constantly being opened for the removal of tablets. We consequently prefer for institution or hospital work to prepare our own solutions freshly sterilized, to which we add just before use the desired quantity of adrenalin or suprarenin synthetic as preferred. This method has been found more satisfactory in major operations, where it is imperative to have an absolutely sterile and dependable solution.

CLINICAL APPLICATION

In starting to anesthetize any area the first step should be the production of intradermal anesthesia, and should be done with a small syringe and fine needle. In highly sensitive individuals the

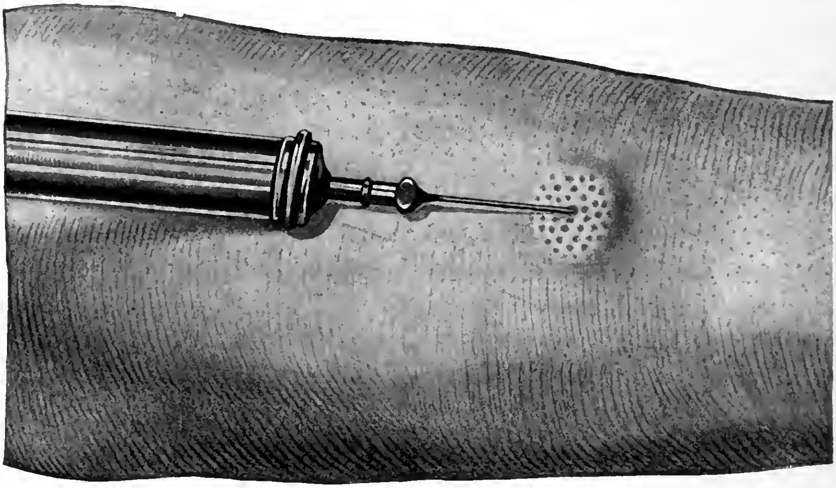


Fig. 6.—Formation of an intradermal wheal (Braun).

point of entrance of the needle may first be anesthetized with ethyl chlorid, but this is ordinarily unnecessary; if the skin at the selected point is first pinched up between the thumb and finger and held firmly it lessens its sensibility; with a quick but light thrust the needle is advanced beneath the epidermis. While making this initial stick the thumb should be on the plunger, so that at the moment that the needle enters the skin the solution can be injected; in this way this initial stick is often made without the patient's knowledge.

This injection must be intradermal and not subcutaneous; it should develop a distinct wheal, which stands up from the surrounding surface like an urticarial wheal (Fig. 6). This anesthetic point should be regarded as a "station" from which the anesthesia is distributed in the desired direction, either continuously in an intra-

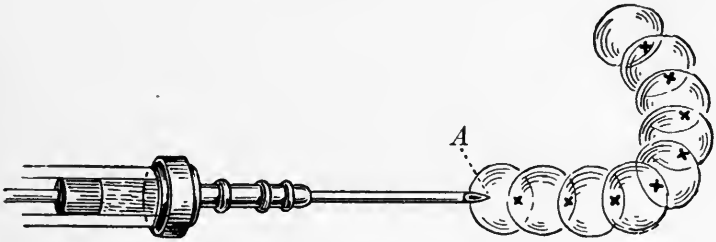


Fig. 7.—Illustrating technic of cutaneous infiltration (Schleich method) (Braun).

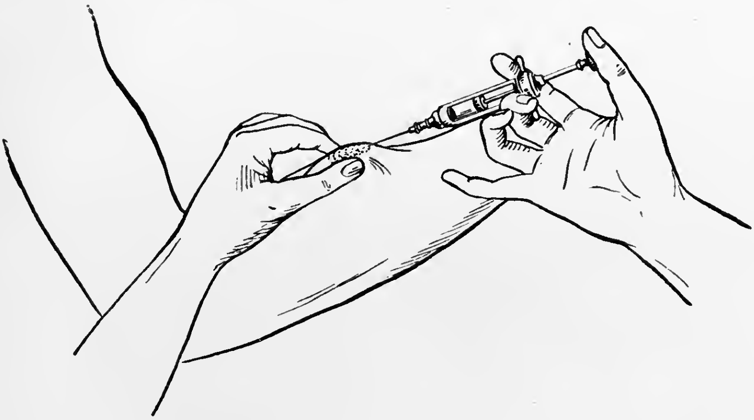


Fig. 8.

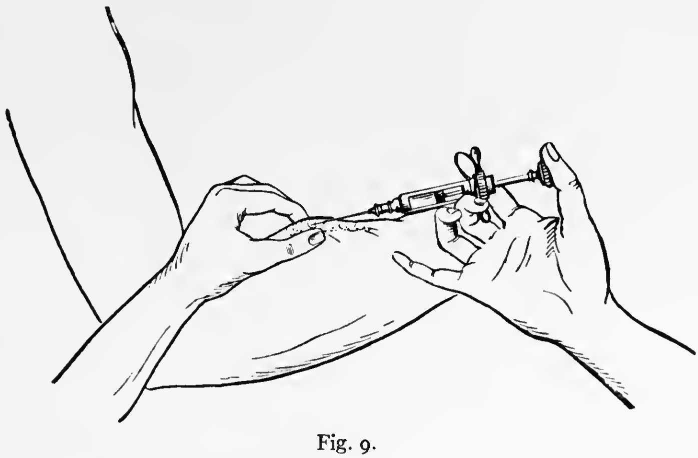


Fig. 9.

Figs. 8, 9.—Intradermal infiltration (after Reclus) (Braun).

dermal line (Figs. 7, 8, and 9), or the long needle on the large syringe can be advanced through the "station" to subcutaneous or deeper parts and paraneural or other injections made as indicated (Figs. 10, 11, 12, 13). The proper method of anesthetizing the skin by intra-

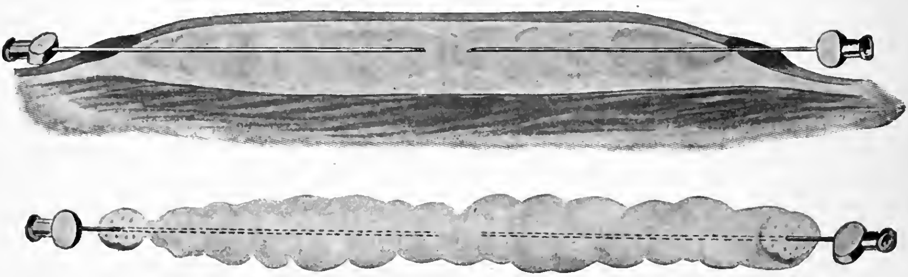


Fig. 10.—Subcutaneous infiltration from opposite points of entrance (Braun).

dermal injections was first taught us by Schleich and Reclus; for this purpose the needle should be advanced in the deeper planes of

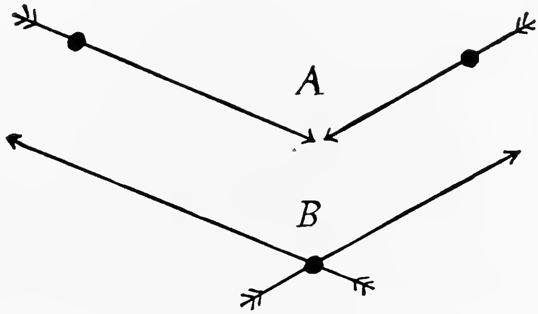


Fig. 11.—Methods of making subcutaneous injections (Braun).

the skin (the papillary layer contains the nerve-end organs); the needle is inserted within the margins of the anesthetic wheal first

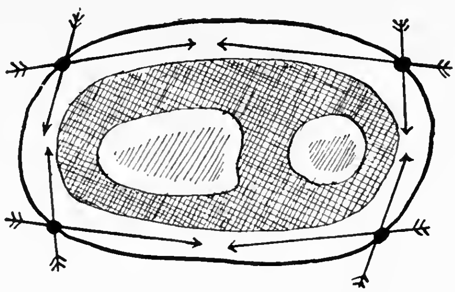


Fig. 12.—Schematic representation of cross-section through forearm and method of infiltration from four points (Braun).

made and progressively advanced, injecting the solutions as the needle is being pushed forward, developing a ridge of infiltration edema along the line of injection. When the needle is reintroduced, this should always be done just within the margins of the last injection, otherwise each additional needle stick will be felt.

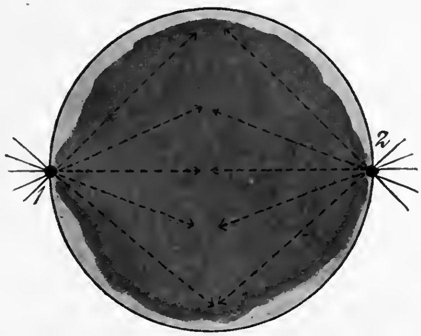


Fig. 13.—Method of producing a plane of anesthesia in subcutaneous or other tissues, when injecting beneath a tumor, etc. (Braun).

The same plan is followed in anesthetizing a tract for aspiration or exploratory puncture—we will say, for illustration of the pleural cavity. This method of procedure is clearly shown in Fig. 14.

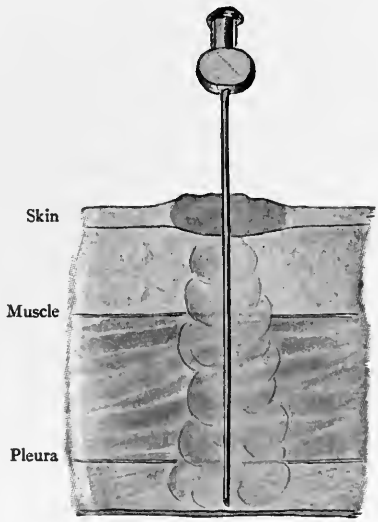


Fig. 14.—Method of infiltrating successive planes of tissue for exploratory puncture or aspiration (Braun).

In making an injection over a wide area subcutaneously, or in the deeper planes of tissues, one, two, or more points are first anesthetized on the overlying skin, and the needle advanced in various directions, continuously injecting as the needle is pushed to deeper depths, and withdrawing the needle only sufficiently to direct its point in another direction, thus avoiding repeated unnecessary punctures of the skin. This is illustrated schematically in Figs. 15 and 16.

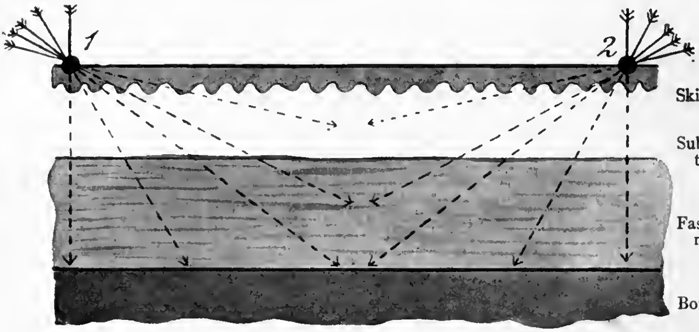


Fig. 15.—Method of infiltrating several planes of tissue, including underlying bone from two points of injection (Braun).

In making the injections they should not be too rapidly done, as the sudden distention of the tissues may cause pain or rupture of delicate parts.

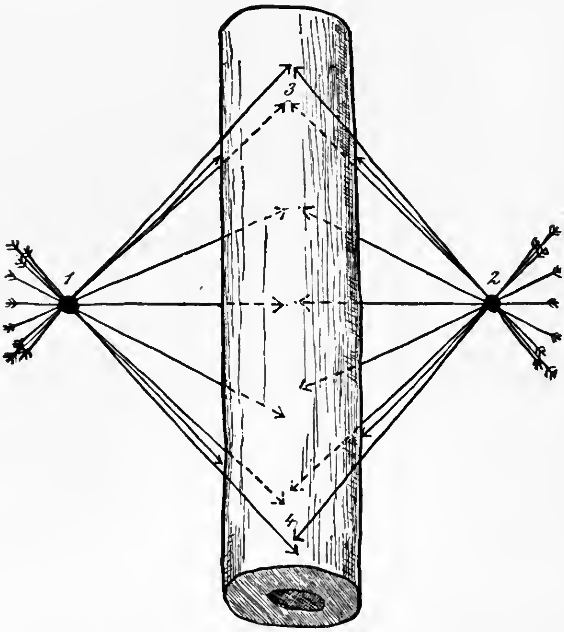


Fig. 16.—Method of anesthetizing area of bone from two puncture points in surrounding soft parts (Braun).

While it is generally advisable to precede any incision by an intradermal infiltration along the proposed line, this is not invariably necessary, as in cases where extensive dissections are to be undertaken the massive infiltration of the subcutaneous tissues reach and anesthetize the nerves in their course to the skin, an indirect method of anesthesia.

COLD

The sedative influence of cold when used alone has already been referred to. Here a brief mention will be made of its intensifying effects upon the anesthetic solutions.

Experimentation led to the information that cold solutions exerted a more pronounced effect than those used at body temperature, but when injected cold they excited pain in proportion to the lowness of their temperature; it was accordingly recommended that they be injected at ordinary temperature and the area then cooled; this was done by packing it in ice or the use of sterile bags filled with ice; this refrigeration of the injected area was practised some years ago, but is now rarely ever employed. Ethyl chlorid spray was also used upon the surface to produce this refrigeration. To favor the diffusion of the anesthetic solutions they were often injected warm and the cold later added to intensify the effect.

The injection of solutions at temperature noticeably above or below that of the body always excites pain, while the injection of such solutions as are advocated in this volume at body or room temperature, at which point they should always be used, is absolutely devoid of any appreciable sensation.

REGIONAL ANESTHESIA

Regional methods of anesthesia include all those methods which control sensation of a peripheral part or area of distribution of any nerve or plexus of nerves, or of any artery by proximal injections into the trunk of the nerve or lumen of the vessel some distance from the peripheral distributions. The same results are obtained by Bier's intravenous anesthesia, and, in a broader sense, by spinal analgesia.

The following is a classification of regional methods:

Paraneural, injections made in contact with a nerve.

Intraneural, injections made within a nerve.

Spinal analgesia (including epidural injections of Cathelin).

Intravenous anesthesia (Bier).

Intra-arterial anesthesia.

Hackenbruch regional anesthesia, by circumferential injections.

By these methods the operator is often able to demonstrate the high state of perfection to which purely local methods of anesthesia have been developed. These procedures may be divided into the paraneural (indirect) and intraneural (direct) methods. Spinal analgesia is also a regional method, which is discussed under a separate heading.

A paraneural injection is made by inserting a needle into the tissues to the known position of a nerve-trunk and there making the injection; the solution surrounding the nerve-trunk envelops it in an anesthetic atmosphere, which gradually diffuses itself into the nerve-tissue. Obviously, an injection thus made should be of larger quantity and greater strength than when made directly into the substance of the nerve, as in the intraneural method; when such an injection is accurately made, and the solution deposited in close contact with a nerve-trunk, time being allowed for thorough diffusion, anesthesia of the entire nerve distribution will result. This method is clearly open to objections, as many errors are likely to result, as in cases where the injection has not been accurately placed no anesthesia will result; also it is possible to injure other structures or to make the injection into a vessel. This method may often be regarded as unsurgical, and is hardly to be recommended where more exact methods can be employed; however, it may be necessary under certain anatomic conditions, as when blocking the branches of the trigeminus at their exit from the skull or the branches of the pudic nerve near the base of the tuberosity ischium. In making the injections in the above cases, and elsewhere in positions where large veins may be encountered, it is advisable never to make the injection when the point of the needle is stationary, but always when it is being advanced or withdrawn, or after the exact position has been reached by the point of the needle slight aspiration on the syringe can be resorted to determine if a vein has been entered before making the injection.

In such cases the injection of the solution into a vein is more to be avoided than its introduction into an artery; the puncture of either vessel by a fine needle is not in itself of any consequence, as no hemorrhage is likely to occur from such a small puncture, and we purposely make them at times in intra-arterial anesthesia, where we wish to anesthetize the area of distribution of a particular artery and use the arterial blood as a means of distributing the solution to the tissues, but in making the injection into a vein the concentrated solution is carried at once into the general circulation and may reach the higher nerve-centers in such quantity as to produce serious toxic results. We must remember that the intravenous administration of cocain is the most toxic; the toxicity of any injection of cocain depends upon the concentration of the solution and the amount reaching the circulation at any one time, and here we would have the maximum action.

While the intra-arterial injection is to be avoided as an accidental occurrence, it is never as toxic as the intravenous administration, as the solution has first to travel through the ultimate distribution of the artery, the capillaries, and which, if adrenalin is used, are completely occluded together with the arterioles leading to them by the first contact of the adrenalin; as this response to adrenalin is immediate, the solution is thus retained for some time in contact with the tissues and its action largely reduced before it is finally carried by the return circulation to the heart. In the case of a vein, if of any size, this action of adrenalin is insufficient to occlude it.

The intraneural (direct method) is more accurate, and decidedly to be preferred whenever possible. It is applicable to any large nerve-trunks, brachial (above the clavicle), ulna, median, and musculospiral at the bend of the elbow, or at any other accessible points along their course, also the sciatic and its divisions in the thigh and leg. This method was first perfected by Cushing, Crile, and Matas; as it is discussed in detail in the surgery of the extremities it will not be repeated here. This method is also utilized in the course of any operation whenever nerves are encountered, as in herniotomies, thoracotomies, etc.

The method of making the intraneural injection is of importance; the nerve should not be pinched up by forceps or other instruments, as any such manipulations cause pain referred to its peripheral distribution, and may be sufficiently severe to make the patient cry out or lose confidence in the promise of a painless operation; the injection should be made with the nerve lying in its bed, by inserting a fine needle in the long axis of the nerve, first within its sheath, which is edematized; the needle is then gently advanced between the different nerve-bundles and the infiltration continued until the nerve presents a fusiform swelling at this point, which may require from 5 to 15 minims of solution.

Complete anesthesia of its entire distribution usually results in from five to ten minutes, but may exceptionally be delayed to twenty minutes or longer. After making the injection the wound made to expose the nerve should not be immediately closed, but loosely approximated by stitches and protected by dressings, as it may occasionally be necessary to make additional injections, particularly if the operation is at all protracted.

Regional anesthesia may also be employed by the Schleich infiltration method by creating a circular ring of infiltration edema around a peripheral part, such as a finger, and might, in exceptional cases, be utilized higher up on the extremities when quite thin, and in parts where the nerves which are encountered are not of such

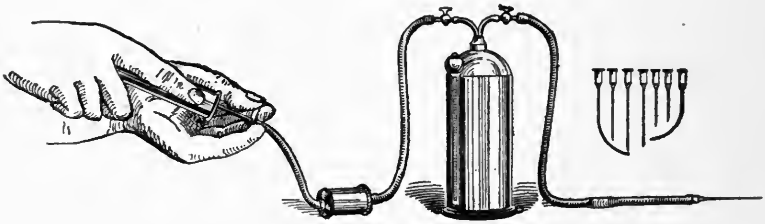


Fig. 17.—Apparatus for rapid massive infiltration anesthesia. Charging the cylinder with air-pump (Matas).

size as cannot readily be penetrated in effective quantities by the weak infiltrating fluid. The above method while simple, effective, and often quickly executed, with suitable instruments, such as the Matas infiltrator (Figs. 17 and 18), is not to be recommended when regional methods or vein anesthesia can be applied.

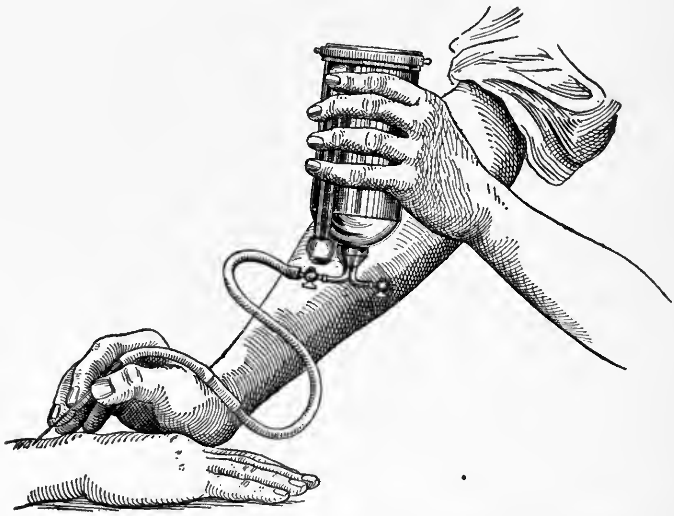


Fig. 18.—Cylinder charged and inverted. The pumping outfit is detached when the apparatus is in operation (Matas).

Conditions may, however, arise in which, through lack of facilities or lack of technic, vein anesthesia cannot be carried out, and amputation or other extensive operation on the peripheral part is necessary, and yet, owing to unhealthy conditions of the tissues, nephritis, diabetes, etc., particularly when complicated by cardiac or pulmonary disease, it is desirable to reduce the number of incisions to a minimum; in such conditions, when the field of operation is in the region of large nerves, a combined method of procedure may be resorted to by first thoroughly edematizing the entire thickness of the limb; the large nerve-trunks can then be sought for as the operation progresses and blocked by an intraneural injection, slightly proximal to the field by slightly stronger solutions than that used for the infiltration, when they can be then safely divided. This method, while open to objections, may still be the method of choice under certain extreme conditions; true, the edematization of the field may favor

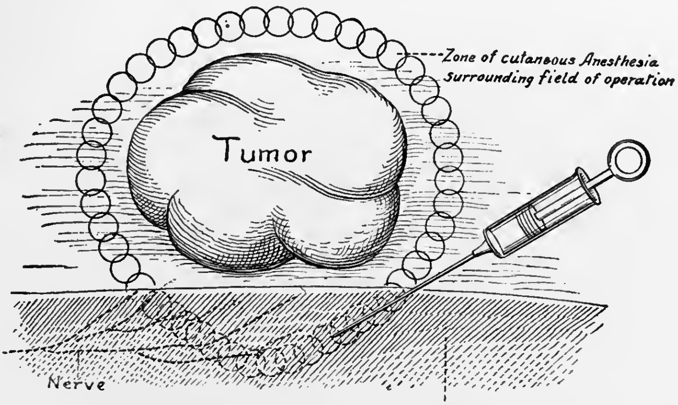


Fig. 19.—Shows method of using Hackenbruch anesthesia around a tumor, carbuncle, or other superficially situated lesion.

suppuration in badly diseased or devitalized tissues, yet in cases of amputation it is at a favorable site for drainage should suppuration occur, and may offer the best and safest means of getting rid of an offending member when gangrenous or otherwise diseased.

Hackenbruch recommended a method of regional anesthesia, which he called circular anesthesia, by creating a wall of infiltration edema around the region to be operated upon, and in this way interrupts the conductivity of all nerves entering the area (Fig. 19). This is a highly useful method, but applicable only to limited areas, for, if too extensive, nerves may enter the area from below at points which cannot readily be reached by the infiltrating solution. When operating by this method, the infiltration of the entire area should be completed before beginning to operate. This plan is particularly applicable to cysts, carbuncles, boils, infected and inflamed areas, where direct infiltration of the inflamed tissues are to be avoided; it is also useful in the removal of epitheliomata and other malignant disease, when superficially situated and of limited extent; this method of operating, and that by the other regional methods, are the only local anesthetic procedures which should be considered when dealing with malignancy, as no injections should be made which approach the limits of the growths, as their infiltration may produce a dissemination of the cancer cells into the surrounding tissues or general circulation.

THE CONSTRICTOR

The important discovery made by Corning in 1885 that the action of cocain can be indefinitely prolonged when the circulation of the part is arrested by the use of constrictors or other mechanical devices proved a decided advantage in all operations upon the peripheral parts; since the advent of adrenalin, the therapeutic constrictor, this advantage has been less apparent, but nevertheless of decided benefit in many cases. Briefly, the advantages of constricting and arresting the circulation of the part permit an indefinite prolongation of the anesthesia, and in addition by prolonging the retention of the anesthetic agent in contact with the tissue-cells, with which it becomes largely fixed and their physiologic activity so reduced that doses which may have been regarded as dangerous or toxic, used by other methods, can often be safely used, or, by the intermittent relaxation of the constrictor, permitted to enter the system gradually, so that no untoward symptoms are produced. Obviously, too, the immediate constriction of a peripheral part will arrest further absorption in cases of poisoning, and permit the system to recover before more is allowed to enter the general circulation.

The intensifying effect of constriction upon the anesthetic influence of any agent used is further emphasized if the part is first rendered ischemic; the absence of blood in the part with its diluting and neutralizing influence removed, the drug can act exclusively upon the tissue-cells and their nerve-endings.

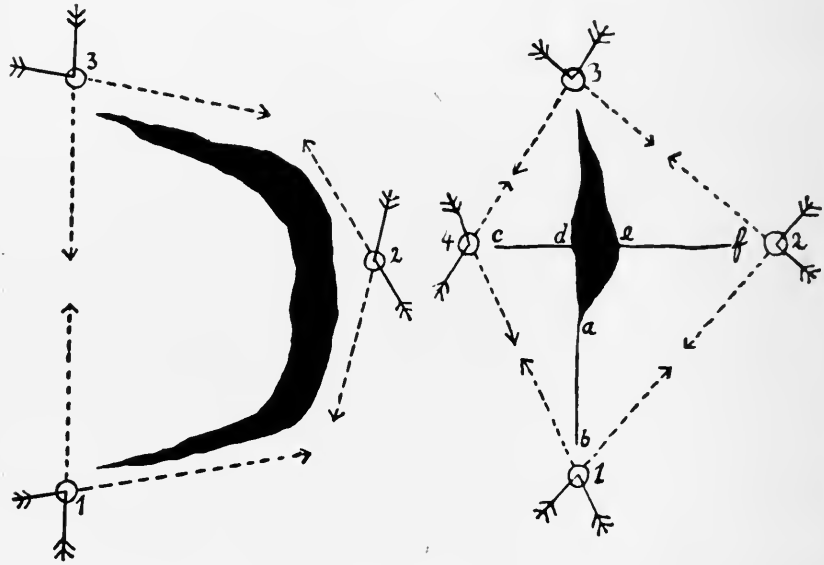
The method of applying the constrictor, when used above the anesthetized area on normally sensitive parts, is a point which should receive careful attention; pressure from a constrictor carelessly applied may be borne without complaint for a short time, but the continuous pressure soon becomes intolerable, and the operation is often interrupted by having to stop and readjust the constrictor. This is best avoided by applying it only over well-padded parts, distributing rolls over an area of 6 or 8 inches in width, and when possible within the margin of the anesthetized area.

TECHNIC OF HANDLING WOUNDS IN GENERAL

In the surgical treatment of wounds, such as contused and lacerated, incised, punctured, gunshot- or stab-wounds of the scalp, face, and other parts of the body, requiring suture, incisions for freer drainage, or painful manipulations necessary for cleansing, local or regional methods of anesthesia may often be used to great advantage in permitting the painless handling of the tissues and freedom of work necessary to thoroughly cleanse or trim up ragged or crushed edges or insert sutures. When these wounds are of small extent and superficially situated, purely local methods of anesthesia will suffice; where they are very extensive or involve the deeper parts or important structures, such as penetration or opening of a joint, division of tendons, nerves, or other important structures, and even under some conditions in compound fractures or crushing or mangling of the limbs, regional anesthesia may often be used to great advantage, both by blocking the nerve-paths, thus preventing shock or permitting painless manipulations necessary for the repair of the damage.

Where purely local methods of anesthesia are used, as, for instance, in a contused and lacerated wound of the scalp, the hair should first be shaved from around the wound, protecting the wound meanwhile with a compress; this surrounding area then lightly cleansed, and, if preferred, painted with 5 per cent. tincture of iodin. The anesthesia is then carried out as indicated in Figs. 20 and 21, the small circles indicating the points in the skin at which stations of anesthesia are established by intradermal infiltration; the dotted arrows indicating the course and direction of a long needle, which is to be inserted subcutaneously, making a rather free injection of solution as the needle is advanced, so as to create a wall of anesthesia which will entirely embrace the wound; the depths of the subcutaneous injections will of course depend upon the depth of the wound; when situated upon the scalp the injection should be carried down to the pericranium; when situated in other parts of the body, the injection should be made according to the Hackenbruch method, by carrying the long needle down into the tissues to below the depth of the wound, but always keeping outside the wound in the surrounding uninjured tissues; the injections should be made more liberally in the subcutaneous tissues, as it is here that the sensory nerves are more freely distributed in their course to the overlying skin; the deeper parts, being more sparsely supplied with sensory nerves, will not require such free injections unless along the course of recognized nerve-paths.

After the anesthetizing procedure has been thoroughly carried out, the compress may be removed from over the wound and the entire area freely cleansed by further shaving if necessary, and the wound washed out or irrigated and otherwise treated, as the indications require, with a freedom of manipulation so necessary for thorough work that is rarely possible except in anesthetized tissues.



Figs. 20 and 21.—Method of surrounding scalp or other cutaneous wounds with zone of anesthesia (Braun).

Fig. 21 shows a contused and lacerated wound with undermined edges; it is to be treated the same as Fig. 20; the radiating lines from the area of laceration will require slitting up to permit access to and drainage from the deeper parts.

Poisoned wounds from snake-bites, rabid animals, or other dangerous sources will require handling as expeditiously as possible, which may not permit of the use of local anesthesia, although in the hands of those skilled in its use but a very few minutes are required for the infiltration, which of course should always be carried out by the above-mentioned Hackenbruch plan, keeping well away from the possible area of infection, and never by making the injections directly into the wounds. Many such wounds occur in surroundings where the necessary facilities and instruments are not at hand for the practice of local anesthesia, or any other form, and the indications may be sufficiently urgent to demand a heroic procedure to remove or lessen the influence of the poison without any anesthetic. However, many cases will present themselves where the indications are not so urgent; here the application of a constrictor will prevent any further absorption, and the few minutes delay necessary for the anesthesia will be more than repaid by the greater facility and thoroughness with which incisions or cauterizations can be carried out, and the great satisfaction on the part of the medical attendant that he is not inflicting pain on a screaming and writhing but otherwise willing patient.

Wounds of the palm of the hand or sole of the foot, but especially the latter in hard-working people, where the tissues are dense and leathery, are often very unsatisfactory for treatment by any method of infiltration; the infiltration of such dense tissues is often very difficult and frequently accompanied by a great deal of pain to the patient, even though quite strong solutions are used. I have often seen the barrel of the ordinary hypodermic syringe break under the pressure necessary for infiltration in such cases. It is far simpler and more satisfactory, both to physician and patient, to practice an intra- or paraneural injection, as described in the chapter on Surgery of the Extremities.

HEMOSTASIS AND CLOSURE OF WOUNDS

The closure of any operative wound made under local anesthesia where adrenalin is a constituent of the solutions used calls for increased care and thoroughness in securing all bleeding-points, even the smallest ooze, for what appears at the time of no consequence may, as the effects of the adrenalin subsides, increase and give rise to hematoma, which may jeopardize the results of an otherwise satisfactory operation. To prevent such consequences, hemostasis should be perfect, and it is also advisable to anchor the overlying planes of tissue to the ones beneath during closure to obliterate the possibilitity of any dead space. The skin sutures should not be drawn too tightly, but should allow of the escape of serum from the wound should any collect. A firm, snug bandage, exerting a moderate amount of pressure, is also a valuable adjunct as a final step in the case.

THE HISTORY OF THE HYPODERMIC SYRINGE

The invention of the hypodermic syringe, that wonderfully useful instrument, is generally credited by most writers to Wood in 1855. However, the idea seems to have originated with Monteggia (1813), who suggested the use of a cannula for this purpose. But the real credit for the invention of the modern hypodermic, as we know it to-day, according to the investigations of Pfender ("Washington Med. Ann.," vol. x, No. 6), who reviewed the literature thoroughly, seems undoubtedly to belong to F. Rynd, an Irish surgeon, who introduced the instrument in 1845. Pravez in 1851 introduced a cannula of capillary size, following out the idea of Monteggia, which was used for injections. In 1885 Wood first wrote on the subject of the syringe, and popularized it through his numerous writings and brilliant demonstrations, but the real discoverer seems undoubtedly to have been Rynd.

The French manufacturers in 1862 introduced an excellent instrument which would compare favorably with those of to-day, but, even with this hypodermic, it was recommended that its use be preceded by the Richardson ether douche, as the ether spray was then called. Rapid improvements in manufacture followed, until we have the perfected instrument of to-day.

CHAPTER IX

THE USE OF MORPHIN AND SCOPOLAMIN AND COMBINED METHODS OF ANESTHESIA

MORPHIN AND SCOPOLAMIN

It is hard to determine exactly when morphin and other synergistic drugs were first used as a preliminary or preparatory treatment to operations under local anesthetics. The discovery of morphin considerably antedates that of cocain, and its hypodermic use began with the introduction of the hypodermic syringe by Rynd in 1845, when it was used extensively as an injection into the site of pain for such affections as neuralgia, pleurodynia, arthritis, etc., with the idea then prevailing that it exercised a considerable local as well as constitutional action. The prevalence of these ideas no doubt largely influenced medical thought later when morphin was combined with cocain in local anesthetic mixtures, such as in the Schleich solutions. These views were found to be largely in error, for morphin, while it does exert a certain limited local action, it is necessary to use 4 per cent. solutions to produce any decided local analgesic effect, a concentration clearly beyond any possible consideration; it is, therefore, more rational to give the morphin separately and preceding the operations, rather than to include it in the anesthetic solution, for, if used in an effective strength in these solutions, in many operations where an undetermined amount of solution will be used, as in very extensive infiltrations, a toxic amount of the drug may be given. What is decidedly better is to administer a definite dose of morphin separately and before the operation—besides the aim should be to simplify rather than complicate the anesthetic solution; it should accordingly contain no agent which is not of decided value locally, either for their anesthetic action or vasoconstriction, as adrenalin, or NaCl, used to make the solution more nearly isotonic with the blood.

However, the discovery that the central analgesic effect of morphin on the cortex and psychic centers greatly assist in preparing the mental attitude of the patient for the action of local anesthetics has materially contributed to the success of local and regional anesthesia.

This suggestion independently occurred to many operators simultaneously, but Ceci, of Genoa, has, since 1897, insisted upon the systematic use of morphin as a preliminary to local anesthesia, and the value of the suggestion has been recognized in almost all clinics where local anesthetics are most frequently resorted to. The advantages in the use of morphin, in doses of $\frac{1}{6}$ to $\frac{1}{4}$ gr., given hypodermically from one-half to one hour before any major operation under local anesthetics as a preparatory injection, are many and are quite apparent to those who resort often to these measures. Here it may be well to refer to the chapter on Pain, particularly the psychic control over pain, to better understand the advantages of this procedure. The mental state of attention and anticipation influences the acuteness of painful impressions; it must, indeed, be a trying ordeal on nervous patients to undergo an operation of any magnitude by purely local means of anesthesia. This feeling of dread and anxiety, with all the senses in a thoroughly active mind anticipating and waiting the first touch of the knife when tactility may be interpreted as pain and the strange surroundings of the operating-room are not those which would restore tranquillity, may prove trying to the operator and is certainly so to the patient.

Some individuals of placid or phlegmatic temperament, who have confidence in the operator, are quite satisfied with his promise that there will be no pain, but many others, nervous or high-strung individuals, are not so fortunate temperamentally, and become restless and uneasy, and will find one-half hour or an hour spent on the operating table in itself quite a severe trial, although they actually experience no pain, but are conscious of the operation being performed.

With such patients it is highly desirable to substitute a more placid, tranquil mental stage for that of anxiety and uneasiness; this is best insured by the administration hypodermically of $\frac{1}{8}$ to $\frac{1}{4}$ gr. of morphin, either alone or in combination with scopolamin, $\frac{1}{150}$ to $\frac{1}{100}$ gr., about one hour before operation; this induces a drowsy, pleasant state of mind, and the patient approaches the operating-room in a quite cheerful attitude, in marked contrast to many not so treated, who are fearful and trembling, and declare at the last minute that they do not feel equal to the ordeal. (See chapter on Anoci-association for effects of fear upon the central nervous system.)

There are other advantages in this preliminary hypodermic, as both morphin and scopolamin congest the cerebrum. Cocain, in exerting a toxic influence, is supposed to produce an anemia or vasoconstriction centrally, the same as it does locally, as an initial phenomenon in its toxic action; while morphin is not the ideal antagonist, as discussed in the chapter on Toxicology, it nevertheless does seem to exert a prophylactic influence in preventing the development of toxic symptoms; this is particularly so in nervous excitable individuals, who are undoubtedly more likely to develop unpleasant symptoms, even if nothing more than a slight palor, nausea, or uneasiness. These manifestations, as well as other unpleasant disturbances and reflexes, are all less likely to occur following the preliminary hypodermic.

As spoken of elsewhere, when toxic symptoms arise it is due to the use of an excess of the drug beyond that needed to produce complete local anesthesia, the result of too strong solutions, poor technic, or its injudicious use. Personally, I have never had any toxic symptoms to combat, but in highly susceptible individuals, with marked idiosyncrasy, such disturbances may occur, and it is well to forestall their development if possible. The effect of such a hypodermic is quite lasting, six to eight hours, and eliminates the necessity of a post-operative injection being needed for after-pains.

The idea of combining two such agents as morphin and scopolamin, while not syngergistic in the entire range of their action, are in so far as they dull the mentality and produce a tranquil somnolent state; morphin, however, acting more especially in its influence over pain, while scopolamin is used entirely for its somnolent effect. This idea of the combination of such narcotics as morphin and scopolamin, which are extensively used together, bear out Burgi's contention that the sum of the combined action of two or more narcotics administered simultaneously, or shortly after each other, produce a much more powerful effect than when a total equivalent quantity of either one narcotic had been administered alone. This increased action is particularly marked when the two narcotics have different cell receptors, and that a dose of any one drug acts much more markedly when given in frequent small doses than when administered at once in a single dose; this last part of his contention is, however, not of value to us here.

Other advantages of the preliminary hypodermic are that it seems to intensify and prolong the action of the local anesthetic used, either by removing the psychic state favorable to the development of pain or by dulling the pain perception centers, enabling the operator to succeed with a minimum amount of the anesthetic solution. This last view is entirely in accord with Burgi's contention; the morphin centrally is synergistic to the action of the cocain locally. While advocating the single preliminary injection of the two agents in medium-sized doses as desirable in nervous and excitable individuals, as a means of allaying this excitement and thus protecting the patient against himself, we do not invariably make use of the procedure except in operations of considerable magnitude, and never use it as a means of anesthesia alone, and wish to very positively condemn such a practice as highly dangerous and unsurgical, to say the least.

The idea of using these two drugs for anesthesia alone or in combination with cactin or other agents is fraught with the greatest risk possible, and had its origin in the suggestion in 1900 by Schneiderlin that they be used in large doses as a means of producing surgical anesthesia; this idea was founded on an erroneous conception that the two drugs exerted a certain cardiac and respiratory antagonism while being synergistic in their analgesic and hypnotic qualities; this, however, was soon shown to be an error, and Wood in 1905 was able to collect 2000 cases with 9 deaths, or 1 to 221—a frightful mortality—and in 69 per cent. of the cases a general anesthetic was necessary to complete the operation.

A few words regarding the action of scopolamin may not prove uninteresting. Scopolamin hydrobromid is claimed by some to be an impure hyoscin hydrobromid; however, its action seems identical with the latter drug. Its principal action is upon the cerebrum, inducing sleep; it is also feebly depressant to the spinal cord, but it exerts no influence as an analgesic.

The pulse-rate, while usually slightly lessened, is not markedly affected. The respiration is depressed by large doses, but seems little or not at all affected by medium doses, $\frac{1}{100}$ gr.; when death does occur, which, however, is said to be extremely rare, with even very large doses, it occurs as the result of asphyxia; $7\frac{1}{2}$ gr. have been injected intravenously into a dog without destroying life.

The skin is usually quite moist following its action, the nose, throat, and mouth dry, and the pupils, as a rule, dilated.

A new narcotic, pantopon, introduced by Sahli, of Berne, in 1909, is now occupying much attention owing to the therapeutic advantages claimed for it. It consists essentially of a mixture of the combined alkaloids of crude opium, said to exist in a definite stable solution in the form of chlorids in a fairly constant proportion—viz., morphin, narcotin, codein, papaverin, narcein, thebein, hydrocotarnin, codamin, laudanin, laudanidin, laudanœin, miconidin, papaveramin, protopin, lanthopin, cryptopin, gascopin, oxynarcodin, xanthalin, and tritopin. It is obtained as a yellowish-brown amorphous powder resembling powdered opium, easily soluble in water, less so in alcohol. Pantopon is particularly recommended for administration before general anesthetics, but it may be, if it fulfils the claims made for it, that it may largely supersede morphin in a more general use; further, the use of such multiple combinations of alkaloids as exist in pantopon bear out Burgi's contention.

The dose of pantopon is given as slightly greater than that of morphin, 0.3 grain of pantopon equalling 0.25 grain of morphin. The anodyne effect is very marked, the pulse is slow and regular, the respirations are quiet, regular, and deeper than after morphin, and their frequency but slightly less than normal; in other respects its action is very similar to that of morphin. Due to its very slight action upon the respiratory frequency and depth, it has been particularly recommended for administration before general anesthetics, but these advantages are not of much value to us here. Other advantages claimed for this drug are that the after-nausea and other unpleasant disturbances are much less than after morphin.

COMBINED METHODS OF ANESTHESIA

While in the preceding remarks the use of morphin and scopolamin are not used for their anesthetic effect, they undoubtedly exert some influence in that direction by acting as cerebral anodynes, and may often contribute, when in combination with local anesthetics and the light superficial use of general anesthetics, to accomplish safely a delicate surgical procedure.

"The discovery of the fact that by utilizing the anesthetic properties of cocain and other local anesthetics (including ethyl chlorid, Bloch) with morphin, a preliminary stage of diminished sensibility is produced, which is also most favorable to the action of general anesthesia, so that an important group of major operations which cannot be undertaken with local anesthesia alone, and in which the condition of the patient contra-indicates chloroform or ether, can be painlessly performed with the aid of a very superficial, intermittent, and purely cortical anesthesia (Morphin-cocain-ether Anesthesia)."

In this method the essential point is also to subdue the sensibility of the skin as a preliminary; after this is accomplished very little general anesthetic will be required to complete the operative work in the deeper tissues. No saturation with ether, as a rule, will be needed, and in this way the dangerous effects of the drug will be avoided or will be reduced to a remarkably safe minimum. (See O. Bloch, loc. cit.; Schleich, loc. cit., and H. Cushing, "Annals of Surg.," January, 1900). (Matas.)

Such conditions may arise in the badly septic or marasmic patient —nephritic, diabetic, endocarditic, and other constitutional states— where surgical relief seems imperative yet inadvisable by any single means alone, as when such patients are suffering from appendicitis with an adherent, embedded, or retrocecal appendix, or from a cholecystitis with a difficultly accessible gall-bladder, ectopic gestation, etc.

In such cases the combination of all methods may prove advisable, making use of a morphin-scopolamin, cocain-ether, or chloroform anesthesia. If the field of operation is so situated that spinal anesthesia will prove effective this should, of course, be given consideration, but often this will not be advisable or suited to the case; under such conditions, with the patient quieted with a preliminary hypodermic, the peripheral or easily accessible parts are anesthetized by local or regional measures, advancing as far as possible by these means to the seat of trouble, when a few whiffs of a general anesthetic, sufficient only for a purely cortical anesthesia, inducing at most a subconscious state, in which pain alone is arrested but memory and the other senses are often retained, and thus enable the operator to execute the deeper parts of the work without pain, the patient allowed to recover as soon as this is accomplished, when the closing steps of the operation are completed by local measures. While conditions justifying combinations of this kind do not often occur, they are occasionally met with, and can often be more safely handled by combined measures than by any single method used alone.

On the other hand, one may often undertake intra-abdominal operations by local anesthesia, and, once within the abdomen, encounter unexpected difficulties by meeting more extensive pathology or complicated conditions not anticipated, and be forced to resort to a general anesthetic to perform the more difficult parts of the operation, withdrawing the general anesthetic when this is completed.

In the above connection we may call attention to the intra-abdominal action of urea and quinin hydrochlorid, as spoken of by Dr. Thibault in the chapter on Quinin, but which we have not so far had occasion to use in this way.

Another class of patients where combined methods of anesthesia may prove highly useful is in operation upon the neurotic, emotional, or highly sensitive individual, where, owing to contra-indications, it is inadvisable to operate by general anesthesia. Resort can often be had to purely cortical anesthesia while performing the operation painlessly under local methods, thus preventing both the psychic influences in their production of shock as well as all reflexes from the field of operation.

Psychic impressions bear no small part in the production of shock, and reflexes thus excited from the brain may affect the vital centers just as seriously as the effects of trauma at the periphery.

Crile has always insisted on this element in the production of shock, and the published results of his experiments show clearly that definite demonstrable changes occur in the cells of the brain as the result of fear. He has amply shown that trauma, anemia, infection, and fear produce not only very definite symptoms, but that singly or in combination may damage the brain-cells, and so influence the immediate results of surgical operations. (See chapter on Anoci-association.)

The idea and advantages of combining spinal analgesia with a light superficial ether narcosis, sufficient to prevent the shock from psychic impressions, has been advocated by some writers, and the advantages of such combinations here may at times be decided.

Combined methods of anesthesia may often be advantageously utilized by the surgeon specialist, as in operations upon children or highly nervous patients for affections about the nose and throat; here all that is necessary is to keep the patient asleep, using a very superficial anesthesia, which can often be administered in a semi-recumbent position, ether being preferred; the anesthesia of the part is secured in the usual way by the local use of cocain; as the field of operation is blocked by the use of the local anesthetic, shock is often less than when operating by general anesthesia alone.

The rationality for the use of combinations such as morphin-scopolamin or cocain-ether is amply explained by Burgi's contention, and if this contention is correct, and it seems to have been amply demonstrated, we can readily understand how the skilful use of small quantities of each agent, each too small to exert any possible injurious actions alone, often enables one to accomplish absolutely painlessly and safely operations of considerable magnitude.

As just stated, it will probably be seen, on further thought, that all four agents are actually more synergistic than might appear. It will be readily conceded that morphin, scopolamin, and ether (or chloroform) enhance the central action of each other; but, how about cocain? This has been amply demonstrated to exert a well-marked central action as well as local. For a confirmation of this statement we refer to the abdominal experiments of Kast and Meltzer, spoken of in the opening part of the chapter on Abdominal Surgery; also to general anesthesia by cocain, as proved by Harrison's and Ritter's experiments, and cited under General Anesthesia with Cocain.

CHAPTER X

INDICATIONS, CONTRA-INDICATIONS, AND SHOCK

INDICATIONS AND CONTRA-INDICATIONS

It has been said that the advantages of operation under local anesthesia are entirely with the patient; this is so in so far as life is concerned, but the surgeon too often shares in the benefits that arise from this method of operation, his aim being always to relieve suffering and save the life of the patient; the reduction of his mortality by safely tiding an operative case through the many dangers which threaten must, indeed, be a source of great satisfaction to the conscientious operator. The special advantages offered to the comfort of the patient are the absence of the disturbances incident to general anesthesia. The fear of general anesthesia entertained by many people, especially if they have had one experience and suffered much from postoperative nausea, will often deter them from subsequent operative treatment unless imperative.

The distinct advantages in addition to those of relief from fear are:

It is unnecessary to starve the patient beforehand. The alimentary canal should, however, be well emptied by a suitable cathartic, and a light nutritious meal given at the regular meal time preceding the operation. All patients stand local anesthetics better when fed beforehand, and it is a distinct advantage in preventing weakness or shock in debilitated subjects.

There is no postanesthetic disturbance to the alimentary canal, which is often so trying to both patient and physician, such as the vomiting and straining accompanying the act, causing both pain and frequently, when severe or prolonged, jeopardizing the results of the work when this has been about the face, mouth, or abdominal walls.

The possibility of dilatation of the stomach and intestinal paresis or tympanites is eliminated.

The regular postoperative nourishment is not interfered with; this is of great importance in weakened individuals, and permits a more rapid recovery and convalescence from the operative procedure. Many weakened subjects may survive the operation, but die from exhaustion due to interruption of nutrition as the result of a disturbed alimentary canal.

The pain in the back so many suffer from after prolonged general anesthesia, due to complete relaxation of all ligamentous supports to the vertebral column, permitting sagging of the lumbar curve with necessary strain, is avoided.

General anesthesia is particularly dangerous to the cachectic, the feeble, aged, arteriosclerotic, in those suffering from advanced cardiac, pulmonary, renal and hepatic disease, and in alcoholics, as well as in many other conditions, such as shock, to be mentioned later.

Chloroform is particularly dangerous in all cases of septic infection. It may be argued that in some of the above-mentioned conditions local anesthesia may present certain dangers; this may be true in some few cases, but the danger is always less than that of general anesthesia.

Local anesthesia seems actually contra-indicated in very few conditions, among which may be mentioned children, epileptics, highly nervous or neurotic subjects, and exceptionally in other conditions there are actually very few pathologic conditions in which local anesthesia is not safer than general.

The additional trauma suffered by the tissues, due to the infiltrations, might in some few cases of low vitality be regarded as a disadvantage, but it is in just such cases of low vitality that general anesthesia is more dangerous.

SHOCK

Shock when severe is a condition in which general anesthesia is contra-indicated; the administration of a general anesthetic does not necessarily relieve the reflexes to the higher centers, and when this condition is marked may prove highly dangerous, and should not be used when it is possible to employ local, regional, or even spinal anesthesia, which block the afferent nerve-paths and prevent further impressions being recorded at the higher centers.

Dr. Crile's studies, demonstrations, and brilliant presentation of this subject has elucidated many points previously but imperfectly understood. In the Brit. Med. Jour. of September 17, 1910, on the "Prevention and Treatment of Shock," he writes as follows:

"It is well also to bear in mind that in inhalation anesthesia only a part of the brain is asleep. Complete anesthesia of the brain produces suspended animation or death. The medulla at least is but little affected, and the response of the unanesthetized portion of the brain is constantly observed in the course of operations; for example, the altered rate and rhythm of the pulse and respiration, the change in the vasomotor tone, as indicated by the fluctuation in the blood-pressure, the contraction of muscles, and, under light anesthesia, purposeless movements of the body, all show that a large portion of the brain is either partially or not at all anesthetized. These subconscious phenomena represent the discharge of nervous energy in response to mechanical stimulation of the nociceptors, and are vain, subconscious efforts of defense or escape. The greater such subconscious action, the greater the shock. In bad risks the subconscious response should, if possible, be wholly excluded by the combination of local with general anesthesia, the local anesthesia physically blocking the afferent impulses, thus sequestering the brain from harmful impulses."

In operations upon the larynx the reflex inhibitory impulses should be prevented by the local application of cocain.

In all operations where the impressions from the field of operation may favor the development of shock local anesthesia should be combined with general; this also lessens the necessity of profound general anesthesia. Also spoken of under the heading of Combined Methods of Anesthesia.

Whenever in the course of an operation large nerve-trunks are to be divided, and the possible effects of shock are to be avoided, as in the division of the sciatic branches of the brachial plexus, etc., the nerves should be first injected with a cocain solution before division.

Dr. Crile in his operations for goiter, which are usually in a class of patients easily shocked, almost always combines local and general anesthesia. For a further consideration of the effects of shock and the use of local anesthetics in its prevention, see chapter on Anoci-association.

CHAPTER XI

ANOCI-ASSOCIATION

A new interest and impetus has been given to local anesthesia by the recent work of Crile on "Anoci-association." This principle, founded on sound physiologic grounds and well tested clinically, marks the beginning of a new era in surgery. Crile's early work, as a pioneer in local anesthesia, had done much to advance the art and help place it upon a firm and scientific foundation, and now he shows the way to new and hitherto unrecognized advantages in its use, either alone or combined with general anesthetics.

His work in this line and the results which he has obtained admit of no controversy.

Trauma, hemorrhage, and psychic influences are the three great shock producers. The effects of trauma may be either conscious or unconscious (as when under an anesthetic).

Crile compares the nerves, whether of special sense or common sensation, to fuses, which when stimulated cause a release of energy in the magazine (the brain-cells).

In inhalation anesthesia only a part of the brain is asleep; if the entire brain were anesthetised it would produce death. The purposeless movements of a patient under an anesthetic are efforts for defense or escape, and represent so much discharge of energy. Muscular contractions under operation, the quickened heart-beat, or disturbed rhythm of respiration, all represent reflexes arising from the field of operation and producing their impression on the brain-cells.

During fear or other psychic strain tremendous energy is given off; if continued, leading to exhaustion and shock. We do not possess a single anesthetic capable of protecting the brain during operation from harmful stimuli or reflexes. General anesthetics prevent the psychic stimuli; local anesthetics block the nerve-paths and prevent traumatic reflexes; the combination furnishes the ideal.

In children and nervous individuals who enter the operating room in fear and trembling the above combination is undoubtedly the best. Too little attention has been paid in the past to these psychic influences and the effect of trauma under anesthetics, and it is in preventing these nocuous influences that much improvement can be attained in the future. In the stout and robust, who have energy to spare, this may not be so apparent, but few of our patients are from this class; many are already reduced by the condition which brings them to surgeons. We too often see patients requiring weeks or months to regain their health following an ordinary operation, their depression being out of all apparent proportion to the operation and coincident confinement in bed, or see the neurotic or neurasthenic made worse by the procedure which was intended to improve.

In these cases too little attention has been paid to, and no provisions made for, the psychic strain and trauma under anesthetics, and which persists from the incised and traumatised parts until healing has taken place.

It is along these lines that improvement must come in our operative surgery of the immediate future. Improvements will come in our operative technic, but the fundamental principles underlying the commonly performed operations of to-day are not likely to suffer any radical change, at least with the present conception of surgical principles. But improvements can come, and are within reach of us all, for the operative handling of our cases.

Children and highly nervous individuals should not be operated on by purely local methods alone, but by combinations of local with general, and here the general anesthetic need not be pushed to the point of profound narcosis, but only sufficiently deep to prevent psychic and cortical reflexes. By this plan we will have accomplished the ideal for these patients by removing the dangers of profound narcosis, and favor a pleasanter and more rapid and complete recovery by removing all elements of shock.

In the average individuals who make up the great majority of our patients, when suffering with conditions favorable for operation under purely local or regional methods of anesthesia, the general anesthetic can be entirely dispensed with, and the psychic influences controlled by a preliminary hypodermic of morphin, $\frac{1}{6}$ grain, with scopolamin, $\frac{1}{150}$ grain; this produces a somnolent, indifferent frame of mind quite favorable for any operative undertaking; when, if our technic is perfect and no pain inflicted, we have accomplished the ideal for this class of patients which make up our great majority, and no major operation should be performed under local anesthesia without this preliminary hypodermic.

Dr. Crile, in employing his anoci principle, begins the injection of the local anesthetic after the patient is unconscious from the general anesthetic; he prefers to use 0.5 per cent. quinin and urea for blocking purposes, and the technic is the same as if the operation was to be performed under purely local methods alone, infiltrating or blocking all regions, consequently the methods described in this book can be followed. We, however, feel some hesitation in using quinin and urea too extensively and in all tissues for this purpose; while it does produce a lasting analgesia for several days to a week, its objectionable quality of often producing massive fibrinous exudates in the infiltrated area, with an occasional tendency to suppuration, must not be lost sight of, as pointed out in the chapter dealing with

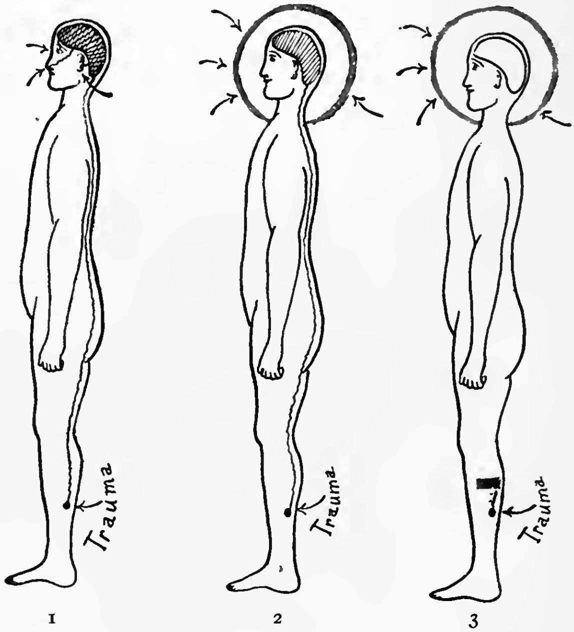
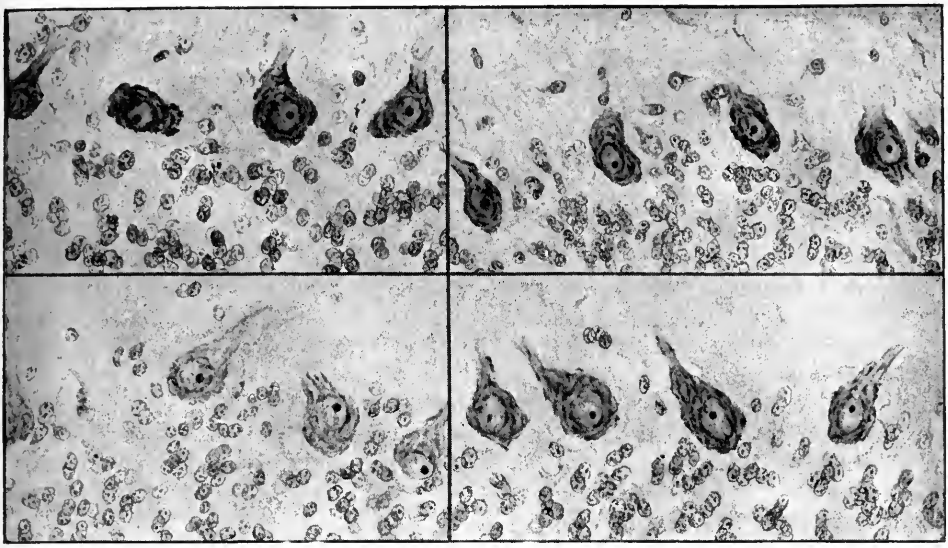


Fig. 22.—Anoci-association diagram: 1, Auditory, visual, olfactory, and traumatic noci impulses reaching the brain; 2, auditory, visual, olfactory associations excluded; 3, nerve blocked by cocain; patient in anoci-association. (After Crile.)

this subject; we consequently prefer to use throughout either 0.25 or 0.5 per cent. novocain with adrenalin, even though its effect may not last much beyond the time consumed in the operation. The employment of the anoci principle is graphically illustrated in Fig. 22, taken from Crile. Figures 23 and 24, taken from the same author, show in a striking way the effects of shock and fear upon the brain-cells of animals. Figures 25 and 26 show the comparative results obtained by different methods of anesthesia, and illustrate very forcibly the advantages of the anoci principle. This latter work of Crile is bound to add a great impetus to local anesthesia, whether we employ it in

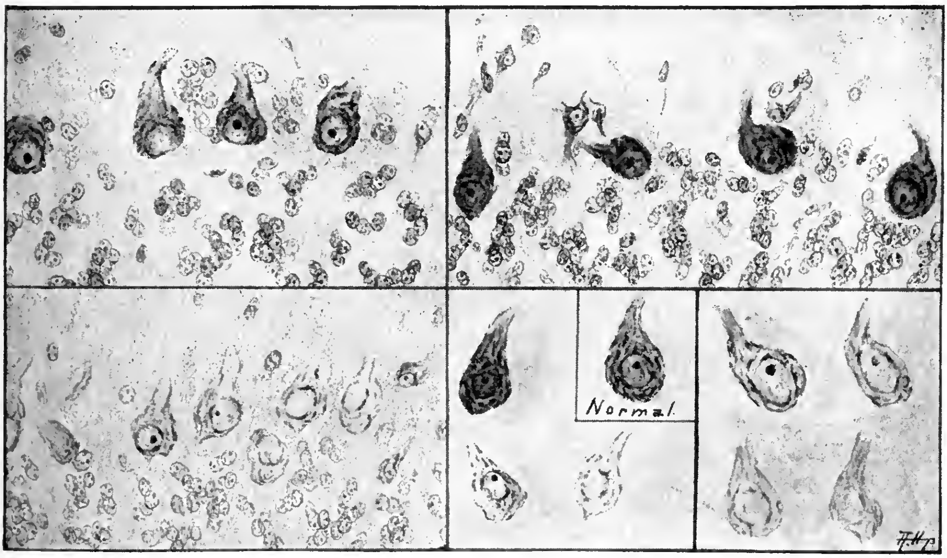
Normal dog. Anoci shocked dog. Cerv. cord severed.



Shocked dog. Ether anesthesia. Shocked dog. N_2O anesthesia.

Fig. 23. (From Crile.)

Normal rabbit. Rabbit. Fright.



Rabbit two hours after fright.

Characteristic changes in brain cells in fright. Hyperchromatic during fright. Exhausted after fright.

Characteristic changes in brain cells in shock. Note swelling and rupture of nucleus and nist-bodies.

Fig. 24. (From Crile.)

association with light cortical general anesthesia or the preliminary hypodermic of morphin and scopolamin, or both.

The survival or failure of any method advocated for practical daily use must rest entirely upon the clinical results obtained. The

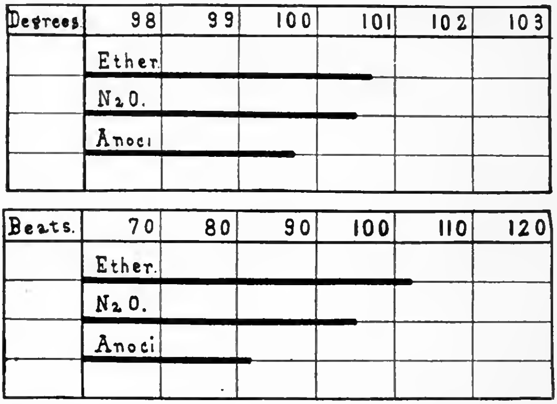


Fig. 25.—Abdominal hysterectomy. The temperature: Each heavy line represents the average 5.00 P. M. temperature of 10 patients during the first four days after operation. The pulse: Each heavy line represents the average 5.00 P. M. pulse rate of 10 patients during the first four days after operation. (From Crile.)

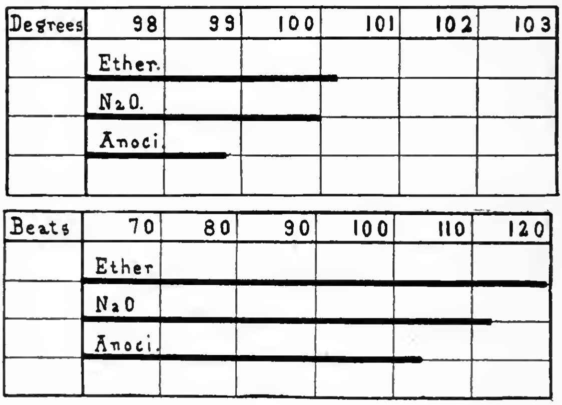


Fig. 26.—Thyroidectomy. The temperature: Each heavy line represents the average 5.00 P. M. temperature of 10 patients during the first four days after operation. The pulse: Each heavy line represents the average 5.00 P. M. pulse rate of 10 patients during the first four days after operation. (After Crile.)

prime object of all surgery, as well as all medicine, is the relief of suffering and the prolongation of life; those measures which attain these ends with the least disturbance to the patient and the least suffering must ultimately prevail to the exclusion of all other harsher and less agreeable methods.

Here local anesthesia in its anoci features, as applied to major operations, has a decided claim in offering to the patient a pleasanter convalescence.

How often one hears the complaint from a patient disturbed by a persistent postanesthetic nausea, or racked by gas pains following a laparotomy: "Oh, doctor, if I had known what I had to go through I would never have consented." Compare this picture with a similar case operated by local anesthesia and note the contrast; the great nightmare of ether, with its resulting nausea removed, and the entire absence or reduction to a minimum of postoperative gas pains in abdominal operations, or lessened painful reaction in other wounds, producing a pleasanter, easier, less dreaded convalescence, with practically no disturbance of the nervous equilibrium, with no exhausting demands for unnecessary and wasted energy upon the central nervous system, less constant and exacting attention on the part of nurses and doctors afterward, less use of the stomach-tube, and less of hot stupes and high rectal flushes. These are the advantages offered by local anesthesia. Crile states that 90 per cent. of his cases operated by the anoci principle have no unpleasant recollection of the day of their operation. How can we explain the differences?

First, The absence of a general anesthetic, or its superficial use for purely cortical anesthesia, removes the postanesthetic nausea, which in itself is a decidedly disturbing factor in its constant retching and efforts at vomiting in disturbing the field of operation, particularly so if it is abdominal, lighting up with each effort new pains by the tug and pull on the incised and sutured parts, requiring for relief repeated hypodermics of morphin, which often aggravate the nausea.

Second, The blocking process by the local anesthesia in the field of operation absolutely prevents all reflexes from reaching the surrounding parts as well as centrally, consequently there is less disturbance of their normal equilibrium and less after-reaction, and this action can be prolonged for several days when quinin and urea are used for this purpose, as recommended by Crile.

The final proof must then come in the clinical use of these measures, and this proof I feel has been already amply furnished by the pioneer workers in this field and to be now passed the experimental stage and beyond all controversy. I have often seen cases operated for serious abdominal conditions practically free from postoperative disturbance and hard to convince that they had gone through a severe major operation.

CHAPTER XII

INTRA-ARTERIAL ANESTHESIA

The first records we have of the injection of cocain into arteries was with a view of determining its relative toxicity when administered in this manner.

Alms in 1886 was the first to report its anesthetizing effect in the field supplied by the artery; he experimented by injecting cocain into the iliac artery of the frog, in this way carrying it to the entire distribution of this vessel in the lower limb, bringing about complete motor and sensory paralysis.

Since the introduction of Bier's intravenous anesthesia, investigators began to consider the arterial route as a means of diffusing anesthetic solutions for surgical purposes. The method was first used by Oppel and Goyanes, who injected weak solutions of cocain into arteries between two constrictors; their results were quite interesting, but not of much value clinically.

The method has, however, recently been brought forward by several operators working along slightly different lines.

Terminal arterial anesthesia has been introduced by Ransohoff, of Cincinnati, who reported his results in the "Lancet-Clinic," 1909, and later, in a more thorough article, in the "Annals of Surgery," 1910. The following is from Prof. Ransohoff's report:

"Case I.—Male, aged seventy-two, in the service of Dr. Robert Carothers, through whose courtesy I am enabled to report this case. The patient had been suffering for three years from a chronic osteomyelitis of the hand, which became so painful as to necessitate an amputation. His age and condition contra-indicated general anesthesia. Operation at Good Samaritan Hospital, July 12, 1909. An Esmarch bandage was applied about the arm 2 inches below the insertion of the deltoid. Under infiltration anesthesia the brachial artery was exposed and the needle of a hypodermic syringe inserted into its lumen, and 1 c.c. of a 2 per cent. cocain solution injected into the artery in the direction of the blood-current. In two minutes anesthesia was absolute and antibrachial amputation done without the patient's knowledge.

"There are two features of special interest in this case—the rapidity of anesthesia and the fact that the operation was performed without the patient's knowledge. After the operation had been completed the patient asked when we would begin. This absolute anesthesia is a salient feature of this method, as well as one of its greatest advantages.

"Case II.—Female, aged fifty, service of Dr. Robert Carothers, Cincinnati Hospital. Diagnosis: Osteoma of scaphoid bone. Operation: Esmarch strap applied tightly above knee. Under infiltration anesthesia the anterior tibial artery was exposed just above the ankle and 1 c.c. of 1 per cent. cocain solution injected into the artery. This was immediately followed by complete anesthesia of the entire foot, during which the osteoma was removed without the patient suffering the slightest pain. The further history was uneventful.

"A series of animal experiments was now done to determine the certainty of anesthesia, its safety, and its applicability in operations other than amputations. In all ten experiments were done—the first series in rabbits, the second in dogs. It will be seen that in operations other than amputations a 2 per cent. cocain solution is too strong to be consistent with safety, because of the danger of absorption into the general circulation. A 0.5 per cent. cocain solution was used and found in every way adequate.

"In the experiments on rabbits the femoral artery was selected as the site of injection. The artery was exposed in the upper part of Scarpa's triangle; 1 c.c. of 0.5 per cent. cocain solution was injected into the artery in the course of the blood-stream, and tests for anesthesia were immediately made. The experiment was in each case controlled by testing the sensibility of the other leg and distant parts of the body. The following uniform results were obtained: Irritation of the anesthetized leg caused no response; that is, the animal gave no evidence of pain, as, for instance, by drawing away the leg. Irritation of the opposite leg was invariably followed by all the evidences of pain.

"Experiment 1. The bone was exposed as roughly as possible, the knife rubbed up and down on the bone, stripping the periosteum. No pain.

"Experiment 2. The femur was broken by manual force and the two ends of the bone rubbed roughly together.

"Experiment 3. The foot was charred with a Bunsen flame. No evidence of pain.

"Experiment 4. The femoral artery was torn, causing great hemorrhage, and necessitating the abandonment of the experiment. This accident, very likely to occur in the thin-walled artery of a rabbit, is impossible, as will be shown, in the thicker walled artery of a dog or man.

"Experiments 5 and 6 were in all respects similar to the preceding experiments, and need not be detailed.

"The disadvantage of working on rabbits is manifest. The puncture of the thin-walled artery was invariably followed by hemorrhage, necessitating the killing of the animal after the experiment. The perfection of the anesthesia was determined, it is true, by the rabbit experiments, but not its freedom from danger. Therefore another series of experiments was done on dogs and the animals allowed to live.

"Experiment 7. Large black-and-tan dog. Under ether anesthesia the femoral artery was exposed and 2 c.c. of 0.5 per cent. cocain solution injected into the artery. The animal was then lifted from the dog board and allowed to recover from the anesthesia. After fifteen minutes the dog seemed perfectly normal, running about the room in the usual way. It was particularly noticed that there was an absence of any muscular paralysis. The animal was now tested for anesthesia. The anesthetized leg was pinched, scratched, and slightly burned. No symptoms of pain were elicited. Irritation of the other leg and other parts of the body gave immediate response. After testing the anesthesia for half an hour the wound was united with a continuous suture. During the maneuver the most perfect demonstration of the anesthesia was obtained. The point of injection into the artery lay about the middle of the wound. The lower half of the wound was sutured without any evidence of pain, the animal lying perfectly quiet and seemingly unconcerned. As soon as the needle entered the skin above the point of injection the animal gave all evidences of severe pain—squealing and struggling. This demonstrated that the anesthesia extends to the point of injection. The dog was watched for a week, during which no untoward symptoms were evidenced. The animal then escaped, none the worse for his experience.

"Experiment 8 was in every particular similar to the above experiment. The subject was a smaller animal, and only 1 c.c. of 0.5 per cent. cocain solution was used.

"Experiment 9 is, according to present indications, more of scientific interest than of practical value. The dog was large. Under ether anesthesia the common carotid artery was exposed and 2 c.c. of 0.5 per cent. cocain solution injected into the artery. The wound was closed with a continuous suture and the animal allowed to recover from the anesthesia. After about fifteen minutes recovery was complete and the animal was apparently normal. What was most interesting was the complete absence of any deviation from normal intelligence. The animal ate and drank from a bowl, also gave evidence of knowing what was going on about him. The animal was now tested for anesthesia. The results were most gratifying.

There was a complete anesthesia of the entire head, face, and upper part of the neck. The skull was exposed and a piece of bone chipped out. Deep incisions were made into the skin of the face, ears, and neck. Even the very sensitive nose and lips were scarified without causing pain. Irritation of other parts of the body elicited symptoms of pain. The bilateral anesthesia of the face and head may be explained by the very free anastomosis between the two carotid systems. A very interesting feature of this experiment is that sight was not interfered with, as shown by persistence of lid reflexes.

"Experiment 10. Medium-sized dog. Under ether anesthesia the femoral artery was exposed and 1 c.c. of 0.5 per cent. novocain solution was injected. The experiment was a failure, the dog showing no diminution of sensation.

"The nature of the anesthesia is terminal—that is, the cocain is carried by the capillaries to the individual nerve-endings. The solution is diffused through the capillary walls into the surrounding tissues, and very little, if any, is returned through the veins to the general circulation. This is shown by the purely local character of the anesthesia.

"The following technic is to be used in man: The main artery supplying the part to be anesthetized is exposed under infiltration anesthesia. An Esmarch strap is now bound around the limb some distance above the point of proposed injection into the artery. The Esmarch should be used as in the Bier hyperemic treatment; that is, snug enough to constrict the veins, but not so tight as to interfere with the arterial circulation. From 4 to 8 c.c. of 0.5 per cent. cocain in normal salt solution should be injected into the artery in the direction of the blood-stream. The needle used should be as fine as possible. After anesthesia is complete the Esmarch may be tightened if perfect hemostasis is desired. At the end of the operation the Esmarch is removed and the wound closed. The maximum dose suggested, that is, 8 c.c. of 0.5 per cent. cocain solution, contains only 0.6 cocain, a safe dose. This method of anesthesia is an ideal one for certain areas of the body when general anesthesia is contra-indicated. It is particularly applicable to the upper extremity, where the brachial, radial, or ulnar artery may be exposed with little difficulty."

In commenting upon the procedure, particularly Experiment 9, in which 2 c.c. of 0.5 per cent. cocain was injected into the common carotid artery (he does not say which side) and produced a "complete anesthesia of the entire head, face, and upper part of the neck," while not questioning the correctness of the observations, it is interesting to know just how the cocain acted. Was it distributed to the parts by the external carotid on the side injected? If so, it is difficult to understand how it reached the other side in sufficient quantities to produce anesthesia, unless the external carotid of that side had been previously ligated; in this case the blood could easily cross over through the numerous anastomoses. Or, did it reach the centers of the fifth nerve (the nerve principally concerned in the sensation of these parts) in the floor of the fourth ventricle through the distribution of the internal carotid artery? If this were the case, it is more readily understood how both sides were equally affected; but, on the other hand, the rest of the brain was bathed in a solution of the drug equally as strong, and should have shown more disturbance of sensation of the entire body as well as paralyzing other centers. Just where the general centers for the pain are we do not know; but we know that it is the brain that feels, and that it is capable of general anesthesia by cocain injected into the blood-current, as shown by Dr. Harrison's experiments upon himself, mentioned elsewhere in this volume, and Ritter's experiments upon dogs. (See General Anesthesia with Cocain.)

The fatal dose of cocain injected into the arteries is eight to ten times greater than the intravenous dose (Oppel), but here he was speaking of arteries in the extremities, where the effect of the cocain was largely reduced and weakened by making the circuit of the blood-stream, and much of it being fixed by contact with the comparatively large capillary area. As its toxic action is due entirely to the amount of the drug reaching the central nervous system through the circulation, when delivered into such arteries as the carotid, the ratio between the intravenous and intra-arterial toxicity must here be reversed and the intra-arterial dose here be many times smaller. Besides, when delivered intravenously most of that reaching the heart is distributed to the trunk and peripheral parts, with the bulk of the circulation and only a small part of it, certainly not over one-fourth, reaching the brain by the vessels going in that direction. With these facts it is hard to reconcile the two observations, that by Dr. Harrison, who injected 5 grains intravenously in himself in thirty minutes and obtained general anesthesia of the entire body, and that of Dr. Ransohoff, who injected into the carotid 2 c.c. of a 0.5 per cent. solution, 0.15 grain; although the dog was large, it must have been a relatively good-sized dose for that method of administration, and produced only an anesthesia of the head, face, and upper part of the neck. Letting alone the action of the drug in this particular case of carotid injection, the method of arterial anesthesia is certainly ingenious and of scientific interest. It is too early yet to state of what practical value it may become, as the writer has had but a limited experience with the method, and it has had but a limited trial in the hands of others who have introduced it. The fact that the main artery of the part must first be exposed is not in itself an objection, for the same dissections frequently are made to expose nerves for regional anesthesia. Of course the method should be tried only in those having healthy arteries; in such vessels the puncture of a fine hypodermic needle is not likely to be followed by any after-result. It would, however, seem preferable, in operating upon the extremities, where infiltration and nerve-blocking cannot be used, to use venous anesthesia, which is a simpler method, and when properly carried out produces very satisfactory results and is free from any possible after-effects.

The following case, operated upon by the author, presents some features of interest:

M., an aged man, presented an advanced carcinoma of the parotid gland, with his general condition contra-indicating the use of general anesthesia. It was decided to ligate the external carotid at its origin, as a preliminary step, after first utilizing it for arterial anesthesia. The problem then presented itself as to how soon after the injection should the ligature be applied; if done too soon no good would be accomplished, as the injected solution, not having reached the capillaries, could not readily diffuse into the tissues, and if delayed too long it would be swept into the return circulation.

Adrenalin was accordingly utilized for determining the proper time for the application of the ligature. After free exposure of the carotid, with the ligature in place but not tied, 5 c.c. of a 1 per cent. novocain solution, containing 15 drops of adrenalin (1: 1000), was now slowly injected with a fine needle; in ten seconds, and before the entire quantity had been injected, the effect came like a flash in the peripheral parts; the face, cheek, and parotid region, previously florid with dilated capillaries, was suddenly blanched almost a perfect white; the effect was so sudden and complete that it was startling and extended over the entire side of the face and head; the remaining solution was now quickly injected and the ligature tied.

Tests for sensibility showed a decided diminution over the entire blanched area, but not sufficient to permit operation. This was probably due to the small amount of novocain used, and its too slow injection to permit of the maximum amount reaching the peripheral parts at one time in such a vascular region. We now injected the trigeminus at the base of the skull and obtained perfect anesthesia, proceeding with the operation in a completely ischemic field.

This procedure of the utilization of adrenalin suggests itself as a simple and reliable means of determining when the injected anesthetic has reached the capillaries and may prove a useful adjunct. It also occurred to the author that it might find an occasional field of usefulness in ligating a large vessel in the presence of anomalous arterial formation when other tests, as peripheral pulse, etc., give uncertain results.

INTRAVENOUS ANESTHESIA

This unique and simple method of anesthesia was introduced by Prof. August Bier, of Berlin, to whom medical science already owes much. In addition to this, his latest discovery in this field, he has done much toward spinal analgesia in placing it upon the plane which it now occupies. This method was first presented by Bier before the Thirty-seventh Congress of German Surgeons, April, 1908. It is applicable only to the extremities. The limb to be operated upon is first rendered completely ischemic by an Esmarch or soft-rubber bandage applied from the distal end to a point above the proposed site of injection. This must be done thoroughly, the presence of blood in the veins interfering with the production of a perfect anesthesia. A soft-rubber bandage (the kind used for stasis hyperemia) is now applied at the upper part of the ischemic area; it must be tight enough to prevent the circulation entering the part, and should be applied over a broad area, so that the pressure does not become painful. A second similar bandage is placed below the proposed site of injection, from 4 to 6 inches below the first. Under infiltration anesthesia the vein is now exposed. The principal vein of the part should be selected and not one of its radicles. In the case of the leg, the saphenous; in the case of the arm, the median cephalic or median basilic, or one of their large trunks, in case the injection is made below the elbow. The vein should be exposed as near the upper bandage as possible, ligatures passed around it, and the upper end tied. An infusion cannula is now passed into its lumen, either through an opening or by having the vein sectioned across. This is firmly secured in the lumen of the vein and the anesthetic solution injected through the cannula. If the operation

Fig. 27.—*a–b*, The proximal; *c–d*, the distal or peripheral bandage; *vb*, vena basilica; *vc*, vena cephalica; *vm*, vena media; +, the place where the injection may be made in the cephalic and at a corresponding point in the basilic veins. Shading shows area of sensibility below the proximal bandage (Bier).

is upon the upper extremity, 50 c.c. of 0.5 per cent. novocain in normal salt solution is used; if upon the lower extremity, 80 c.c. of the same solution is used. Any large syringe can be used for making the injection, although to facilitate the work a special syringe has been devised (Fig. 28). A stout piece of tubing can be used for making the connection between the nozzle of the syringe and the cannula within the vein; it must be firmly attached to both and the syringe be in good working order, as it requires some little pressure to drive the solution into the veins. The Matas infiltration apparatus is admirably suited for this injection. The injection should not be too rapidly made, but done slowly, allowing time for the solution to flow into the veins, which are seen slowly distending as they are filled with the solution. The solution diffuses through the vein walls into the surrounding tissues, the distended veins becoming less and less distinct until they

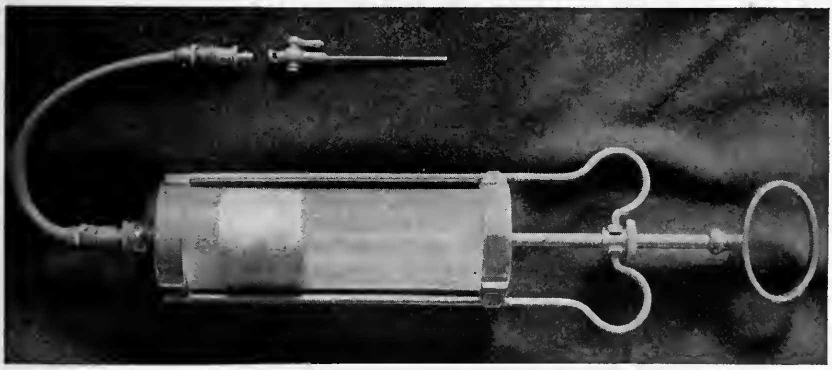


Fig. 28.—Large syringe for Bier intravenous anesthesia. (From Braun.)

are no longer discernible. The valves in the veins offer no obstruction to the injection, as they are forced by the fluid and the distention of the veins.

Anesthesia is said to be produced in from ten to fifteen minutes in the area between the bandages (direct anesthesia). In the parts distal to the lower bandage anesthesia is complete in from fifteen to twenty minutes (indirect anesthesia). Anesthesia does not reach quite to the upper bandage, and frequently leaves a strip on the side opposite to the vein which reaches down to the second bandage only partially, or not at all, anesthetic.

The circumferential spread of the anesthetic solution can be favored and increased by massage and kneading of the parts after the injection has been made and while waiting for the anesthesia to develop.

The muscular relaxation is said to be more prompt and pronounced than under ether anesthesia.

The duration of the anesthesia is absolutely under control and persists as long as the upper bandage remains in place, and rapidly disappears after the removal of the latter, sensation returning in a very few minutes. For this reason it is necessary that the entire operation be completed and, if possible, the dressings applied before the upper bandage is removed. The duration of the operation is said to bear no relation to the rapidity of the return of sensation.

Care should be exercised in securing all bleeding-points, which are easily overlooked when operating by this method. Salt solution injected through the cannula, when operating in the area of direct anesthesia, may be used to show the points of venous hemorrhage. After the completion of the operation the veins may be washed out with salt solution to remove any excess of the anesthetic solution which may still remain in them. This process does not lessen the anesthesia or seem to hasten the return of sensation, which confirms the observation that the anesthetic agents have formed compounds with the tissue-cells which is only broken up by nutrition with arterial blood.

In the numerous cases reported operated on by this method no cases of intoxication from the anesthetic used have been recorded.

In the case of amputation, or extensive operation in the area of direct anesthesia, the washing out process of the veins may be omitted, as the incisions furnish ample opportunities for the escape of any excess of solution.

In preparing the limb for injection it is said to cause less discomfort to sensitive patients if the main artery of the part is first compressed and the limb elevated and rendered ischemic in this position. Should the pressure from the upper bandage become troublesome to the patient during operation, an additional bandage can then be applied within the anesthetic area and the upper one removed.

Precautions suggested to guard against toxemia in addition to the washing-out process above mentioned are to release the bandages gradually after the completion of the operation or to tighten the upper one after it has been released for a few moments.

Here, as in all major operations under any method of local or regional anesthesia, it is desirable to give a preliminary hypodermic of morphin, $\frac{1}{6}$ grain, with scopolamin, $\frac{1}{150}$ grain, about one hour before the operation. It greatly lessens the fears and anxiety of the patient and overcomes any undue sensitiveness.

The operative possibilities under this method are not limited to any particular class of operations, but include the entire range of surgical interventions upon these parts.

The only contra-indications mentioned for this method are diabetes, advanced arteriosclerosis, and senile gangrene.

In a recent article Prof. Bier has suggested exposing the vein under local anesthesia before rendering the parts ischemic and identifying it by passing a ligature around it, as it is not always easy to recognize the one wanted in ischemic tissues, particularly if surrounded by much fat; the field can then be covered by a sterile towel and the process proceeded with.

CHAPTER XIII

GENERAL ANESTHESIA THROUGH THE INTRAVENOUS INJECTION OF LOCAL ANESTHETICS

Ritter, experimenting in Payr's clinic, produced complete general analgesia by injecting into superficial veins of dogs 10 c.c. of a 1 per cent. solution of cocain, or 5 c.c. of a 3 or 5 per cent. solution in a 0.1 per cent. salt solution. The animals lay perfectly quiet, but alert. Respiration and circulation were not disturbed, but they were completely insensible to every kind of irritation that could be used, even to the actual cautery applied to the penis, vagina, anus, tail, face, ear, and lining of the mouth. There was no sign of pain, and the dogs wagged their tails during these performances. Only when forceps were applied to the tongue did they seem to object, but here not apparently from pain.

The duration of the anesthesia was from fifteen to twenty minutes or longer, and was not followed by serious after-disturbances. Only a few showed any unpleasant by-effects, and these were small animals upon which the larger doses had been used. One dog, however, always reacted in the same way, even to small doses. The disturbances were always of the same kind, the animal becoming very restless, tossing his head about, and, if placed on the floor, ran around in circles. This would continue for about fifteen minutes, after which time the animal quieted down and remained apparently normal. Actual convulsions were never observed with any dosage. None of the larger dogs showed any by-effects.

Still more interesting are the observations made by Dr. B. W. Harrison upon himself, and reported in the Boston Med. and Surg. Jour., February 2, 1911. The doctor showed great courage in using upon himself, by the method he employed, what would have been considered a thoroughly toxic dose of the drug; but he observed the precaution of proceeding very slowly and stopping with the first unpleasant symptoms. He states that, except for minor operations, there had been no other use of cocain or allied drugs upon himself. The experiment was performed as follows:

Into one of the superficial veins on the back of the hand there was slowly injected 5 gr. of cocain in a 2 per cent. solution. The injection was made very slowly, and was completed in thirty minutes. It was deemed advisable to stop here, as dizziness and palpitation occurred. Tests of the patient's condition as to general anesthesia were now made, and were found to conform in an incomplete way with those observed in animals similarly experimented with. There was fairly marked analgesia everywhere. An incision $\frac{3}{4}$ inch long, and carried well down into the fat, was made on the anterior surface of the leg. The incision could be felt, but caused a mere trifle of pain. When several small nerves in the fat were cut each caused a small twinge of pain, but, apparently, operative procedure might readily have been undertaken with only moderate discomfort. Two hours later a similar incision was made on the opposite leg; by now the sensation of pain had nearly recovered its normal intensity. During the experiment cerebration was normal, except for a restless inability to keep the mind long on one subject. Motor power was unimpaired.

This experiment and those on dogs by Ritter are highly interesting, and, at least, of scientific value. The enormous dose necessary upon Dr. Harrison, and then producing only an imperfect analgesia, makes it an impossibility in human surgery. The dose used by Dr. Harrison was several times that necessary to show toxic symptoms, and may have proved fatal had he injected it all at once, but he made the injection slowly over a period of thirty minutes.

It is interesting to compare the results obtained by these injections with that by Prof. Ransohoff, when he injected 0.15 gr. of cocain in the common carotid of a dog, and obtained only analgesia of the head, face, and upper part of the neck. (See Arterial Anesthesia, Experiment 9, and the discussion which follows.)

A comparison of the toxicity of cocain, when injected in the various ways, is given by Oppel as follows:

"Subcutaneous injections are two to three times less dangerous than the arterial and fifteen to twenty times less dangerous than the intravenous injection, and arterial injections are eight to ten times less dangerous than the intravenous." (Here he was no doubt experimenting with arteries of the extremities, but he does not state.)

CHAPTER XIV

THE UPPER AND LOWER EXTREMITIES

"As a general proposition, it may be safely asserted that all operations can be made painless by local or regional anesthesia in all parts of the body in which the circulation can be absolutely controlled by circular constriction. Hence, the entire surgery of the upper and lower limbs (with exceptions to be considered later) can be made tributary to these methods. It is in the surgery of the extremities that the combined local (infiltrations) and regional (neural) anesthesia has attained its degree of efficiency and accomplished its most convincing, if not most brilliant, results. On the other hand, the efficiency and applicability of these methods is decidedly restricted, impaired, and at times wholly inefficient at the root of the limbs. This is more especially the case in the hip and gluteal regions, where, on account of the overlapping of the cutaneous nerve distribution and because of the great depth of the most important nerves—as, *e. g.*, the sciatic, where it issues from the pelvis—it is impossible to expose the great nerve-trunks without inflicting an additional traumatism, which is scarcely compatible with the conservative aims of the local anesthetic methods.

"It is only fair to state that these objections do not apply to all cases, and that even in these most difficult regions many perfect successes can be obtained by purely local and intraneural methods when they are applied to suitable subjects. This is particularly true of emaciated, wasted patients, in whom disarticulation at the hip can be performed by simple edematization and intraneural infiltration as effectively as in the minor amputations and disarticulations of the fingers and toes" (Matas).

In the upper extremities the difficulties to be encountered are much more successfully met by the comparatively easy access to the brachial plexus, which can be exposed and infiltrated above the clavicle.

But whatever doubts may exist as to the invariable success of cocain and its allies in controlling the sensibility of the root of the limbs, there can be none in asserting that all operations, including amputations, disarticulations, and excisions below the insertion of the deltoid in the arm, and below the middle third of the thigh in the lower limbs, can be made painless by purely local or neural (peripheral) methods of anesthesia. In anesthetizing the extremities the methods will vary with the individual regions, and the technic will demand more skill and anatomic knowledge as the surgeon proceeds from periphery to center. In all major procedures, in which a large part of the thickness and circumference of the limb is to be exposed to the knife and to painful manipulations, the neuroregional methods is to be preferred, as in excision of bones and joints and in amputations. In more superficial or well-circumscribed lesions the simple infiltration method of Schleich will be most applicable. In thin and marasmic subjects this method will also find frequent and ready application because of its greater simplicity, even when amputations are required, provided they are strictly typical and do not involve extensive excursions away from the infiltrated area. But whether the method adopted be the edematization of Schleich or the neuroregional method, the circular elastic constrictor applied on the Corning principle should be applied after the analgesic drug has been injected and the exsanguination of the limb by elevation and gravity has been obtained.

The introduction of vein anesthesia by Bier has greatly simplified all procedures upon the extremities where this method can be employed; however, there still remain many conditions in which it cannot be successfully used—the necessary appliances may not be at hand, or the operator may prefer to use other methods.

The ability to control the blood-supply in the extremities greatly facilitates all surgical procedures in these parts, and in the use of local anesthetics intensifies and prolongs their action.

The course of the long cutaneous trunks is fairly constant in both upper and lower extremities, and should be carefully studied, as well as their points of emergence through the deep fascia; the smaller cutaneous branches are, however, subject to variations within certain limits, and cannot always be definitely located. But the main trunks of these parts are quite constant throughout their entire course and can be easily reached, either through deep paraneural injections along their course or by free exposure and direct (intraneural) injections.

In all operations upon the bones it must be remembered that bone and cartilage have no sensation, but that the periosteum, perichondrium, and synovial membranes are nearly as sensitive as the skin; bone-marrow is also slightly sensitive.

In operating here by infiltration the periosteum should be included; after this has been infiltrated or denuded from the bone no further sensation is felt.

In operating upon bones for inflammatory conditions, such as periostitis or osteomyelitis, it is preferable always to use the regional methods of anesthesia, but in cases where this is not feasible, or in the absence of inflammations, where it is preferred to operate by infiltration, as in the removal of an osteophyte or for a simple osteotomy, in such cases it is desirable, where the bone is superficial and easily accessible, to infiltrate the periosteum before making the incision; the infiltration is done with a long needle passed down from the skin from two or more points and directed in different directions, so as to embrace the entire operative field on the bone (see Fig. 15). In case the bone is deeply situated or overlaid by heavy muscles, as in the case of the femur, it would be preferable to anesthetize the periosteum later after the bone has been exposed by the division of the overlying soft parts. Where the periosteum has been well anesthetized the use of chisels or other bone-cutting instruments is unaccompanied by any pain. In operating by regional methods the injections should be made at sufficiently high levels to include the nerve supply to the periosteum when possible, otherwise the periosteum will have to be infiltrated. The humerus receives its nerve-supply from the musculospiral and musculocutaneous nerves; the radius and ulnar, from the median nerve; the elbow-joint and wrist receive nerves from the three large trunks in the arm; the femur, from the sciatic and obturator nerves; the tibia, from the anterior and posterior tibial nerves; the fibula, from the peroneal; the knee-joint, from the internal and external popliteal, obturator, and crural nerves.

The entire contents of the joints contained within the synovial sacs can be anesthetized by passing a needle into the sac and filling it to a point of moderate distention with solution No. 2 (0.5 per cent. novocain), or slightly lesser quantity of a stronger solution, and allowing it to remain for about five minutes, when it can be withdrawn or will escape from the incision.

Fractures.—Local anesthesia has been used occasionally in reducing fractures of the long bones. While in certain cases it may be useful where general anesthesia is contra-indicated, it is certainly not the method of choice, for with it we do not get the complete muscular relaxation so necessary for the perfect reduction of the fractured fragments. Lerda, in the "Centralblatt für Chirurgie," 1907, states that during the last two years extensive use has been made of local anesthesia for fractures in Isnardi's service at Turin, where he is assistant; he applied this technic in 30 cases before reduction of the fracture and has never observed the slightest inconvenience. He uses a long, strong needle, and injects the anesthetic mixture at various points between the fractured ends and tangential to them, so that the entire focus of the fracture, the bone-marrow, periosteum, and surrounding tissue become impregnated with the anesthetic. He adds a drop of 1:1000 solution of adrenalin to each cubic centimeter of a 0.5 per cent. solution of cocain. Sometimes as much as 0.08 gram of cocain (about 1 grain) was injected without appreciable by-effects. The contraction of the vessels aids in preventing hematoma at the point. The anesthesia is generally complete in about eight minutes. Not only is the pain abolished, but the fracture can be reduced much more perfectly, attaining results otherwise impossible without general anesthesia.

While the method recommended by Lerda has the advantage of simplicity, it may be preferred in many cases to use regional anesthesia, which produces a certain amount of muscular relaxation, though always less than that obtained from general anesthesia; for this reason general anesthesia is always to be preferred except in those cases which positively contra-indicate its use; here, where some form of anesthesia is needed in complicated cases, the local or regional methods may prove of valuable assistance.

THE BRACHIAL PLEXUS

The nerves of the upper extremity are all derived from the brachial plexus except the intercostohumeral; the lateral cutaneous branch of the second intercostal, which crosses the axilla, pierces the deep fascia at the inner side of the arm, and is distributed to the skin of the upper parts of the arm on its inner and posterior surface; sometimes the third intercostal gives off a similar branch. The brachial plexus is quite easily exposed and blocked; for this purpose it should be exposed above the clavicle by an incision running downward and outward from the outer border of the sternomastoid over the course of the plexus (see Fig. 69), which is easily recognized lying on the surface of the scalenus medius, where each of its branches may be separately injected, each with a few drops of 0.5 per cent. novocain solution with a few drops of adrenalin to the ounce.

The results of an intraneural injection of the brachial plexus are shown in from five to ten minutes in a complete analgesia of the shoulder and entire arm, and can be made use of in extensive operations upon these parts, and is particularly suited to high amputations and disarticulations at the shoulder. Where the operative field enters the region of distribution of the intercostohumeral nerve, this may be blocked by a few drams of solution injected subcutaneously along the floor of the axilla on its outer and posterior border. All operations above the elbow, when too extensive to be readily performed by infiltration, should be done by blocking the brachial plexus, thus controlling all nerves, superficial and deep, of this part as well as the forearm and hand. The localization and injection of the cutaneous trunks of this region is unsatisfactory, as they are derived from a variety of sources and overlap each other; superficial or minor operations should, therefore, be done through infiltration, reserving blocking of the brachial plexus for the more extensive or major procedures. Operations at or near the elbow, involving extensive dissections, resections, or amputations, had best be performed by the above method, which, of course, may also be used for any operation on the distal parts of the forearm or hand, but here it would be preferable to block the nerves at the elbow.

"We believed in January, 1898, that in cocainizing the three great nerves of the arm at the elbow by direct intraneural infiltration a considerable territory had been conquered from the domain of general anesthesia. We were not then aware that a few months before our first operation at the Charity Hospital the same principle had been successfully applied to the lower extremity by the direct infiltration of the sciatic and anterior crural nerves in the performance of an amputation of the leg. The credit of applying this direct intraneural method in major amputations is due, I am pleased to say, to Dr. Geo. W. Crile, of Cleveland, Ohio, whose remarkable and most exhaustive experimental study of shock has made his name familiar to all readers of surgical literature. It was precisely with the view of diminishing shock that Dr. Crile was led to apply this method, which he very appropriately designates the 'blocking method,' because the infiltration of a nerve-trunk with cocain 'blocks' or completely interrupts the conduction of all afferent, irritant impressions made upon the nerve below the blockade. Crile's first operation was performed May 18, 1897, and was suggested by the well-known experiments of the physiologists, U. Mosso (1886) and François Franck (1894)" (Matas).

In a personal communication addressed to Dr. Matas, August 24, 1899, Dr. Crile stated that he had operated by the "blocking" method, up to that time, on 7 patients, 1 of these being a case of amputation at the shoulder-joint anesthetized by "blocking" the brachial plexus above the clavicle. Dr. Crile's first case of amputation of the leg was reported to the Ohio State Medical Society in 1897, and excited the attention of that body, but the great merit of his performance has failed of sufficient general recognition as one of the most brilliant and useful contributions to the technic of regional anesthesia that have emanated in recent years from an American surgeon.

"The effect of intraneural injections is usually and promptly felt, and the effect is almost identical with that following the complete section of a mixed nerve. The only difference between this and complete anatomic section lies in the remarkable fact that the voluntary control of the parts below the 'blocked' nerves is largely retained, so that the patient can materially assist the surgeon in his manipulations. All pain conduction, all thermal sense is entirely lost; the muscular sense is impaired, but the deep reflexes are not lost; common sensation, tactile sense, is profoundly obtunded, but is not altogether abolished. This affinity of cocain for the pain-conducting and thermal fibers is one of the many remarkable features of its marvelous anesthetic action" (Matas).

In some unusual cases the anesthesia following intraneural injection has been retarded; this retardation has been sometimes so prolonged that on more than one occasion I have felt worried at the prospect of total failure. After waiting patiently for fifteen and in 1 case twenty minutes, the characteristic subjective paresthesia began, and in a few seconds thereafter the anesthesia was complete. Once established, the anesthesia will remain as long as the circulation is arrested by the constrictor, but in places where constriction is not satisfactory, as at the groin (anesthesia of the anterior crural) and at the brachial plexus, the nerves will remain anesthetized for forty-five minutes to an hour, if a 1 per cent. novocain or a 4 per cent. beta-eucain solution is used with adrenalin.

The anesthesia is more transitory if the weaker solutions are injected, and for this reason a 1 per cent. novocain or 4 per cent. beta-eucain should be preferred. Should the anesthesia begin to disappear before the completion of the operation, the nerves can be re-injected. In injecting the nerves great care should be observed to use the finest needle, and to employ only fresh and perfectly sterile solutions. The fluids must be introduced into the center of the nerve with the needle directed parallel to the nerve-fibers. Very few drops will usually suffice to give the nerve a slight fusiform swelling at the point of injection, which is characteristic of a thorough infiltration. Injections made in this manner into a healthy nerve are never painful, provided that the nerve is held slack, so that the injection can be made without the least traction upon its fibers. Should traction be made upon the nerve-trunk or tension made upon its fibers pain will be produced. In case a nerve is inflamed from the extension of a surrounding inflammation intraneural injections will always cause pain. For this reason, when practicing regional anesthesia the nerve-trunks should be injected sufficiently high above the area of inflammation to be well beyond a possible lymphangitis of the nerve-sheath. For instance, if it is necessary to amputate a finger, and the inflammation extends well up toward its base, it would be preferable to inject the nerves above the wrist; or should it be necessary to open a deep palmar injection or resect a metacarpal bone, and the inflammation extend to or above the wrist, it would be better to inject the nerves at the elbow.

The *paraneural injection of the brachial plexus* both above the clavicle and below it in the axilla, as has been recommended and practiced by some operators, but particularly in the axilla, is a far too dangerous procedure to find a place in the operative methods of conservative operators.

It is far better, safer, and surer, as well as quite simple, to resort to the free exposure of the plexus above the clavicle, and inject each individual nerve by the intraneural method, as first advocated by Crile. These nerves are too large to be readily penetrated in effective quantities by the anesthetic fluid with any degree of certainty, and the use of strong solutions at these points, highly vascular and close to the trunk, in any effective quantity is likely to prove dangerous, as absorption is active, and with no practicable means of retaining it *in situ* by constriction.

Aside from the danger in the solution injected, if made in effective quantity and strength, the anatomy of this region should be sufficient to deter any but the most venturesome from this practice.

Above the clavicle the brachial plexus lies well to the base of the neck on the scalenus medius, just to the outer border of the scalenus anticus; the subclavian artery in this position passes behind the scalenus with the plexus above, giving off in this neighborhood branches of large size (Fig. 29). Many veins are encountered in all directions, and, while their puncture with a fine needle would not be of much consequence, an intravenous injection may prove a more serious matter.

Below the clavicle the plexus lies to the outer side of the first portion of the artery, embraces the second portion, and lies somewhat more widely distributed around the third. The vein in both cases is fairly out of the way.

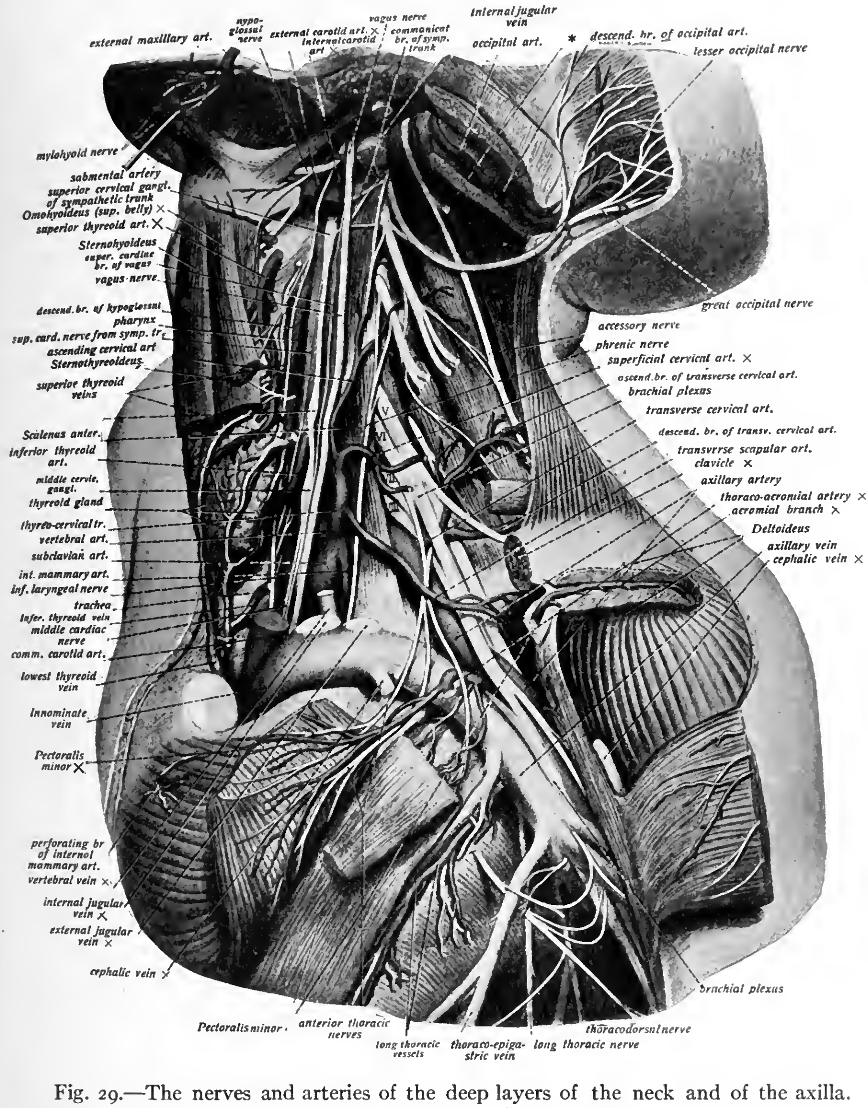


Fig. 29.—The nerves and arteries of the deep layers of the neck and of the axilla. (Sixth layer of neck, deeper layers of the axilla.) The greater portions of the infrahyoid muscles and of the common carotid artery have been removed; the clavicle has been disarticulated at the sternoclavicular joint and sawn through at about its middle. The pectoralis major and minor have been divided and the deltoid incised along the deltoid branch of the thoraco-acromial artery. *, Accessory sympathetic ganglion. (Sobotta and McMurrich.)

Notwithstanding these anatomic arrangements, paraneural injections have been made in both positions. The Kulenkampff method, above the clavicle, has been favorably spoken of by Braun, and is done in the following manner: That portion of the plexus is selected for injection at the point where it passes over the first rib; in this position the artery lies below and on the inner side, the clavicle above and in front, the pleura and lung beneath (Fig. 30).

The direction of the brachial plexus, as it passes under the clavicle, is at about right angles to the long axis of this bone, and passes under at about its midpoint in the erect position of the body; for this reason, as well as the fact that in this position the clavicle descends slightly downward and forward, thus affording a better exposure of the field, it is advised that the injection be made in the sitting position (Fig. 31). The method of procedure is as follows·

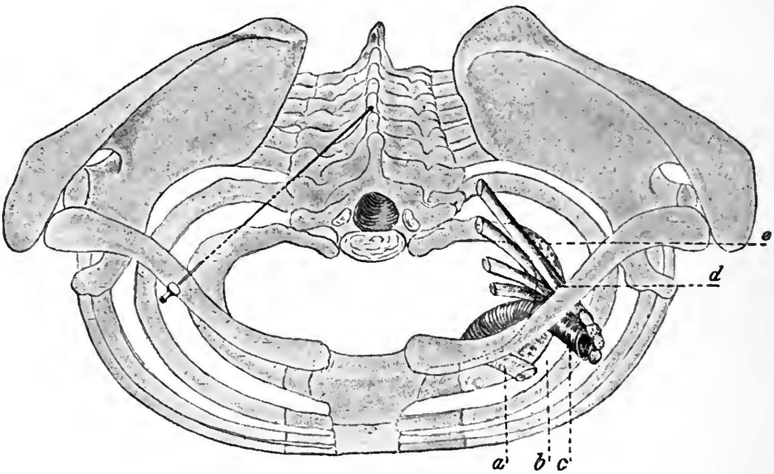


Fig. 30.—Thorax from above, after Kulenkampff. On one side is shown the position of the brachial plexus and subclavian artery to the clavicle, on the other the direction the needle should take in making the injection: *a*, Subclavian vein; *b*, point of attachment of anterior scalenus muscle; *c*, subclavian artery; *d*, brachial plexus; *e*, point of attachment of scalenus medius muscle. (From Braun.)

With the patient sitting erect the finger is passed over the midpoint of the clavicle and accurately locates the artery by its pulsations; the skin and subcutaneous tissue is now lightly infiltrated, and a long fine needle, unattached to the syringe, is passed in a direction downward, inward, and backward from the midpoint of the clavicle in such a direction that it aims at the spinous process of the second or third dorsal vertebra; the distance to be penetrated and the amount of fat vary, but it is usually from 2 to 4 cm., the plexus lying just under the deep fascia. When the plexus is reached a slight radiating pain or paresthesia is felt down the branches of the radial or median nerve in the hand or fingers; at this point the needle is held stationary, the syringe attached, and the injection made. The object in not attaching the syringe earlier is that should the artery be entered blood will flow; should this occur with a fine needle it is not likely to be of much consequence, the needle being withdrawn slightly, and the point directed a little more laterally. About 10 c.c. of a 2 per cent. novocain-suprarenin solution is injected; the needle is now slightly withdrawn, and an additional 10 c.c. injected around in the neighborhood, to be sure to reach any cord of the plexus that the first injection may have missed.

It is said that when paresthesia occurs, which indicates that the plexus has been reached, anesthesia is certain, and usually is es-

Fig. 31.—Position of patient for Kulenkampff brachial plexus injection. (From Braun.)

tablished in from one to three minutes; occasionally, however, it may require a longer delay, from ten to fifteen minutes; failure to obtain anesthesia by this time usually indicates the need of another puncture, when 5 to 10 c.c. of a 4 per cent. solution is used in the same manner, except that the paresthesia in the extremity does not occur unless the first injection has gone wide of the mark; should the first injection fail, the second is not near so likely to succeed (Fig. 32).

In the hands of Kulenkampff and his associates, who injected a large number of cases in this way, very few failures were recorded.

The duration of the anesthesia is from one-half hour to three hours, and is associated with complete muscular relaxation of the part.

Paraneural Injection Within the Axilla.—The arm is abducted to a right angle, the index-finger of one hand is passed up on the outer

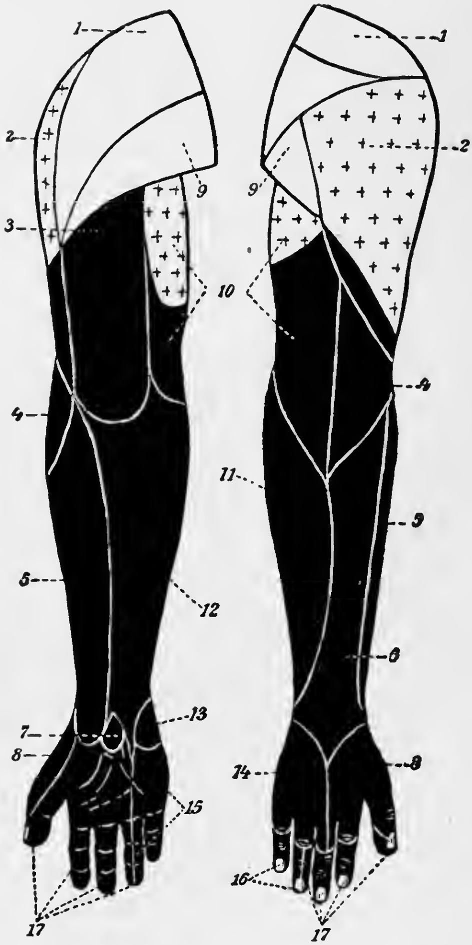


Fig. 32.—Areas of distribution of cutaneous nerves (after Toldt), showing effect of Kulenkampff plexus anesthesia: ■, Anesthesia; + +, hyperesthesia; □, normal sensation; 1, supraclavicular nerves; 2, circumflex; 3, external cutaneous; 4, musculospiral; 5, radial; 6, musculocutaneous; 7, median; 8, radial (terminal branches); 9, lateral cutaneous from second intercostal; 10, musculospiral; 11, ulnar; 12, internal cutaneous; 13, palmar branch of ulnar; 14, dorsal branch of ulnar; 15, palmar branch of ulnar; 16, digital branches of ulnar; 17, digital branches of median. (From Braun.)

side of the fossa, and the brachial artery located and slightly displaced downward and inward; a long fine needle is now passed over the tip of the finger and directed up in the long axis of the limb until well within the axilla, when the injection is made; the precaution should be followed here, as elsewhere, when making an injection in the neighborhood of vessels to continuously inject the solution as the needle is being advanced; in this way the vessels may be pushed aside and their puncture avoided.

The needle is now passed behind the artery near the insertion of the tendon of the latissimus dorsi to reach the posterior cord of the plexus, and an additional injection made at this point; 30 to 40 c.c. of a 2 per cent. novocain adrenalin solution is recommended as the necessary amount (containing in this concentration a quantity of the drug clearly beyond the safe limits). While the supraclavicular injection will find a place in our recognized methods of procedure, this last injection within the axilla is, to say the least, unsurgical and is not to be recommended.

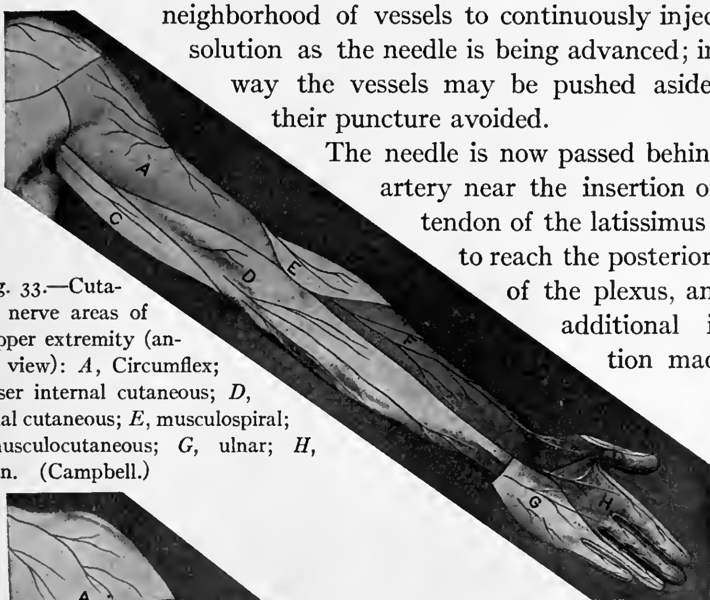


Fig. 33.—Cutaneous nerve areas of the upper extremity (anterior view): *A*, Circumflex; *C*, lesser internal cutaneous; *D*, internal cutaneous; *E*, musculospiral; *F*, musculocutaneous; *G*, ulnar; *H*, median. (Campbell.)

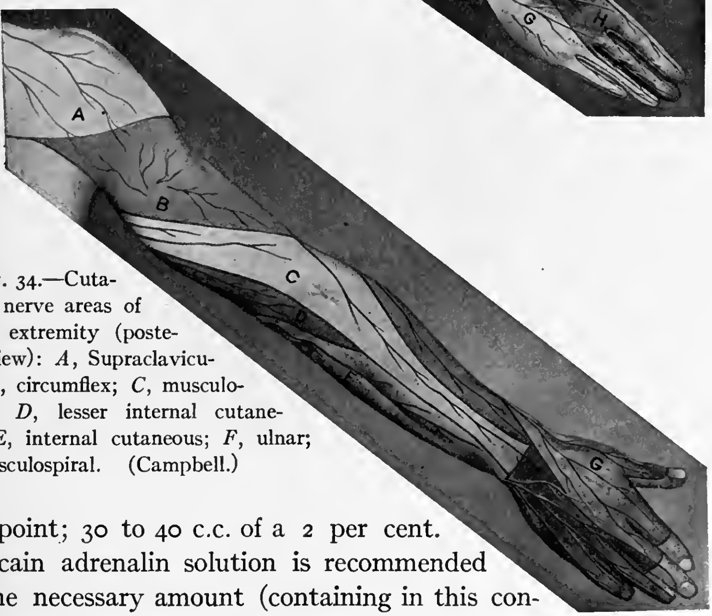


Fig. 34.—Cutaneous nerve areas of upper extremity (posterior view): *A*, Supraclavicular; *B*, circumflex; *C*, musculospiral; *D*, lesser internal cutaneous; *E*, internal cutaneous; *F*, ulnar; *G*, musculospiral. (Campbell.)

The location and distribution of the nerve-supply from the elbow down should be carefully studied for the application of regional methods of anesthesia to these parts, particularly the cutaneous distribution, which is fairly constant (Figs. 33 and 34).

NERVES OF THE UPPER EXTREMITY

The *Musculocutaneous* (*External Cutaneous Nerve*).—The cutaneous portion winds around the outer border of the tendon of the biceps, and, piercing the deep fascia, becomes superficial, passing behind the median cephalic vein; it divides opposite the elbow-joint into anterior and posterior branches.

The anterior branch descends along the radial side of the forearm as far as the ball of the thumb, giving off cutaneous branches to this region back of the wrist and carpus; at the wrist-joint it is placed in front of the radial artery.

The posterior branch passes along the back part of the radial side of the forearm, supplying this region as far as the wrist.

The *internal cutaneous nerve* pierces the deep fascia with the basilic vein about the middle of the arm, and, becoming cutaneous, divides into anterior and posterior branches. The anterior branch descends usually in front of, but occasionally behind, the median basilic vein, and is distributed to the skin on the anterior part of the ulnar side of the forearm as far as the wrist.

The posterior branch passes obliquely downward and backward over or in front of the internal condyle to the posterior surface of the inner side of the arm, and is distributed to the skin as far as the wrist.

The *lesser internal cutaneous nerve* pierces the deep fascia on the inner side of the brachial artery at the middle of the arm, and is distributed to the skin on the inner and posterior surface as far as the elbow.

The *median nerve*, at the bend of the elbow, lies beneath the bicipital fascia to the inner side of the tendon of the biceps, separated from it by the brachial artery. It passes between the two heads of pronator radii teres, and it is deeply situated until about 2 inches above the wrist, when it becomes superficial, lying between the tendon of the flexor sublimis and flexor carpi radialis beneath or slightly to the ulnar side of the tendon of the palmaris longus, and follows this course into the hand.

This nerve can be easily reached by an open dissection at the bend of the elbow for an intraneural injection, or by passing a needle beneath the tendon of the palmaris longus above the wrist for a paraneural injection. In the hand this nerve supplies the superficial muscles of the thumb, two outer lumbricales, both sides of the thumb, index, and middle fingers, and radial side of the ring finger on their palmar aspect; each digital nerve opposite the base of the first phalanx gives off a dorsal branch which joins the dorsal branch from the radial, and runs along the side of the dorsum of the finger to end in the skin over the last phalanx.

The *ulnar nerve*, at the bend of the elbow, lies against the bone between the internal condyle and olecranon, and is easily reached in this position for a paraneural injection by passing the needle down to it through the skin. In the forearm the nerve is deeply situated, but becomes more superficial near the wrist, lying to the radial side of the tendon of the flexor carpi ulnaris covered by the skin and fascia, where it can be fairly easily reached by a needle for paraneural injections.

In this position the ulnar artery lies to the radial side and slightly more superficial than the nerve, and is to be carefully avoided by keeping the needle nearer the tendon of the flexor carpi ulnaris; the injection should be made sufficiently free to permit some of the solution reaching the artery upon which the palmar cutaneous branch, given off higher up in the arm, descends to the skin of the palm.

The injection should be made about 2 inches above the wrist, to reach also the dorsal cutaneous branch which is given off in this position, and curves around the wrist beneath the tendon of the flexor carpi ulnaris, to divide into branches to be distributed to the inner side of the little finger and adjoining sides of the little and ring fingers; if the injection is made too low these branches will escape.

The nerve continues down on the outer side of the tendon of the flexor carpi ulnaris to its attachment to the pisiform bone, and immediately beyond divides into superficial and deep palmar branches. The superficial branch supplies the palmaris brevis and skin on the inner side of the palm, sending digital branches to the inner side of the little and adjoining sides of the little and ring fingers. The deep palmar branches supply the deep muscles of the palm.

The *musculospiral nerve* appears at the bend of the elbow after piercing the external intermuscular septum, and descending between the brachialis anticus and supinator longus to the anterior surface of the external condyle, where it divides into the radial and posterior interosseous nerves. In addition to these terminal branches there are three cutaneous branches: an internal cutaneous, which is distributed to the arm above the elbow, and is not of much concern to us here, as all of these nerves should be reached by blocking the brachial plexus above the clavicle.

The upper and smaller branch passes to the front of the elbow, lying close to the cephalic vein, and is distributed to the skin on the anterior surface of the arm; some fibers from this nerve may descend below the elbow.

The lower branch is the more important to us here, and its position should be borne in mind in all nerve-blocking operations at the elbow. It pierces the deep fascia below the insertion of the deltoid, running down along the outer side of the arm and elbow, then along the posterior surface of the radial side of the forearm as far as the wrist.

The *radial nerve* passes down the arm from the bend of the elbow, lying beneath the supinator longus to the outer side of the radial artery; about 3 inches above the wrist it turns outward, passing beneath the tendon of the supinator longus, pierces the deep fascia on the outer border of the forearm, and becomes superficial. In this position it gives off its digital branches, an external branch which descends to the radial side of the thumb, and an internal branch which divides into three digital branches to supply the adjoining sides of the thumb and index-finger, index- and middle fingers, and the adjacent sides of the middle and ring fingers.

This nerve can best be reached for a paraneural injection about 2 inches above the wrist to the outer side of the tendon of the supinator longus, making the injection into the deep fascia and carrying it across the outer border of the forearm for about an inch, to insure reaching all branches of the nerve.

The above is a brief review of the nerve-supply of the forearm and hand which concerns us in the regional anesthesia of these parts. It can be seen from a study of the points at which these nerves are accessible, the opportunities offered for blocking them either by direct exposure and intraneural injection or through paraneural injection by directing the needle down to the positions in which the nerves will be found. But the possibilities here of an occasional anomalous distribution must also be remembered. For all operations below the elbow, including forearm, wrist, and hand, the intraneural method of blocking at the elbow the three principal nerve-trunks in this region—radial, ulnar, and median—after free exposure by open dissection, as first practised by Dr. Matas, will produce a perfect anesthesia of all distal parts where the technic has been properly carried out. It must, however, be remembered that, in addition to the three above-mentioned nerves, the skin of the forearm is supplied by the internal and external cutaneous nerves, and if account is not taken of these in making the injection the resulting anesthesia will be imperfect or unsatisfactory.

The musculocutaneous nerve at the bend of the elbow passes behind the median cephalic vein, then divides into anterior and posterior branches. The anterior branch of the internal cutaneous passes in front of or behind the median basilic vein, at the bend of the elbow, its posterior branch passing over the inner condyle.

On account of the existence and position of the above cutaneous nerves the infiltration done at the bend of the elbow to expose the three principal nerve-trunks—radial, ulnar, and median—should be made in an oblique or transverse course, and not vertical over the course of the large trunks, unless it should be preferred to inject the lateral subcutaneous tissue by a separate injection. In exposing the radial in the groove between the brachialis anticus and supinator longus, if the infiltration is carried in toward the middle line in the neighborhood of the median cephalic vein, it will include in the anesthetic atmosphere the external cutaneous nerve.

It must also be remembered in injecting the radial not to omit the posterior interosseous nerve, which is found in the substance of the supinator brevis. The infiltration to expose the median nerve will probably reach and anesthetize the anterior branch of the internal cutaneous which lies under the median basilic vein, but, to be sure that this nerve as well as the posterior branch have been reached by the solution, it is advisable to inject a few small syringes of solution subcutaneously between the median nerve and the internal condyle. The ulnar nerve in thin and emaciated subjects, where it can be readily felt, need not be directly exposed, but can be injected paraneurally, but where overlaid by much tissue it is safer and more surgical to directly expose it. In discussing this particular procedure Prof. Matas, in his report on "Local and Regional Anesthesia" before the Louisiana State Med. Soc., 1900, states the following:

"Personally, I regard the open intraneural method of cocainization of the three nerves—musculospiral, median, and ulnar—at the bend of the elbow as the most effective, certain, and simple means of securing total anesthesia of the hand, wrist, and forearm.

"It is a strictly anatomic procedure which admits of no guesswork, and for this reason is not likely to be popularized except in the clinics of surgical specialists.

"The practicability of this method suggested itself to me in 1897, but no opportunity presented itself for its application until January, 1898, when an old man, aged seventy-six, applied to my clinic for the relief of an extensive and deep epitheliomatous ulcer, which involved a large part of the dorsal and hypothenar regions of the right hand. The patient was profoundly arteriosclerotic, his radials were hard and rigid as a pipe-stem, and his heart was the seat of loud aortic and mitral murmurs, which indicated advanced valvular lesions. He was a decidedly unfavorable subject for general anesthesia, and I decided to anesthetize the hand by the direct neuroregional method.

"The musculospiral, the median, and the ulnar were readily and painlessly exposed (under infiltration anesthesia, Schleich No. 1) by separate incisions, made over the region of the individual nerve-tracts, where they are most superficial at the bend of the elbow; the nerves were then exposed, and each injected with 5 to 8 minims of a 1 per cent. solution of cocain. This caused a slight fusiform swelling at the point of injection.

"The wounds were sutured, but the threads were not tied, to provide for further injection, and the entire region was protected by a carefully applied aseptic dressing. The arm was then exsanguinated by elevation, and the elastic constrictor was applied over the middle of the arm. The anesthesia of the extremity was now complete from the finger-nails up to the elbow. We were then able to extirpate the growth very freely, including the fourth and fifth fingers with their metacarpals and the corresponding palmar and dorsal aspects of the hand, proceeding throughout with all the freedom that is permitted by general anesthesia. After completing the work in the hand the incision at the elbow was closed by tying the knots of the loose catgut sutures, which had been purposely left untied before the constrictor was removed. The operation was in this way not only painless, but bloodless. Before the operation the patient was given a hypodermic, consisting of $\frac{1}{4}$ gr. morphin, $\frac{1}{40}$ gr. strychnin, and $\frac{1}{100}$ gr. digitalin.

"Since the first operation (January, 1898) was performed the procedure has been repeated by myself several times and once by my assistant, Dr. Larue. In all these cases the intervention was necessitated by bone lesions of either the hand, wrist, or forearm.

"In all of these cases the patients were able to walk to their beds after leaving the operating-table. None suffered from the least shock or constitutional disturbance, and in none were the postoperative sequelæ such as to suggest that any injury had been done by cocainization of the nerves. All the small wounds made to expose the nerves healed kindly under the usual aseptic dressing. In all of these cases the anesthesia of the regions tributary to the nerves injected continued for a variable period, extending from ten to fifteen minutes after the removal of the constrictor.

"In view of the practical success of this method of obtaining complete insensibility of all the parts below the elbow, it is superfluous to enumerate or discuss all the operations that can be performed in this region without the help of general anesthesia. It is evident that in absolutely anesthetic fields all operations are possible.

"I would again lay stress upon the fact that the method here described is a regional method, in which the anesthesia is obtained by the direct infiltration of the nerves at a distance from the field of operation, and differs from all other methods suggested to accomplish the same regional object except that of Dr. Crile, of Cleveland, Ohio, which is identical in principle and technic, except that it is applied at a higher level by injecting the brachial plexus in the supraclavicular space.

"At the time that my first operation was performed I was not aware that very nearly the same results had been obtained by Reclus some time before the publication of his remarkable book, 'La Cocaine en Chirurgie,' in 1896. Reclus' operation differs, however, from the one here described in the essential fact that he attacked the three nerves at the elbow by subcutaneous paraneural injections. He erroneously attributes the suggestion to Krogius, of Helsingfors, Finland, and his results, though apparently satisfactory, were not sufficiently encouraging to decide him to continue its further application. In addition to his doubts as to the general reliability of this method, he fears that traumatic neuritis may result from the direct injection of the nerves, and also believes, very justly, that the introduction of the needle in search for the nerves in the vascular sheaths at the root of the limbs is fraught with too much risk to justify the general adoption of this practice. We concur in these criticisms, as they apply to the subcutaneous paraneural method, which is largely a matter of approximation and guessing. These objections do not hold, however, with the open intraneural method, in which the nerve to be injected is directly exposed to view.

"As to the possibility of traumatic neuritis, which Reclus fears, I have never noticed the least evidence or trace of it in the many cases in which I have had an opportunity to practice this method in various regions of the body. Le Fort ('Soc. Centrale de Med. du Nord.,' October 27, 1899, and 'Gaz. des Hôpitaux,' November 25, 1899) has also more recently directed attention to the paraneural regional method and applies it at the elbow and wrist, just as Reclus, Manz, and Holscher have done. He refers to Desoutte's experiments with neural anesthesia in horses and expresses confidence in its value. He also expresses a theoretic fear of neuritis from trauma of the nerves by direct injection, but this fear, as I have stated, is unfounded. I do not doubt that the subcutaneous paraneural method is a feasible procedure, and will yield satisfactory results in emaciated, fleshless patients, in whom the larger nerve-trunks are almost visible under the skin; in such patients there should be no difficulty in reaching the immediate vicinity of the nerves, or the nerves themselves for that matter, since they are practically exposed to view. It is also in just such patients that the Schleich's general infiltration anesthesia will find a successful application. Not long since Dr. Gessner reported a case of amputation of the arm above the elbow for tubercular arthritis of the elbow-joint, in which the anesthesia was obtained with perfect success by the Schleich infiltration method. Schleich, Reclus, and their numerous followers have reported many cases of the same kind (*vide* among other recent contributions).

"'La Nacose et l'anesthesie locale par J. Richbon Kjamerund, Bull. gen'l de Therap.,' January 15 and 30, 1899; and T. Wiekerhauser, 'Operationen mit Schleichscher Anälgesie, Centralbl. für Chir.,' October 21, 1899.

"In the earlier years of my experience with cocain I also performed an amputation of the arm by Corning's infiltration for advanced tubercular arthritis with excellent results; but these successes do not mean that Schleich's infiltration method is applicable to all cases; it only illustrates the advantage to be derived from the adoption of the various methods of anesthesia to different conditions."

Dr. Matas, in his previously mentioned report, in writing of the hand and wrist, states the following:

"The anesthesia of these regions is obtained by any one of three methods: (1) Direct infiltration (Schleich); (2) paraneural infiltration at the wrist (Reclus, Braun, Manz, Lefort); (3) regional direct (open) intraneural infiltration at the elbow (Matas)." To these we can now add the intravenous method of Bier and intra-arterial anesthesia.

"The utility of the infiltration method is practically limited to fractional areas of these parts, and can be applied successfully in the evacuation of purulent collections, palmar abscesses, the removal of well-defined tumors, warts, epitheliomata, etc., foreign bodies, the extirpation of ganglions, etc. It has also proved sufficient in my practice, as in that of others, for the amputation of one or two fingers with their metacarpals, but in all these the effectiveness of the infiltration will be very materially increased by a knowledge of the distribution of the cutaneous and deeper nerves supplying the area of operation. Thus in resecting or disarticulating the metacarpals, the infiltration is not only carried into the entire periphery of the bone, including the periosteum, but the deep, adjoining interosseous nerves must likewise be enveloped in a cocain atmosphere. When the injuries or lesions are such that the operation is likely to be extensive, irregular, or ill-defined, as, for instance, when several digits with their metacarpals are to be amputated with a part of the palmar tissues, a recourse to the neuroregional method at a higher level is preferable, if not absolutely necessary, from the point of view of effectiveness and simplicity. In anesthetizing the hand and wrist in its totality, the radial, ulnar, and median nerves can be anesthetized by injecting the anasthetizing fluid deeply into the perineural tissues along the well-known anatomic paths of these nerves in the lower forearm, just above the wrist, where they are known to be most superficial. This procedure was first described and practiced by O. Manz (Kraske's clinic; 'Centralbl. f. Chirurg.,' 1898, No. 7), by Holscher ('Muench. Med. Wochenschr.,' February 21, 1899), and by F. Berndt ('Muench. Med. Wochenschr.,' 1899, No. 27), and in their hands has yielded some fairly good results. Holcher and Berndt, following Oberst and Braun, apply an elastic constrictor 1 or 2 inches above the wrist, and inject 20 c.c. of a 2 per cent. cocain solution, distributed in the region of the three nerve-trunks, and wait fifteen minutes, when the insensibility of the entire hand will follow. But the paraneural method applied in this blind subcutaneous fashion is, as Manz himself admits, an uncertain and unsatisfactory procedure at best, and it is not likely to find many adherents."

THE FINGERS AND HAND

In the practice of regional anesthesia of the hand and fingers we have many opportunities for blocking the nerve-trunks just above the wrist by taking advantage of their superficial position and exposing them by dissection for intraneural injection, or through paraneural injections by passing the needle through the skin down to the points where these nerves are to be found. The following experiments, made by Prof. Heinrich Braun, of Zwichau, and given in his book on "Die Lokal Anasthesie," illustrates the possibilities of its use here:

"Experiment 1 (June 18, 1898, Dr. B.). Firm constriction of the arm. Injection of 1 c.c. of 1 per cent. tropococain solution 3 cm. above the wrist under the tendon of the palmaris longus (Fig. 35). The constricting rubber band was now sufficiently loosened to permit a marked stasis hyperemia of the arm. Fifteen minutes after the injection complete anesthesia of the distribution of the median nerve, as well as paralysis of the short muscles of the thumb, was produced. The anesthesia remained fifteen minutes after the removal of the constrictor.

"Experiment 2 (May 14, 1902, Dr. B.). One-half cubic centimeter of 2 per cent. cocain solution was injected at 10 : 45, 4 cm. above the wrist under the tendon of the palmaris longus; the arm was not constricted; at 10 : 47 a feeling of tickling and warmth in the first, second, third, and fourth fingers and palm of the hand; 10 : 55, complete anesthesia on the flexor surface of the thumb, second and third fingers, and the radial side of the fourth finger, in the palm of the hand a very marked depression of the sensibility in the entire nerve territory, with a paresis of the thumb muscles; 11 : 25, sensation returned.

"Experiment 3 (Oct. 10, 1902, medical student, B.); 11: 55, injection of 1 c.c. of ½ per cent. cocain solution with 3 drops adrenalin around the median nerve above the wrist. The arm was not constricted. After fifteen minutes the sensibility, as indicated in Fig. 33, Nos. 1 and 2, almost completely disappeared; on the ball of the thumb, in the palm of the hand, and on the flexor surfaces of the thumb and index-finger completely disappeared. There was very pronounced paralysis of the short muscles of the thumb, and the skin over the distribution of the median nerve was hyperemic, red, and showed increased temperature, while the skin over the neighboring ulna distribution remained normal. The sensibility returned about 2 o'clock, two hours after the injection."

By taking advantage of the superficial position of the radial nerve just above the wrist, where it passes beneath the tendon of the supinator longus on the outer border of the arm, and making the injection in a transverse manner at this point beneath the skin and superficial veins, an anesthesia of its peripheral branches is obtained, as illustrated by the following experiments:

"Experiment 4. After constriction of the arm 1½ c.c. of ½ per cent. cocain solution was injected in the above manner. After five minutes anesthesia appeared, as indicated in Fig. 36, Nos. 3 and 4.

"Experiment 5 (May 13, 1899, Dr. B.). The same experiment with 2 c.c. of ½ per cent. tropocain solution with constriction of the arm resulted in an anesthesia of about similar extent.

"Experiment 6. Forms the continuations of experiment No. 3 on the same hand, where previously the median nerve had been blocked, 1 c.c. of ½ per cent. cocain solution, with the addition of 3 drops adrenalin solution (1 : 1000) was now injected on the radial nerve above the wrist. Fifteen minutes later the hand, as indicated in Fig. 33, Nos. 5 and 6, was completely insensible and remained so for about four hours."

As mentioned by Braun in commenting upon this experiment, it is not likely to be of much value alone except for very limited superficial operations, but when combined with a simultaneous injection of the median nerve it is a simple and effective means of anesthetizing the entire radial side of the hand. Higher up in the forearm, at the junction of the middle and lower third on the outer border, where the intermuscular septum divides the flexor from extensor muscles, the radial nerve is also fairly accessible, and may be successfully blocked at this point by passing the needle vertically inward beneath the supinator longus. The following experiment by Dr. Braun illustrates the results obtained:

"Experiment 7 (May 2, 1902, Dr. D.). Twelve o'clock, an injection of 1 c.c. of 2 per cent. cocain solution in the above-described way, the needle had exactly met the nerve-trunk, as indicated by the radiating paresthesia. No constriction. Immediately after the injection occurred a marked radiating paresthesia and sense of warmth in the thumb. 12 : 10, complete regional anesthesin of the nerve; anesthesia of the skin is indicated, as in Fig. 34, No. 2. Motor paralysis of the radial. After forty minutes sensibility and motility returned.

The ulnar nerve is accessible, either for exposure by dissection and intraneural injection or for paraneural injection, above the

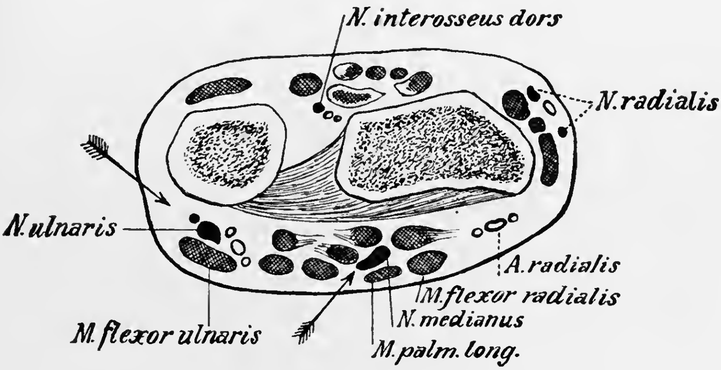


Fig. 35.—Cross-section through forearm three fingers-breadth above pisiform bone. (From Braun.)

wrist-joint, preferably three or four fingers' breadth above to insure reaching the posterior branch, which may be given off this high up. In this position the nerve lies between the tendon of the flexor carpi ulnaris and the ulnar, as shown in Fig. 35, and is best reached for paraneural injections by introducing the needle from the ulnar side between the tendon and the bone in the direction indicated by the arrow. It is rather unsafe and inadvisable to attempt to reach it from in front (except by dissection) on account of the proximity of the ulnar vessels, which here lie slightly more superficial than the nerve and slightly to the radial side. Figure 36, VII and VIII, indicate the extent of the resulting anesthesia after an injection of 1 c.c. of a 0.5 per cent. cocain solution with 3 drops of adrenalin (1 : 1000) as practiced by Braun in the above-mentioned way. It may, however, be easier and preferable, instead of injecting the nerve at this point to reach it back of the internal condyle. In thin subjects, where the nerve can be readily felt, a paraneural injection may be undertaken by first locating the nerve between the thumb and finger of one hand while making the injection with the other; the inferior profunda artery, which lies in this position, is more deeply situated in the muscle just over the bone. The following experiments by Braun illustrates the result ob-

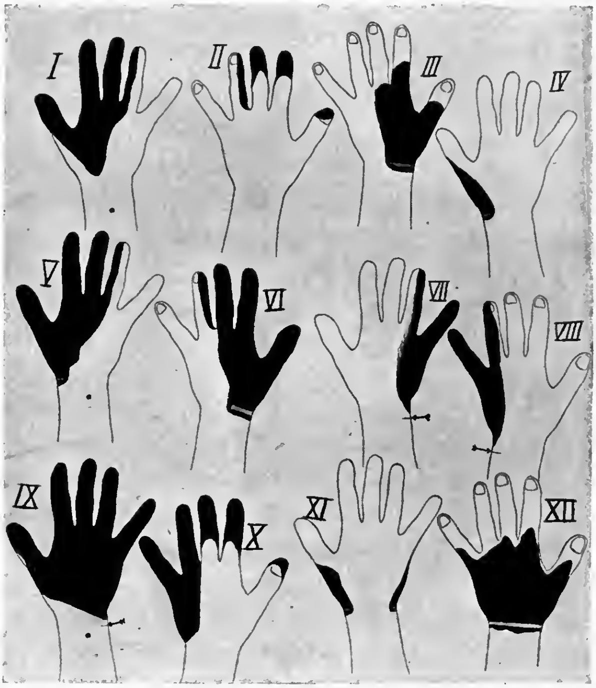


Fig. 36.—Resulting areas of anesthesia of hand and fingers from subcutaneous and paraneural injections. (From Braun.)

tained, while Experiment 9 is a paraneural injection of the ulnar and median nerves above the wrist:

"Experiment 8 (May 13, 1902, Dr. L.). 12 : 50 o'clock injection of 1 c.c. of 2 per cent. cocain solution in the previously mentioned way. No constriction. Immediately paresthesia and sense of warmth as far as the ends of the fourth and fifth fingers. After six minutes complete regional anesthesia of the skin occurred, as indicated in Fig. 37, I. Sensibility returned fifty minutes after the injection.

"Experiment 9 (Dec. 9, 1902, medical student). One cubic centimeter of 1 per cent. cocain solution with 3 drops of adrenalin solution was injected three fingers' breadth above the wrist on the ulnar and median nerves. After twenty minutes anesthesia appeared in the territory, as indicated in Fig. 36, IX and X. The sensibility returned after four hours in the ulnar territory and after five hours in the median."

Experiment 10 represents the results of a linear injection made subcutaneously from the region of the radial artery across the back of the wrist to the pisiform bone.

"Experiment 10 (Feb. 10, 1899, Dr. B.). Three cubic centimeters of 1 per cent. cocain solution was injected in the previously mentioned way in the arm after constriction. After five minutes anesthesia appeared in the territory, as indicated in Fig. 36, XI and XII. Twenty minutes after removal of the constriction sensibility returned,

"Experiment 11. Five cubic centimeters of 2 per cent. cocain solution was injected in a line across the extensor surface of the forearm, 6 cm. above the head of the ulna.

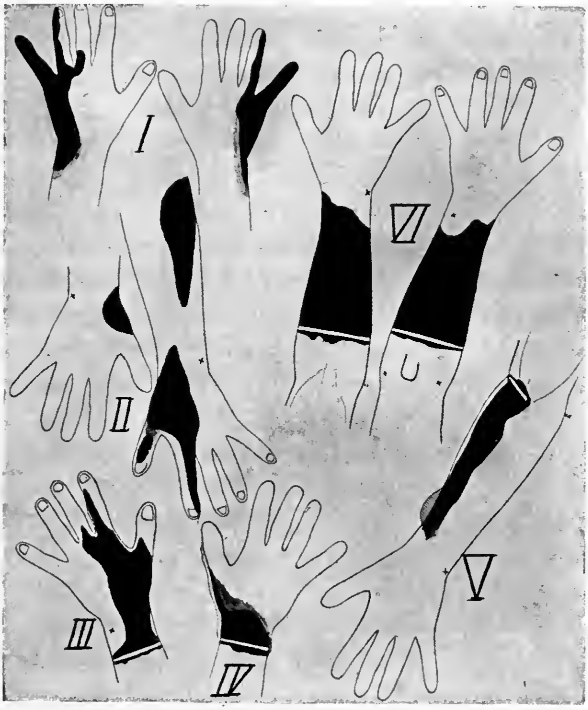


Fig. 37.—Resulting areas of anesthesia of arm, hand, and fingers from subcutaneous and paraneural injections. (From Braun.)

The arm was not constricted. After fifteen minutes anesthesia appeared, as indicated in Fig. 37, III. A transverse subcutaneous injection was made on the flexor side of the wrist, which resulted in an anesthetic field being produced, as shown in Fig. 37, IV. It is clear from a study of the picture that only the more superficial cutaneous branches in the immediate neighborhood were effected, and none of the deeper branches."

The result of a circular subcutaneous injection above the middle of the forearm is shown by Braun in Fig. 37, VI; 8 c.c. of a 0.5 per cent. tropacocain solution was used, the forearm being constricted.

The anesthesia, as indicated in the shaded area, was complete in ten minutes. The following experiments are also of interest. In commenting upon experiment No. 15, Braun states that he has often employed this method for opening and excising an inflamed bursa over the olecranon:

"Experiment 13 (Dr. B.). Four cubic centimeters of ½ per cent. cocain solution with 8 drops of adrenalin solution, 1 : 1000, was injected in a continuous subcutaneous line, which began posteriorly over the olecranon and extended laterally over the external condyle to the middle of the biceps tendon in front. It required twenty-five minutes for anesthesia to be produced, as indicated in Fig. 38, III. The anesthesia then remained several hours.

"Experiment 14 (Dr. P.). Four cubic centimeters of 0.5 per cent. cocain solution with 8 drops of adrenalin, 1 : 1000, was injected in a subcutaneous line, which began over the olecranon posteriorly and extended over the internal condyle to the middle of the biceps tendon. After thirty minutes the anesthetic area, as indicated in Fig. 38, IV, appeared. In the lower half of the forearm, as in the preceding experiment, the anesthesia was not complete.

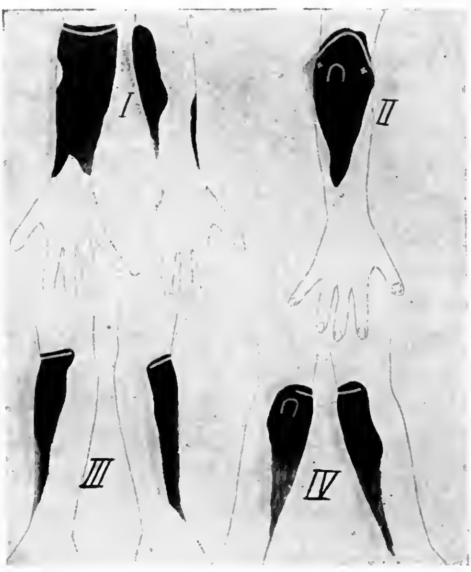


Fig. 38.—Resulting areas of anesthesia from subcutaneous infiltration of forearm. (From Braun.)

"Experiment 15 (Dec. 12, 1902, Dr. L.). Four cubic centimeters of 0.5 per cent. cocain solution with 8 drops of adrenalin solution, 1 : 1000, was injected in a subcutaneous line, beginning over the internal condyle and extending in a curve over the posterior surface of the arm and ending over the belly of the supinator longus at the external condyle. After fifteen minutes the anesthetic area, as indicated in Fig. 38, II, was complete. Deep needle sticks over the olecranon and over the posterior surface of the ulna showed that the periosteum was also insensible.

"Experiment 16 (Nov. 1, 1902, Dr. B.). Four cubic centimeters of 0.5 per cent. cocain solution with 8 drops of adrenalin, 1 : 1000, was injected subcutaneously in a line which began over the internal condyle and extended deeply across the bend of the elbow to terminate over the belly of the supinator longus. The veins were avoided without difficulty, passing the needle under them. After thirty minutes the area, as indicated in Fig. 38, I, also almost the entire flexor surface of the forearm and a part of the extensor surface had become anesthetic. The injection was made at 12 o'clock, and about 4 o'clock in the afternoon sensation returned."

Anesthesia of a part of a finger can be obtained by direct local infiltration; more often the anesthesia of an entire finger is necessary, especially in inflammatory affections (bone felons, panaritium, tenosynovitis, traumatism, foreign bodies, etc.). In all such cases the paraneural infiltration method applied at the root of the fingers will yield perfect results. This is the method which we have continuously followed in our practice. If, for example, it is a bone felon that we wish to open, the skin of the root of the finger, a little above the level of the palmar web, is infiltrated on the dorsal side (Fig. 39); a fine hypodermic needle is used for infiltration, and a wheal of intracuticular

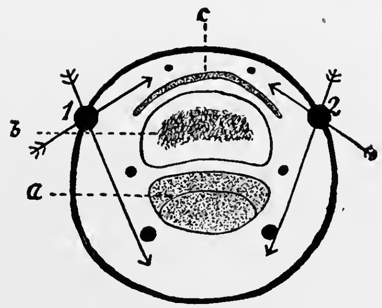


Fig. 39.—Cross-section of finger: *a*, Flexor tendon; *b*, bone; *c*, extensor tendon; 1 and 2, points of entrance of needle to reach dorsal and palmar nerves. (From Braun.)

edema serves as the starting-point from which a circle of anesthesia is carried around the base of the digit. After this has been done, the needle is driven in painlessly through the infiltrated skin into the lateral aspect of the finger in search of the digital nerves, which lies on each side of the phalanx in close proximity to the blood-vessels; a few drops (5 to 10) of strong solution of novocain (0.5 per cent.) are injected into the paraneural regions so as to create an anesthetic atmosphere around the nerves.

The arm is now raised and the finger is exsanguinated by gravity, after which the circulation is arrested by applying a narrow elastic band around the finger, just above (centrad of) the ring of infiltration. In a few minutes the finger will be "numb," and will bear any operation that may be required in any part of the digit.

"In inflammatory affections the action of the anesthetic will be intensified by injecting the solution warm in order to favor its diffusion

(Corning, Tito-Costa, Hackenbuch). After the constrictor had been applied and the limb has assumed a cadaveric appearance, the application of ice-cold water, or ethyl chlorid spray, for a few minutes to the finger will hasten and greatly intensify the anesthetic effect. This is particularly true of acute inflammatory conditions, which are the most rebellious to local anesthetic influences. If the anesthesia is retarded we should be in no hurry to add more anesthetic. The best plan is to relax the constrictor, allow the circulation to return, and diffuse the anesthetic for half a minute, and again exsanguinate and constrict the digit. The elastic constrictor combined with exsanguination is not only valuable in prolonging the anesthesia indefinitely, but it helps to intensify it as well. In fact, it is possible by simple exsanguination and prolonged elastic compression at the root of the finger and limbs to produce a degree of anesthesia which is itself

Fig. 40.—Areas of digital anesthesia resulting from tranverse subcutaneous infiltration on dorsal and palmar surfaces. Compare with nerve distribution, shown in Fig. 41. (From Braun.)

compatible with the painless performance of small and superficial operations. (This fact, long ago utilized by James Moore, 1784, and by Hunter, has been especially insisted upon in recent times by Corning, Kauffman, Kummer, and every surgeon who has had experience with it.) The paraneural method which we have described is simply a regional application of Corning's principles (1885)" (Matas).

"In Germany it is known as Oberst's method, the only difference between his method and Oberst's consisting in the fact that Oberst applies the constrictor first; it is also referred to by some writers as Kummer's (1886) and Kroguis' (1896) method, but the principles of the method are really of American origin, and began with the experiments of Hall and Halsted (1884) and Corning (1885).

"An effort has been made in some quarters to establish an antagonism between Schleich's method and the paraneural regional method, as here described, but this, as Briegleb and others have shown, is not really true. Schleich's infiltration method, as applied to the anesthesia of a finger or toe, is a regional method, since he com-

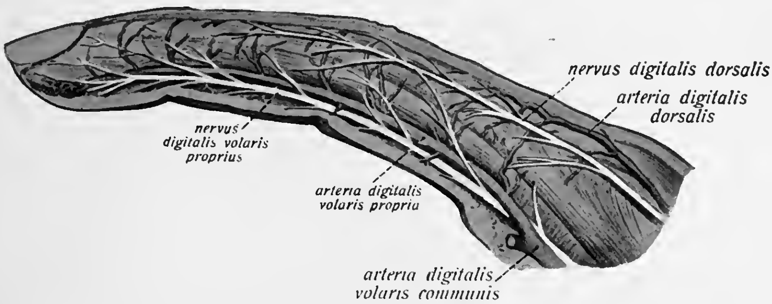


Fig. 41.—A lateral view of the nerves and vessels of the index-finger. (Sobotta and McMurrich.)

pletely edematizes the circumference of the finger at its base and thus controls the entire nerve-supply of the digit. The regional method simply accomplishes the same results in a more economic manner,

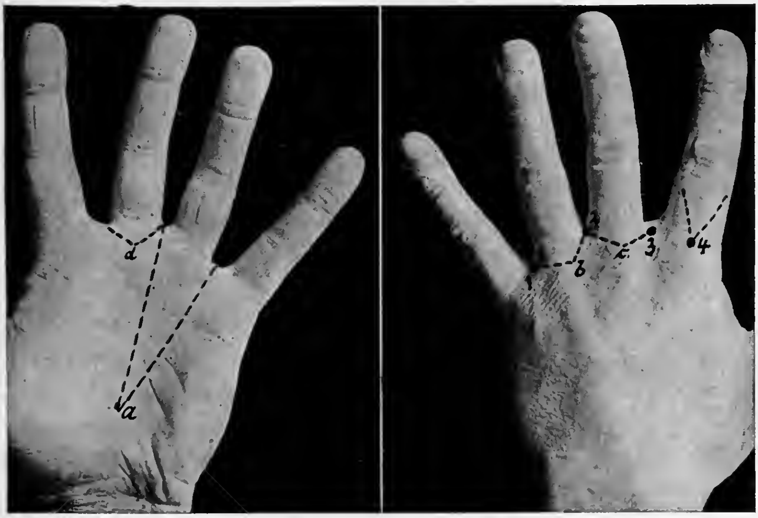


Fig. 42.—Points of injection and lines of infiltration in operating upon fingers and hand. (From Braun.)

the solutions being more concentrated in percentage and injected in direction of the nerve-tracts, thus avoiding the complete edematization of the tissue that is necessary in using Schleich's weaker solutions" (Matas).

Figure 40 illustrates the results of a subcutaneous injection made on the palmar surface of the middle finger and the dorsal surface of the index-fingers, in each case making the injection deep enough to reach the corresponding digital nerves. It illustrates beautifully the

Fig. 43.—Points of injections and lines of infiltration for anesthetizing two or more fingers. (From Braun.)

distribution of the digital nerves, the palmar digital nerves supplying the entire palmar surface and the dorsal surface of the last phalanx, the dorsal digital nerves reaching only as far as the middle phalanx.

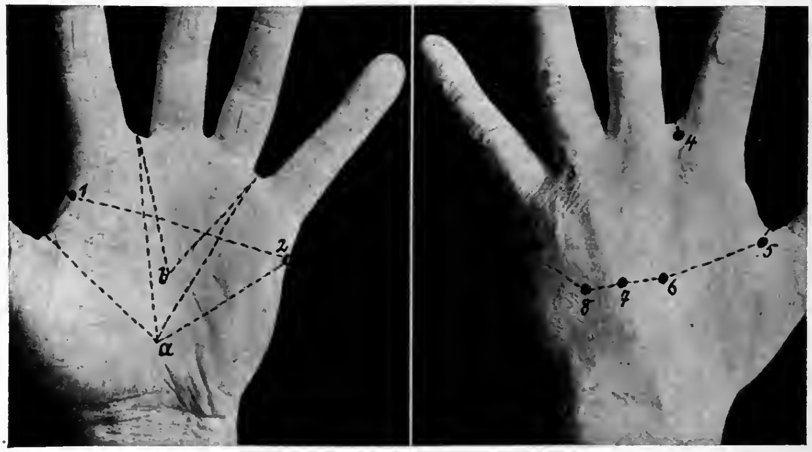


Fig. 44.—Points of injections and lines of infiltration for resecting part of hand. (From Braun.)

The disparity in the two shaded areas represents the overlapping of the fields of the two nerves (Fig. 41).

A study of Figs. 42–46 will suggest the further application of regional methods to the base of one or more fingers and parts of the hand, the large dots indicating the points at which the nerves are to be reached by subcutaneous injection for paraneural infiltration, the dotted lines marking the course for intradermal infiltration. As the nerves in the hand are all small it is practicable to use Solution No. 1

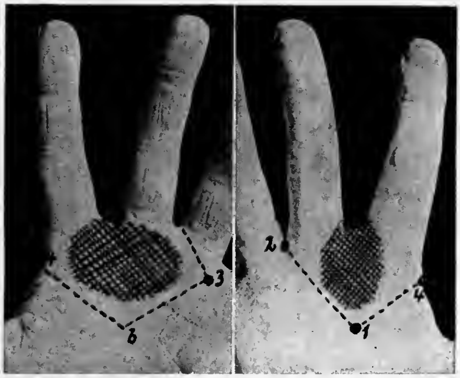


Fig. 45.—Points of injections and lines of infiltration for anesthetizing abscess at base of fingers. (From Braun.)

throughout, but, if preferred, the paraneural or deep injections can be made with 0.5 per cent. novocain solution, using 10 to 20 minims about each nerve. It is evident that in extensive resections of the

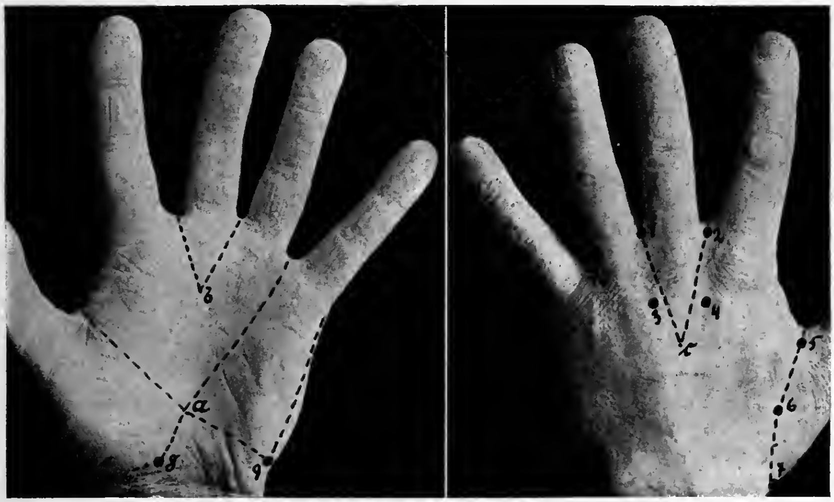


Fig. 46.—Points of injections and lines of infiltration for resecting digits or part of hand. (From Braun.)

hand it is preferable to resort to regional anesthesia at the elbow or above the wrist, rather than resort to too extensive infiltrations in this region.

THE LOWER EXTREMITY

"What has been said of the upper extremity may be, in a great measure, repeated in regard to the lower limbs. The general principles and methods are the same, except that they vary in their topographic application. The infiltration, the paraneural infiltration, and the regional (open) intraneural methods can all be utilized with advantage according to the regions involved and the local and constitutional indications furnished by the patients themselves.

"The infiltration method with weak solutions, according to Schleich, with or without constriction, and the mixed infiltration-neural methods are alone able to meet a vast number of indications. The surgery of the toes and of their metatarsals and limited areas of the soft parts, including the ligations of all vessels of the lower extremity from the external iliac (R. N. Hartley, Leeds, 1895) to the dorsalis pedis, can be made subservient to the infiltration method. In our own practice we have notes of cases of ligation of the superficial femoral at Scarpa's triangle, of the anterior and posterior tibial (in one case a traumatic aneurysm of the middle third), and of the anterior tibial, in which these operations were performed with infiltration on the Corning plan. We have repeatedly extirpated the varicose saphenous vein from the groin to the knee, and performed Sonnenburg's operation for varicose veins by ligation and partial excision of the internal and external saphenous with simple infiltration anesthesia. Infiltration is also sufficient for opening abscesses, including large, diffuse, purulent collections; in draining joints; in the extraction of foreign bodies; in the removal of tumors, and in the excision of ulcers of moderate size. It is particularly valuable in making all variety of exploratory incisions to clear up doubtful diagnosis, etc. As early as 1888 I was able to extirpate a subperiosteal sarcoma of the femur in a very thin subject. Josiah Roberts, of New York, was able to perform a femoral supracondyloid osteotomy (Macewen's operation for genu valgum) in a boy four years old, and an excision of the hip (the head of the femur being removed below the great trochanter) in a child six years of age by the same procedure. These operations were performed by Corning's method as early as 1885, a 5 per cent. cocain solution being used ('New York Med. Jour.,' October 24, 1885). Varick, by utilizing the same technic, successfully amputated the thigh in 1886 ('New York Med. Jour.,' vol. x, No. 111).

"Trapani was also one of the first to report an amputation of the thigh by Schleich's method (*vide* Alessandri's reports on anesthesia to the Italian Surgical Society, Transactions for 1897). Schleich and his followers, Rhodes (of California), Cowan, and others, were among the earliest to report instances of amputation of the leg by simple infiltration, and Wilkerhauser ('Operationen mit Schleichscher Anälgesie,' abstract, 'Centralbl. f. Chir.,' October 21, 1899, No. 42) reports 18 extensive bone operations out of a list of 113 major operations done by this method, in which the sections of the thigh and leg bones were required. All of these earlier reports, which can now be multiplied many hundred times, simply confirm the statement previously made that it is necessary to exercise judgment in the adaptation of the various methods of local and regional anesthesia to special conditions. The operator should not be wedded to any single method, but knowing the capabilities of each can select his technic and, at times, obtain surprising results with a method that would appear to the inexperienced as theoretically inadequate to meet the demands of the case" (Matas).

"But, in spite of the numerous interventions on the lower limbs which have been obtained by simple infiltrations with the Corning or Schleich methods, it must be recognized that these successes have been (with the notable exception of the toes) more conspicuous by their rarity than by their frequency. They simply illustrate what can be done with the method in exceptionally favorable conditions, both as regard to the morale of the patient and the favorable anatomic condition of the parts. This is particularly true of all extensive operations involving the skeleton of the foot, leg, and thigh in robust, fleshy subjects. In this class of patients local anesthesia is, as a rule, inadequate, and when an excision of a large joint (the ankle or knee), or when a large sequestrotomy, ostectomy, or an amputation is contemplated, a method more positive and reliable is required to accomplish the intervention with that freedom of action that can only come from absolute analgesia. It is precisely under such circumstances, and when the contra-indications to general anesthesia are positive, that the regional intraneural method can be confidently appealed to" (Matas).

The Nerve-supply of the Lower Extremity.—The inguinal region receives its nerve-supply from a variety of sources which are not capable of being dealt with collectively by regional methods; consequently, all operative procedures here should be done under infiltration.

The *external cutaneous* nerve emerges from the pelvis, close to the anterior superior spine of the ilium, beneath Pouparts' ligament. In thin subjects it is easily reached in this position or just below it by a paraneural injection. The anterior branch of this nerve emerges from beneath the fascia lata, about 4 inches below Poupart's ligament, and becomes subcutaneous, supplying the skin on the anterior and outer side of the leg as far as the knee.

The posterior branch curves backward and supplies the skin on the outer and posterior aspects of the thigh as far as the middle of the limb.

Dr. Hugh Young was one of the first to utilize paraneural injections of this nerve to obtain skin-grafts from the outer side of the thigh.

The *obturator* nerve enters the thigh through the upper part of the obturator foramen and divides into anterior and posterior branches, which are separated from each other by fibers of the obturator externus and adductor brevis muscles. The anterior branch passes down behind the pectineus and adductor longus and communicates with the internal cutaneous and internal saphenous nerves, forming a plexus around the femoral artery, which descends on this vessel to near the knee-joint; occasionally this communication furnishes a cutaneous branch to the thigh and leg; when this occurs this nerve passes beneath the adductor longus and sartorius muscles and becomes superficial at the inner side of the knee, communicating with the long saphenous nerve, and is distributed to the inner side of the leg as low as its middle. When this branch is absent its place is supplied by the internal cutaneous. The posterior branch supplies the adductor muscles, and sends a branch to the knee-joint which descends upon the popliteal artery to the back of the joint.

The deep position of the obturator nerve where it enters the thigh, and its occasional contribution to the cutaneous nerve-supply of the leg, makes this nerve often a troublesome factor in the regional anesthesia of the lower extremity.

The *anterior crural nerve* emerges from beneath Poupart's ligament, lying on the outer side of the femoral artery; it immediately divides into an anterior and posterior set of branches, which are separated by the external circumflex vessels.

The *middle cutaneous*, from the anterior division of the crural, becomes superficial about 3 inches below Poupart's ligament by piercing the fascia lata; it divides into two branches, which descend on the front of the thigh supplying the skin as far down as the knee.

The *internal cutaneous nerve*, from the anterior division of the crural, passes obliquely across the upper part of the sheath of the femoral artery, and divides in front or at the inner side of that vessel into anterior and posterior branches. The anterior branch passes down on the sartorius muscle and perforates the deep fascia at the lower third of the thigh, and is distributed to the skin of this region and the inner, anterior, and outer surfaces of the knee. The posterior or internal branch pierces the fascia lata on the inner side of the knee in front of the sartorius tendon, and is distributed to the skin on the inner side of the leg.

The *internal or long saphenous nerve*, from the posterior division of the anterior crural, approaches the femoral artery beneath the sartorius muscle, lying first in front and then on the inner side of this vessel; continuing down with it in Hunter's canal, it becomes superficial by piercing the deep fascia on the inner side of the knee between the tendons of the sartorius and gracilis muscles; it then descends along the inner side of the leg in company with the internal saphenous vein, lying just behind the inner border of the tibia, distributing branches to the inner and anterior aspects of the leg, and terminates by passing in front of the internal malleolus, to be distributed to the skin on the inner side of the foot as far forward as the great toe.

The *small sciatic nerve* descends beneath the pyriformis muscles with the great sciatic, lying slightly to the inner side of the latter; the perineal and pudendal branches curve upward to these regions, while the femoral cutaneous branches pass down the back of the thigh to supply the skin as far down as the back of the leg.

The *great sciatic nerve* descends into the thigh beneath the pyriformis muscle, lying midway between the tuberosity of the ischium and the great trochanter, and passes down to about its lower third, where it divides into internal and external popliteal nerves; this division may, however, take place at any part of its course from the pelvis down, and should be borne in mind in injecting this nerve high up to insure getting both trunks.

The internal popliteal, the larger of the two branches, descends along the back part of the thigh and middle of the popliteal space, lying first on the outer side of the artery, then crossing behind it to its inner side and passing with it beneath the arch of the soleus, when it becomes the posterior tibial.

The *posterior tibial nerve*, deeply situated above, becomes more superficial lower down, where it is covered by the skin and fascia; in the lower third of the leg it lies just internal to the margin of the tendo achillis; in the interval, between the malleolus and the heel, it lies external to the artery against the posterior surface of the tibia and about 1 cm. internal to the tendo achillis; in this position it is readily accessible for paraneural injections. Lower down in this space the nerve divides into internal and external plantar branches. The internal branch supplies the sole and inner side of the foot and gives off digital branches to the inner side of the big toe, adjoining sides of the big and second toe, second and third and fourth toes. It will be observed that the distribution of this nerve is almost identical to the distribution of the median in the hand, the digital branches giving off dorsal cutaneous branches at the base of the toes in the same manner as occurs in the hand.

The external plantar nerve supplies the outer side of the foot, little toe, and adjoining side of the fourth toe, together with deep muscles of the foot, closely corresponding to the distribution of the ulnar in the hand.

The *external popliteal or peroneal nerve* descends close along the inner margin of the biceps tendon on the outer side of the popliteal space; it then passes between the tendon of the biceps and outer head of the gastrocnemius muscle and curves around the head of the fibula, where it can be readily felt, and is again accessible for exposure or for paraneural injection; it then descends into the substance of the peroneus muscles. The cutaneous branches from this nerve supply the skin of the back part and outer side of the leg as far down as the heel. In the substance of the peroneal muscles this nerve divides into anterior tibial and musculocutaneous branches.

The *anterior tibial nerve* is deeply situated in the upper part of its course, but becomes more superficial near the ankle, lying to the outer side of the dorsalis pedis artery and between the extensor proprius hallucis and the extensor longus digitorum; at this point, just above the annular ligaments, it is fairly accessible for exposure and direct injection or for paraneural injection after locating the dorsalis pedis pulse by passing the needle down to the deep fascia just external to the artery; however, it would be preferable in making a paraneural injection to do so higher up, where the peroneal nerve winds around the head of the fibula, thus reaching the anterior tibial and muscular cutaneous distribution. At the ankle-joint the nerve divides into an internal and an external or tarsal branch. The internal branches supply the adjoining sides of the great and second toes. The external branch supplies the adjoining sides of the second, third, and fourth toes and extensor brevis muscles.

The *musculocutaneous nerve* becomes superficial at the lower third of the leg by passing forward between the peronei muscles

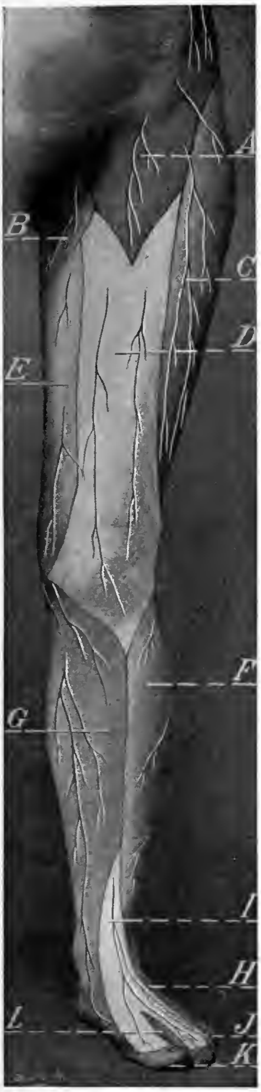


Fig. 47.—Cutaneous nerve-supply of the lower extremity (anterior view): *A*, Genitocrural; *B*, ilio-inguinal; *C*, external cutaneous; *D*, middle cutaneous; *E*, internal cutaneous; *F*, lateral cutaneous of peroneal; *G*, internal saphenous; *H*, external saphenous; *I*, musculocutaneous; *J*, external plantar; *K*, internal plantar; *L*, anterior tibial. (Campbell.)

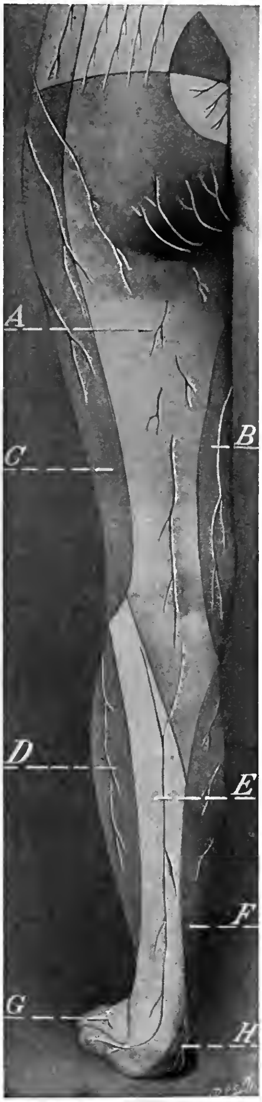


Fig. 48.—Cutaneous nerve--supply of the lower extremity (posterior view): *A*, Small sciatic; *B*, internal cutaneous; *C*, external cutaneous; *D*, lateral cutaneous; *E*, internal saphenous; *F*, external saphenous; *G*, musculocutaneous; *H*, internal calcaneus. (Campbell.)

and extensor longus digitorum; in this position it can be reached by a subcutaneous injection, made across the lower portion of the leg at this point, over the tendons of the above muscles. As the nerve descends it divides into two branches, an internal, which passes over the front of the ankle-joint and supplies the inner side and dorsum of the foot, inner side of the great toe, and adjoining sides of the second and third toes. The external branch supplies the skin on the outer side of the foot and ankle, and the adjoining sides of the third, fourth, and fifth toes (Figs. 47, 48).

A study of the above nerve-supply, with an observance of the points at which the nerve-trunks and their principal branches are accessible, will suggest many opportunities for the practice of regional anesthesia. The following operative procedures are a fairly thorough review of the surgical possibilities.

Scarpa's Triangle.—All superficial operations here can be readily done under infiltration, from the simple incising of a suppurative bubo to the removal of the entire superficial group of glands. Where the deep group are involved, requiring dissections beneath the fascia lata, a general anesthetic should if possible be used.

In operating here it is preferable to complete the entire infiltration before making the incision, as it is difficult to anesthetize the different planes of tissue after they have been divided, as the solution runs out as fast as injected. The infiltration had best be done on the Hackenbruch plan, by first encircling the mass by a line of intradermal anesthesia; the needle is then passed from this line into the deeper tissues, all around and under the mass of glands, thus completely enclosing them within a wall of anesthesia (Figs. 19–49). Solution No. 1 and a few drops of adrenalin to the ounce is used; after a few minutes' delay allowed for thorough saturation of the tissues the operation may be begun, and should be entirely painless. Where the deep glands are involved, and it is necessary to go below the fascia lata, the different tissues should be infiltrated as the operation advances, but this procedure here may sometimes prove difficult. Care should be observed to bear in mind the position of the vessels, and when infiltrating in a doubtful region to make the injection only when advancing or withdrawing the needle.

Other tumors of this region can be removed in the same way. It is also quite a simple matter to ligate and divide the upper end of the long saphenous vein for varicosities of the leg, as in the Trendelenburg operation, or the entire vein can be removed by a progressive anesthesia extending from above downward.

The removal of skin-grafts is quite easily performed from the antero-external aspect of the thigh, the usually selected site, either by direct intradermal infiltration of the entire area, from which the grafts are to be removed (this intradermal edematization of the skin greatly facilitates their removal without apparently affecting the vitality of the grafts), or by a paraneural injection of the external cutaneous nerve, where it emerges from beneath Poupart's ligament close to the anterior superior spine, as first practiced by Dr. Young of Johns Hopkins. For this injection the needle is best entered from the

Fig. 49.—Shows method of infiltrating base of bubo area by passing needle obliquely downward and inward after embracing area within circle of cutaneous anesthesia.

outer side and penetrated to a sufficient depth to reach beneath the fascia lata, under which it is advanced, depositing 2 drams of about a 0.5 per cent. solution of novocain in the recognized position of the nerve. Anesthesia should set in after a few minutes, and be sufficiently extensive to allow of a fairly liberal removal of tissue.

The removal of varicose veins of the leg need no special description, as it is best done through infiltration. Any of the accepted procedures may be easily carried out by local anesthesia (except stripping of the vein, which will be difficult by this method), the multiple incisions with ligation and division of the vein or resection of parts. The Schede operation, or the entire removal of the vein from the saphenous opening to the ankle, have all been practiced by us with perfect satisfaction.

THE HIP AND THIGH

"Regional anesthesia, in amputation of the middle third of the thigh, was first accomplished by Crile in 1899 ('Cleveland Medical Gazette,' July 1, 1899, vol. xiv), and by Berndt (Gritti's osteoplastic amputation) ('Muench. Med. Wochenschr.,' 1899, No. 27), the former by the intraneural and the latter by the paraneural methods. I know of no case in which the disarticulation of the hip has been done by 'blocking' the nerves, though I believe that this is feasible when it is possible to cut the soft parts at a lower level, as in the Furneaux-Jordan amputation. In such a case the preliminary anesthesia of the anterior crural and external cutaneous at the groin, and the sciatic, just below the gluteus maximus muscle, will suffice, if care is taken not to cut the obturator, when this is reached in making the deeper inner section of the thigh, until this nerve has been recognized and infiltrated. In amputation at a higher level (Wyeth's operation) the anesthesia could only be accomplished by a preliminary circular infiltration, including the individual nerve-trunks, which would have to be anesthetized as they were met. Such a procedure would tax the self-control of the patient to the utmost, and would be so tedious that it could scarcely be recommended except in very thin and wasted subjects" (Matas)

In amputations at the lower third of the thigh, as well as at the middle, disarticulations at the knee or amputations at the knee, as in the Gritti-Stokes operation, the difficulties presented by the obturator nerve are more easily met. The anterior crural, external cutaneous, great sciatic, and lesser sciatic should all be injected intraneurally at the root of the limb with 0.5 of 1 per cent. novocain solution, with a few drops of adrenalin solution (1:1000) to the ounce. It is very necessary not to overlook the lesser sciatic, which lies just to the inner side of the great sciatic, where this nerve enters the limb, as its branches are distributed to the skin as low down as the popliteal space and back part of the leg; it is probable that some failures reported by this method have been due to this neglect as well as other details. It is more convenient, when operating by the neuro-regional method, to use a posterior rachet incision, after the posterior incision has been made, and the deep muscles slightly separated with the finger to expose the vessels; a long needle is used to infiltrate the region around the vessels (the path of the obturator nerve) with solution No. 1 or less freely with 0.5 per cent. novocain; a few minutes following this last injection all parts involved in the field of operation should be as anesthetic as under general narcosis and the steps of the operation proceeded with in the usual way. It would seem unnecessary to state that all these operations should be performed with the use of a constrictor applied to the upper part of the thigh after the injection of the crural, external cutaneous, and sciatic nerves.

The incisions made to expose these nerves should not be permanently closed until the operation is completed, but only loosely ap-

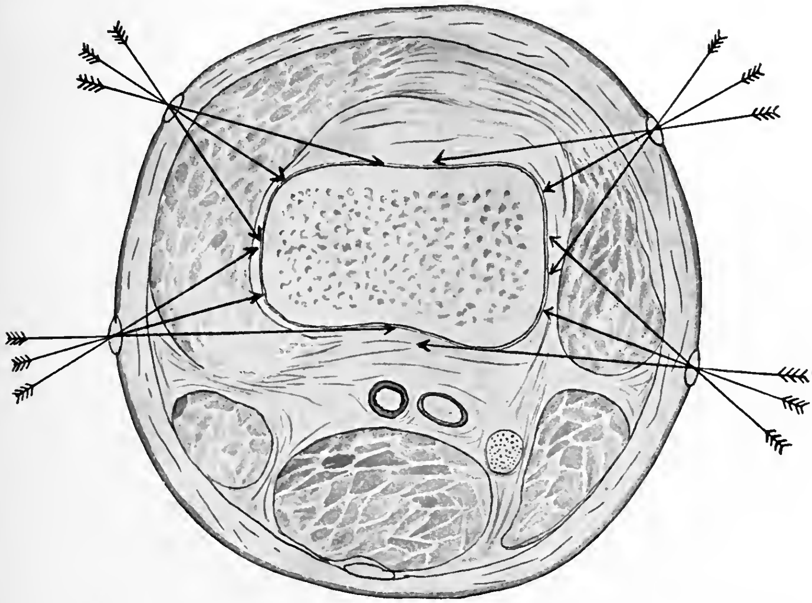


Fig. 50.—Method of securing anesthesia of femur for supracondyloid osteotomy. (Braun.)

proximated with superficial stitches, for if anesthesia is not complete it may be necessary to reopen the wounds for further infiltration of the nerves; this, however, will not be at all likely if the nerve has been properly infiltrated, producing a fusiform enlargement at the point of injection, in the case of a very large nerve like the great sciatic entering the needle at two or more points in the nerve; this, as mentioned elsewhere, should be a very fine needle entered in the long axis of the nerve-fibers; care should also be observed not to make traction on the nerve, which will cause pain, but to make the injection when the nerve is slack. Some operators in discussing these operations have preferred, after injecting the anterior crural and external cutaneous nerves at Poupart's ligament, to infiltrate the superficial tissues on the back of the thigh, making the handle of the racket incision first, and exposing the sciatic nerve or its branches at the upper part of this incision and injecting them high up here, then infiltrating the recognized course of the obturator nerve. The objection we have to offer to this procedure is that the small sciatic is not injected, and its territory, together with that of any of the branches of the great sciatic given off above the point of its injection, will have to be infiltrated. In the operations about the knee-joint—disarticulations and Gritti-Stokes amputation—these objections are not of as much consequence, as the area here to be infiltrated is necessarily much smaller.

For operations upon the femur, as in the removal of osteomas, sequestrotomy, etc., the method of injecting around the bone is shown graphically in Fig. 50. If the operation is to be performed exclusively by infiltration, the soft parts must be infiltrated from the skin to the periosteum along the proposed line of incision; or superficial regional methods may be employed, in addition to the periosteal injections, by blocking the external cutaneous or anterior crural nerves just below Poupart's ligament, and this would seem the preferable plan except in emaciated subjects.

THE KNEE-JOINT

As this joint receives, either in its cutaneous covering or deeper parts, branches from practically all the nerves in the lower part of the thigh, what has been said regarding the neuroregional methods of that part are equally applicable here.

It will be seen that the deeply situated and difficultly accessible obturator nerve may offer serious obstacles to a thorough and satisfactory anesthesia of this part; it is here, then, that Bier's venous anesthesia or spinal puncture may be advantageously used; however, in the hands of the skilful operator, this disadvantage may be overcome, and almost any operation on the joint performed by purely regional methods.

First block the anterior crural, external cutaneous, and sciatic nerves at the root of the limb; this will leave only the territory supplied by the obturator unanesthetized, which is represented by a small area on the inner side of the knee and a part of the joint. With all the other parts anesthetized, the operative incision could be made in such a way as to expose or easily approach the path of the obturator nerve on the inner side and just above the knee, and sufficiently deep to feel freely the femoral vessels; rather free infiltration between and around the vessels and on their inner side should reach all branches of the nerve and leave the parts below completely anesthetic. Such a thorough procedure as the above will, however, only be necessary in extensive resections of the joint, many lesser procedures involving only the anterior parts of the joint (the parts most frequently the site of surgical intervention) can be easily performed through infiltration, or by blocking the anterior crural and external cutaneous nerves at Poupart's ligament. The latter procedure will suffice for the operative treatment of fracture of the patella, drainage in infected arthritis, the removal of foreign bodies, lipomatosis, and other similar conditions.

In operating upon fracture of the patella by infiltration, the joint cavity should be filled with 1 or 2 ounces of solution No. 2, with 5 drops of adrenalin (1:1000), and allowed to remain for from five

Fig. 51.—Peri-articular infiltration for operation in patella region. (Braun.)

to ten minutes before the joint is opened; this will anesthetize the synovial surfaces and permit the painless removal of clots or a thorough washing out of the joint. Even strong solutions, up to 2 per cent. novocain, could be used if necessary, as most of it escapes after the joint is opened. It is, of course, advisable to use a constrictor above the knee in extensive operations here under infiltration and after making a strong intra-articular injection. The method of infiltrating around the patella region is seen in Fig. 51.

These intra-articular injections may be made use of in breaking up adhesions within the joint when not too firm; it should be withdrawn after five or ten minutes and the necessary manipulations resorted to; or, after withdrawing the anesthetic solution, it can be replaced with the 2 per cent. formalin-glycerin solution of Murphy, which, by its hydroscopic action, moderately distends the joint cavity and thus prevents further immediate contact of the joint surfaces, particularly when combined with extension.

THE LEG

All operations below the knee, involving the leg, ankle, and foot, no matter what their extent, can be painlessly performed by a single method. When near the knee by injecting the external cutaneous, anterior crural, and sciatic nerves as in the higher operations; if some distance below the knee (middle third of the leg and below), it will be sufficient to inject the sciatics at the root of the thigh and the long saphenous by a paraneural injection, made transversely over the inner surface of the knee between the tendons of the sartorius and gracilis muscles, where this nerve becomes superficial.

It would seem superfluous to detail or describe the many operations possible, for where a part is thoroughly anesthetic all operations are possible.

The following is taken from Prof. Matas' report on "Local and Regional Anesthesia," etc., 1900, and cites one of the many clinical cases which might be mentioned to illustrate these procedures:

"Without any previous knowledge of Crile's work, and encouraged by previous successes with the same methods, as applied to the upper extremity, I performed a Pirogoff operation for frost-bite by this method in March, 1899. From March, 1899, to present date I have availed myself of this mode of anesthesia many times, my colleagues operating on other cases in their practice at the Charity Hospital and elsewhere. In my cases there were reasons which made the administration of a general anesthetic undesirable.

"In one of these, operated on before the medical class of Tulane University, the inestimable advantage of possessing a reliable safe method of analgesia as an alternative to general narcosis was made particularly apparent. This case not only illustrates the circumstances in which this method is especially applicable, but it will serve to describe the technic of the method as well.

"F. S. W., aged thirty-two, was admitted to the hospital December 18, 1899, for the treatment of a diffuse tubercular arthritis of the right tarsus. The patient was suffering with advanced pulmonary tuberculosis (cavity in lung), but his sufferings were so great that an operation was decided upon. In view of his weakened condition, special precautions were taken to guard against the accidents of general anesthesia. In addition to the preparatory administration of strychnin, digitalis, and nitroglycerin by hypodermic, the nares were sprayed with a 2 per cent. cocain solution to diminish the nasolaryngeal reflexes (Franck-Rosenberg). Chloroform was then administered over an Esmarch mask by the 'guttatim' method. Notwithstanding all the care taken, the patient rapidly entered into a most violent stage of excitement and became rigid and cyanosed; respiration was arrested, the pulse became irregular and imperceptible, and when the tetanic rigidity ceased the patient sank as if completely collapsed, and it was only by the immediate application of artificial respiration and other measures that he finally came back to consciousness again.

"As the operation was imperative and all general anesthetics were not to be thought of (ether being contra-indicated by the phthisis), I decided to try the intraneural method of regional anesthesia, which should have been the method of election at the start. Accordingly, after careful preparation of the parts, the skin and underlying tissues of the upper popliteal space were infiltrated with a Schleich No. 1 cocain solution, and an incision 4 inches long was made so as to bring the sciatic nerve into view. This done, an injection of 25 minims of the same No. 1 ($\frac{1}{5}$ of 1 per cent.) solution was injected into the trunk of the nerve. A constrictor was applied—after exsanguinating the limb by gravity—care being taken to pad the limb well so as to minimize the discomfort it might produce. Eighteen minutes after the injection of the cocain some sensibility still existed in the foot; fearing that the solution would be insufficient, 20 minims of a 1 per cent. cocain were then injected into the exposed nerve. In three minutes the anesthesia of the entire region below the sciatic infiltration was complete and the operation was begun twenty-five minutes after the first injection into the nerve had been given. The tarsus was then explored by making a free externolateral incision, and all the bones, including the tarsometatarsal articulation, were found to be involved in a diffuse tuberculosis. The astragalus alone was saved. The chisel, gouge, and bone curet were used freely with the hope that a simple excision might suffice, but the lesions of the skeleton and soft parts, including the tendon-sheaths, were so extensive that an atypical subastragaloid amputation on the Roux-Lignerolles plan was decided upon. The patient, who had been perfectly quiet and passive, was now asked his consent to the amputation, which at first he refused, but, after showing him the extent of the lesions and explaining to him the advantages of a radical extirpation in a man in his condition, he consented, and the amputation was performed.

"The patient gave us very material assistance in this operation, not only by holding his foot and leg in the most favorable attitudes for our work, but by turning his body around without assistance when, at the termination of the operation on the foot, we closed permanently the sciatic incision. The contrast between the alarming condition induced by the general anesthetic (chloroform) and the passive and calm attitude of the patient throughout the operation was most impressive. In this case it should be mentioned the saphenous nerve was not injected, as in the other similar cases; but, instead of this, the short incision through the skin connecting the inner border of the foot with its outer edge, which is supplied by this nerve, was bridged over by a line of infiltration edema. The operations successfully performed by this method in my practice have been (1) Pirogoff's amputation for frost-bite; (2) Syme's operation; (3) two atypical resections of the tibio-astragaloid joint, in which the astragalus and calcaneum were excised together with the tibiofibular surfaces and their malleoli, for tuberculosis; (4) Guyon's supramalleolar amputation of the leg for trauma; and (5) an extensive search in the thigh for a lost bullet embedded in the neighborhood of Hunter's canal. In the last case the anterior crural nerve and external cutaneous were cocainized under Poupart's ligament. In this case we were misled in the situation of the bullet as indicated by radiograph, and failed to find the bullet even after a most extensive dissection in the lateral and posterior femoral aspects of the thigh had been made. The anesthesia in this case was complete from the middle of the thigh to the toes, but there was marked sensation in the upper femoral regions in consequence of the preservation of the lesser sciatic filaments which overlapped beyond the points of the greater sciatic infiltration which had been effected just below the crossing of the lower gluteal fibers. The small area of persistent dermal sensibility could have been easily controlled by a short transverse line of purely dermal infiltration, the deeper parts being completely insensitive."

The Toes Metatarsals, and Sole of the Foot.—What has been said regarding the fingers and metacarpals may be largely repeated for the foot. With certain modifications, any of the smaller toes may be easily anesthetized by edemetization carried around its base. The big toe is, however, more effectually treated by paraneural injections made around the base, or, as in Fig. 52, when operating for bunions, by resecting the head of the metatarsal. In operating for ingrowing toe-nails, Dr. Braun speaks highly of the use of ethylchlorid spray, used about the base of the toe, claiming it is to be quite sufficient to remove the matrix as well as the nail. We have never used this method, always preferring to use infiltration or paraneural injections at the base with solution No. 1, to which is added 5 drops of 1:1000 adrenalin to the ounce. This method has the ad-

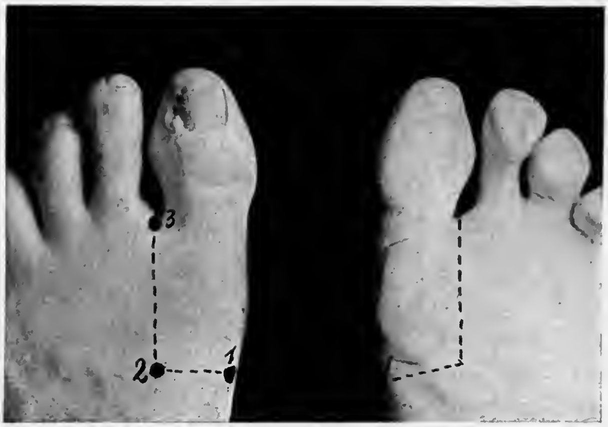


Fig. 52.—Points of injections and lines of infiltration for bunion operations or resection of great toe. (From Braun.)

vantage of producing quite a lasting analgesia, and by the time sensation does return very little pain is experienced; should the operation be performed in the office and the patient allowed to go home afterward, he is quite likely to reach his destination before any discomfort is felt, although few rarely complain of any but slight soreness following. Figure 55 shows method of anesthetizing the lesser toes.

In operations upon the sole of the feet for removal of splinters and other foreign bodies it is often quite a difficult matter to satisfactorily infiltrate the pulp of the foot; this tissue is so dense and unyielding that even with solutions of considerable strength much difficulty is experienced. Rather than continue at efforts of infiltration after this has been found difficult, it would be simpler and preferable to at once make a paraneural injection around the posterior tibial nerve, as described in the following experiments, thus securing at once anesthesia of the entire foot; additional injections being made over the inner or outer ankles to reach the branches of the long saphenous or peroneal nerves should this be necessary. A review of the following quotations from Braun ("Die Lokal Anesthesie"), will suggest many useful applications in practical surgery when limited in extent or confined to the superficial parts, but any extensive operations involving resections of the foot had better be performed by the intraneural methods of blocking the nerve higher up, as already described.

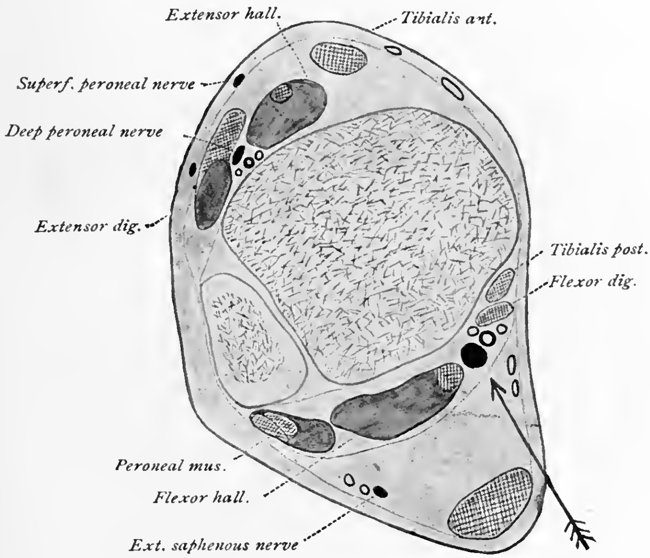


Fig. 53.—Method of reaching posterior tibial nerve at ankle-joint for paraneural injection. (From Braun.)

Figure 53, from Braun ("Die Lokal Anesthesie"), shows a cross-section through the ankle-joint, at the level of the most prominent portion of the internal malleolus; the posterior tibial nerve is best reached as indicated by the arrow, the artery lying internal to the nerve. Braun gives the following directions for reaching it at this point: "The needle is inserted about 1 cm. from the inner side of tendo achilles, and directed from behind forward until the posterior surface of the tibia is reached; the needle is then slightly withdrawn and the solution injected. He states that the injury of the vessel which lies on the inner side of the nerve is hardly to be feared, but it should first be made sure that the point of the needle is not in the vessel, by resorting to a little aspiration before the injection is made by slightly withdrawing the plunger. Should it be found that the vessel has been punctured, no unpleasant consequences are likely to result if the needle has been fine."

The following experiment indicates the results of an injection made in this manner:

"Experiment 1 (Dr. B.). One-half cubic centimeter of a 1 per cent. solution with 1 drop of adrenalin (1 : 1000) was injected in the above-described manner, and almost immediately anesthesia appeared as indicated in Fig. 54, No. 1, and lasted for three hours." The affected area on the extensor surface of the foot and toe is indicated by the shaded surface."

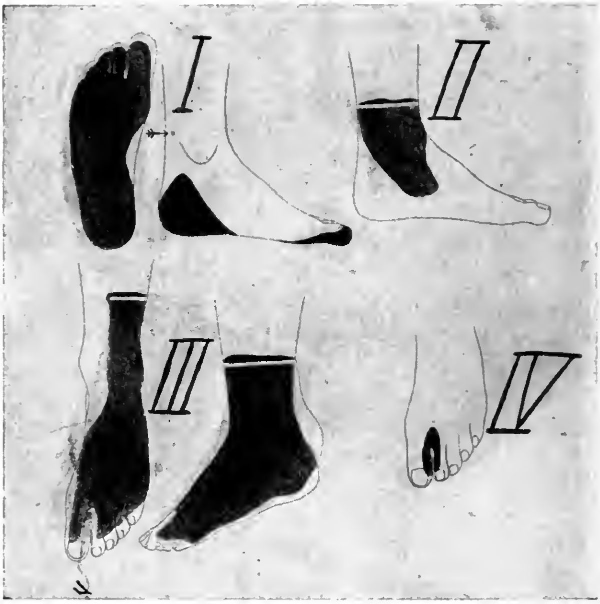


Fig. 54.—Lines of subcutaneous infiltration and resulting areas of anesthesia in foot. (From Braun.)

This procedure was once employed for opening an abscess and removing a foreign body from the sole of the foot. The anesthesia extends to the metatarsals and tarsus:

"Experiment 2. Two cubic centimeters of 0.5 per cent. cocain solution with 4 drops adrenalin solution, injected subcutaneously over the inner ankle, beginning behind the tendo achillis and extending around to the middle line of the joint in front. This will meet the terminal branches of the internal saphenous nerve; the extent of the resulting anesthesia is shown in Fig. 54, No. 2."

The injection in Experiment 2 reaches the terminal branches of the internal saphenous nerve, and may often be combined with the injection of the posterior tibial, as in Experiment 1, for anesthesia of the inner side and sole of the foot.

In commenting upon these experiments, Braun states that a subcutaneous injection, made across the extensor surface of the ankle-joint, reaches only a few of the fibers of the internal saphenous and produces only a limited area of anesthesia on the back of the foot, the same as in a corresponding injection made on the back of the hand, while a much more extensive area is affected if the injection is made slightly higher, as in Experiment 3, where the superficial branches of the peroneal nerves are reached.

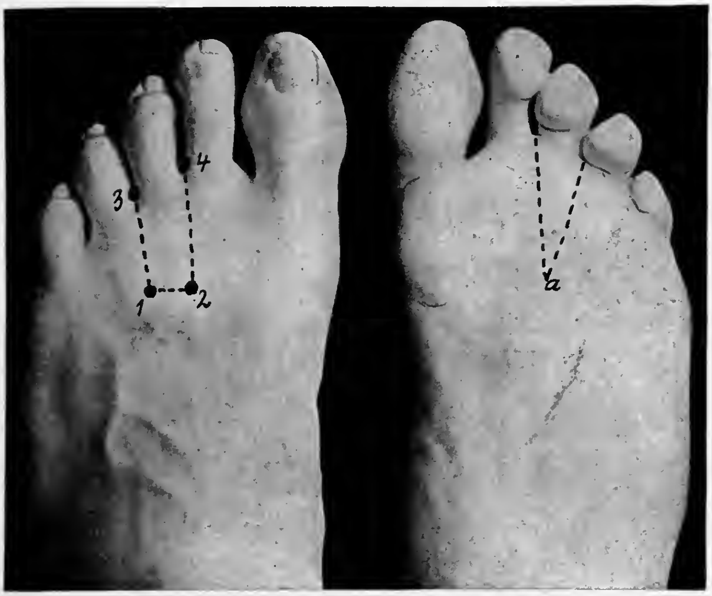


Fig. 55.—Disarticulation of third toe. (From Braun.)

"Experiment 3. Three cubic centimeters of 0.5 per cent. cocain solution with the addition of 10 drops adrenalin solution (1 : 1000) was injected a hand's breadth above the outer ankle, across the axis of the limb, from the tendo Achillis behind to the edge of the tibia in front. After six minutes the skin, as indicated in Fig. 54, No. 3, had become anesthetic and remained so for three to four hours."

In discussing this experiment, Braun states that this injection reaches all of the superficial fibers of the peroneal nerve, the anesthetic field extending from the territory of distribution of the internal saphenous at the inner ankle and inner side of the foot across the dorsum to the outer side of the foot. The results obtained in Experiment 4 may also at times be applied practically.

"Experiment 4. Three fingers'-breadth above the internal ankle the needle was entered laterally, between the tendons of the tibialis anticus and extensor hallucis longus, vertical to the cutaneous surface till the bone was reached; the needle was now turned laterally under the tendon of the extensor hallucis and an injection of 1 c.c. of 0.5 per cent. cocain with 3 drops adrenalin solution (1:1000) was injected; ten minutes later anesthesia was established in the terminal branches of the peroneus profundus, as indicated in Fig. 54, No. 4."

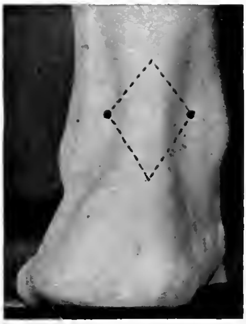


Fig. 56.—Area of anesthesia for tenotomy of tendo-achilles. (Braun.)

The method of infiltration for tenotomy of the tendo achilles is shown in Fig. 56, the infiltration carried well down around the tendon.

CHAPTER XV

NECK

"In the surgery of this region local anesthesia has made large and permanent conquests. The neck is most favorable for the display of the infiltration method, the paraneural and intraneural methods of regional anesthesia having found comparatively few typical applications. In the neck the lesions of the skin and its appendages and those of the supra-aponeurotic planes are everywhere submissive to cocain or its allies. Local infiltration is most valuable in dealing with inflammatory lesions—abscesses, boils, inflamed sebaceous cysts, and carbuncles of moderate size. In opening deep cervical abscesses connected with submaxillary and pharyngotonsillar infections, in which the suppurative focus must be reached by careful dissection (the Hilton-Rose method), it is invaluable.

"In the major surgery of the neck, local infiltration finds its most brilliant applications in the anterior cervical and subclavian regions, and in the operations on the vessels in the carotid triangles.

"Apart from the avoidance of postoperative constitutional disturbances, the immediate advantages of local anesthesia are that it permits the dissection of the parts with the precision, neatness, and deliberation that are required in all the deep vascular regions; that the great turgidity of the veins and general increase in vascularity incident to the use of inhalation anesthetics is avoided; and that the surgeon is materially assisted in his work by the different attitudes that the patient can assume to favor the better exposure of the parts.

"In the postcervical triangle the conditions for local anesthesia are less favorable, except in the supraclavicular space, in which the subclavian artery and brachial plexus are readily exposed for operative purposes" (Matas).

Nerves of the Neck.—In the neck the only opportunity for the application of regional methods of anesthesia, aside from paravertebral methods, is to the superficial branches of the cervical plexus as they emerge around the posterior border of the sternomastoid about the middle of the neck (Fig. 57). Here the occipitalis minor, auricularis magnus, superficialis colli, and the descending or supraclavicular branches are all fairly accessible, and in their emergence from the deeper parts are all met within a comparatively limited area. To

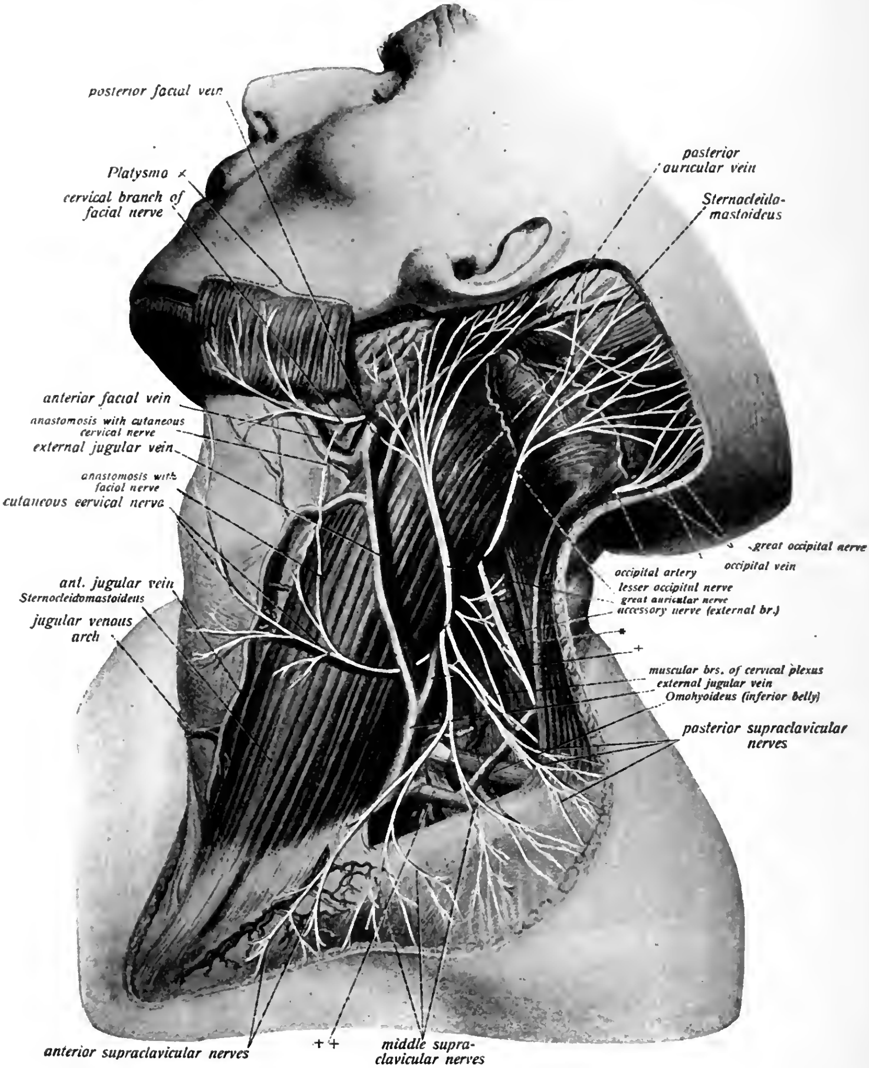


Fig. 57.—The superficial nerves and veins of the left side of the neck (second layer of neck). The platysma has been divided, the upper portion reflected toward the jaw, and the lower portion removed. The fascia has been divided along the facial veins. × = Anastomosis of accessory nerve with cervical plexus. + = Communication of external jugular vein with deep veins. The upper perforating branches of the internal mammary vessels (not represented in the illustration) make their appearance between the origins of the sternocleidomastoideus. (Sobotta and McMurrich.)

reach and block these nerves in this position it is, however, not necessary to make an open dissection, though this can be done, applying intraneural or perineural injections to each individual nerve; it will, however, be found equally satisfactory and much simpler to pass a long needle down to the posterior region of the sternomastoid at the midpart of its course to the point of emergence of these nerves, and here making a fairly liberal infiltration of from 3 to 4 drams of 1 per cent. novocain, containing a few drops of adrenalin, distributing the solution up and down this area for about $2\frac{1}{2}$ inches, thus effectually reaching all these nerves. The result of such an injection is seen in the anesthetic area, as indicated in Fig. 58 (ten or fifteen minutes' delay is necessary for the full effect to be shown). The anesthesia of the superficial parts is complete almost to the midline of the neck; here the nerves from the opposite side lap over; it will consequently be

Fig. 58.—Line of deep subcutaneous infiltration over sternomastoid and resulting area of anesthesia. (From Braun.)

necessary to make the injection on both sides if the operation is to be near the midline.

The depth of the anesthesia will depend upon the depth of the injection; however, in making the injection into the deep parts, care should be taken not to pass the needle too far forward under the sternomastoid, for fear of injuring the deep vessels in this position.

Some of the deep branches will be found, upon deep dissections, to have escaped the effect of the injection; these deep branches are for the anterior parts, communicating branches to the pneumogastric, hypoglossal, and sympathetic nerves, communicans hypoglossi and muscular branches; posteriorly, these are communicating branches to the spinal accessory and a deep muscular set.

However, for extensive dissections of this region, the above-mentioned method will be found extremely helpful, greatly lessening the amount of infiltration which will be needed and this only in the deeper parts.

Innervation of the Larynx.—This is through the superior and inferior laryngeal nerves. The superior laryngeal divides, by the side of the pharynx, into internal and external branches; the internal, the principal nerve of sensation, passes through the thyrohyoid membrane, just below the posterior extremity of the hyoid bone, and, after coursing a short distance forward between the membranes, enters the larynx; this nerve supplies sensation to all parts above the vocal cords as far as the base of the tongue.

Fig. 59.—Method of making paraneural injection for superior laryngeal nerve.

To reach this nerve for regional infiltration have the patient lie on his back, with a small pillow under the back of his neck; have an assistant, by pressure on the opposite side, displace the hyoid bone from one side, rendering it more prominent; with an index-finger on the great cornu, the needle is passed down in this direction and 2 or 3 c.c. of 0.5 per cent. novocain with 1 drop of adrenalin (1:1000) is injected into the thyrohyoid membrane, a little below and in front (about $\frac{1}{2}$ inch) of the great cornu (Fig. 59); the opposite side is treated the same way; the anesthesia appears in from five to ten minutes, and frequently lasts one hour or longer, and is sufficient for all operations above the vocal cords. The external laryngeal passes down the side of the larynx beneath the sternothyroid and is distributed to the cricothyroid muscle; it also contains sensory filaments. The inferior or recurrent laryngeal passes up in the grove between the trachea and esophagus, and passes under the lower border of the inferior constrictor; entering the larynx behind the articulation of the inferior cornu of the thyroid cartilage with the cricoid, it is distributed to all muscles except the cricothyroid, and supplies sensation to all parts below the vocal cords.

Before the introduction of cocain and its successful application to this region investigators attempted to produce anesthesia of the larynx in many ways. Eulenburg injected solutions of morphin into the thyrohyoid membrane at the point of entrance of the internal laryngeal nerve, and obtained in this way a certain amount of anesthesia of the larynx. Later other substances, such as saponin, were used in a similar way by Pelikan, Köhler, and others. Rossbach has produced an anesthesia of the larynx by freezing the tissues over the point of entrance of the above nerve for two or three minutes by the use of ether spray. Since the advent of cocain and its congeners, these earlier efforts, while in the right direction, are only of interest historically.

OPERATIONS ON THE NECK

Ligation of the Common Carotid Artery.—This is easily accessible in any part of its course. Infiltration with a few drams of solution No. 1, used first in the skin and subcutaneous tissues and successively in the deeper layers as they are approached (Fig. 60), render this procedure extremely easy; with very few exceptions this vessel should never be ligated except under local anesthesia, and, instead of the ordinary ligature, it is far safer to use aluminum bands, as recommended by Matas and Allen. It has been recognized that it is never safe, even in young subjects (here we may have deficiencies in the circle of Willis), to cut off the blood-supply from such vessels as the common or internal carotid without first being sure of the competency of the collateral circulation; for this reason ligation or occlusion should, if possible, always be done under local anesthesia, so that the sensations of the patient may at once be determined, which would not be the case with a general anesthetic, and, instead of using a ligature which produces permanent damage to the artery, the aluminum bands, as recommended by the author, should be substituted, which are capable of removal without damage to the vessel, if necessary, as long after as seventy-two hours.

It is accordingly always our practice to occlude these vessels in the above manner and always under local anesthesia.[1]

The internal and external carotids, except in very stout subjects and in case of abnormally high division, are easily exposed at their origins through infiltration with local anesthesia and need no special description (Fig. 60).

The internal jugular vein, except at the base of the skull, is easily accessible throughout its entire course, and may require ligation or excision, as in the case of septic thrombosis from middle-ear disease.

Fig. 60.—1, Area of anesthesia for exposing external carotid artery; 2, common carotid.

In operating under conditions of this kind, where it is often uncertain to what extent the vessel will have to be exposed, it is preferable to block the cervical plexus as already described, thus securing anesthesia of the superficial parts throughout the entire extent of the vein; it would then be necessary to use only light infiltration anesthesia as the deeper parts are approached.

The subclavian artery is easily exposed by infiltration in its

[1] Occlusion of large surgical arteries with removable metallic bands to test the efficiency of the collateral circulation (Matas and Allen, "Jour. Amer. Med. Assoc.," January 28, 1911).

second and third portions, but has been ligated without much difficulty and painlessly by Matas in the first portion as well.

Lymphatic Glands.—Isolated groups of diseased glands when well defined can be easily removed by infiltration of the surrounding parts, but when extensive, as is often the case in tubercular adenitis, had best be left to the domain of general anesthesia.

The submaxillary and submental groups are quite accessible to extirpation by local infiltration and no special technic is required.

Malignant disease unless superficial or well defined, had better be operated by general anesthesia unless contra-indicated; when operating by local methods, as already advised, care must be taken not to infiltrate diseased tissues, but to create a zone of anesthesia around the area to be extirpated by the Hackenbuch plan; non-malignant growths when well defined are easily removed (Fig. 19).

The following case, reported by Dr. Matas in 1900, illustrates the possibilities here:

"One of the most extensive operations performed with cocain anesthesia was the extirpation of a large retropharyngeal fibroma of more than thirty years' duration in a very aged negro, who sought relief in our hospital service four years ago. In this case the removal of the growth became imperative, on account of progressive inanition and marasmus induced by the outward displacement of the pharynx and esophagus. The larynx and trachea were also so displaced by the neoplasm that breathing was seriously obstructed. The huge mass occupied the right half of the neck and bulged under and to the outer side of the sternomastoid, which was spread like a thin sheet in front and to the inner side of it. The right carotid was displaced to the left of the median line and could be felt pulsating under the skin. The skin was cocainized in a line extending from the mastoid to the sternoclavicular joint in the long axis of the tumor. The tumor immediately bulged out the moment the tension of the overlying aponeurosis was relieved. The division of the sternomastoid materially aided in prolapsing the tumor, which was easily enucleated by peeling it away from the surrounding tissues. It was then lifted out of the wound, and a broad pedicle attached to the posterior pharyngeal wall, tonsil, and basilar of the occipital was divided, after securing a number of nutrient vessels, while an assistant controlled the exposed carotid, at a lower point, by digital pressure.

"In removing the growth from its tonsillar and pharyngeal attachments the pharynx was opened and part of its lateral wall was excised. The fauces, root of the tongue, and glottis were exposed. The opening was closed with silk, and after the extirpation of the parts the dislocated larynx and other organs were replaced in their natural position. The mass was a fibroma and weighed 4½ pounds. The manner in which the old man withstood this huge traumatism was remarkable. He never moved or uttered a word of complaint, and his slow pulse never wavered until traction was made upon the pharyngeal pedicle. In this case it must be recognized that we were dealing with a stoic of Spartan type, and that as much credit is due to his heroism as to the cocain, which was only used to anesthetize the skin and pharyngeal attachment of the tumor.

"It is a source of genuine sorrow and regret that so brave a man should not have been awarded by a better result than that which followed this extraordinary exhibition of psychic fortitude. After lightly packing the vast cavity left in the neck with a weak iodoform gauze and reducing the length of the cutaneous incision by a few stitches, the patient was sent to bed and thoroughly stimulated. His pulse was slow and full, and he expressed himself as being very comfortable. He was well until about seven hours after the operation, when suddenly and without any warning he sank into a syncopal spell and died in a few minutes, before any assistance could be rendered. The exact cause of death was never ascertained, but it is presumed that death was caused by thrombus or embolus."

THE LARYNX AND TRACHEA

The great advantage of operating without inhalation narcosis in the asphyxiating diseases of the larynx and trachea, requiring laryngotomy and tracheotomy, led to the early trial of cocain in these operations.

In small children, suffering from diphtheria, the restlessness and pscychic disturbance of the patient contra-indicates its use; here, however, incubation has practically supplanted tracheotomy altogether.

But in operations on the laryngotracheal passages in adults local anesthesia has become the routine procedure, and its success in these cases is as fully and indisputably established as it is in the removal of an ingrowing toe-nail.

Dr. Matas first performed tracheotomy under cocain in 1889 in relieving a laryngeal stenosis from abductor paralysis, and since that time it has become the routine anesthetic in our practice. We have had occasion to test its value in such delicate intralaryngeal operations as the extirpation of the vocal bands for paralytic stenosis, using a Trendelenburg tampon-cannula to prevent the entrance of blood into the lower trachea and in the removal of foreign bodies. In these operations the reflex irritability of the mucosa must also be subdued by spraying the larynx directly with cocain solution. Such formidable major operations as laryngectomy may prove more difficult to any but the experienced operator under local anesthesia; however, it is thoroughly feasible, though tedious; but, in view of the tremendous mortality associated with this operation under inhalation narcosis, due to pneumonia, it has much to recommend it, and we believe should never be done under general anesthesia.

This procedure is best illustrated by a report of the following case by the author.

Laryngectomy.—The advantage of the routine use of local anesthesia in all minor operations upon the upper respiratory passages which do not require great haste, such as tracheotomy, laryngotomy, etc., is readily conceded by most surgeons; many of whom, however, would hesitate to employ it for such major operations as laryngectomy.

This formidable procedure, attended by high mortality (about

25 per cent. in cases collected from all sources), due largely to pneumonia, no doubt partly contributed to by the irritating effects of the anesthetic, can be performed under purely local and regional methods of anesthesia with no greater difficulties to the experienced than those attendant upon herniotomy under local anesthesia, and should certainly present a mortality far below the discouraging statistics presented under general anesthesia.

The following case illustrates the technic employed in a bad case involving the larynx and esophagus:

Fig. 61.—Area of anesthesia for laryngectomy. Over double-lined area on sides infiltration is more liberal and is carried well down to sternomastoid muscle.

May 30, 1912: Preliminary tracheotomy under local anesthesia to relieve the dyspnea.

June 3, 1912: Gastrostomy by the Ssabanajew-Frank method under local anesthesia to secure safe and easy access to the stomach and enable us to have full control over nutrition following operation.

The Operation, June 10, 1912, 10 A. M.: Preliminary preparatory hypodermic of morphin, $\frac{1}{4}$ grain; scopolamin, $\frac{1}{150}$ grain, to prevent any pscyhic disturbance or uneasiness on the part of the patient.

The anesthetic solution used is the one in use in our clinic for general surgical purposes: novocain, 0.25 per cent., NaCl, 0.4 per cent., plus 10 to 15 drops of adrenalin (1:1000) to each 4 ounces of the solution to be used.

A deep subcutaneous injection of about $1\frac{1}{2}$ ounces of the above solution was made on each side of the neck, over the middle of the sternomastoid, distributed up and down the course of the muscles for about 2 inches; this blocks the superficial branches of the cervical nerves (Fig. 61).

The hyoid bone was then displaced to one side to render it more prominent, and the needle inserted just beneath the cornu and about 2 drams injected on each side in this manner into the substance of the thyrohyoid membrane; from this point forward on each side another 2 drams was distributed subcutaneously over the surface of the hyoid bone; this blocks the superior laryngeal and descending branches of the hypoglossal.

Following this last injection the skin of the midline of the neck was tested and found anesthetic. An incision was then made from the hyoid bone to near the sternum in the midline, and a short cross-incision joined this at right angles, above near the hyoid and below near the sternum; at this last point a little subcutaneous infiltration was previously done for fear that the anesthesia would not extend out the full distance of the proposed incision.

These incisions were extended down to beneath the platysma, which was dissected up and turned out with the skin flaps, exposing the deeper plane of muscles; the sternomastoid on each side was now partially divided to allow freer access. The sternohyoid and sternothyroid muscles were divided below and retracted upward, exposing the thyroid gland; this was divided at the isthmus, ligated, and pushed to either side.

The trachea was now freely exposed, and the interval between it and the esophagus gently infiltrated low down on each side to block the recurrent laryngeal nerve. With a finger passed in as a guide alongside of the larynx, the cellular tissue was lightly infiltrated as far back as the vertebral column and extending well up toward the pharynx; this was the last injection made, and reached the deeper fibers of the cervical and pharyngeal plexuses, which were not anesthetized by our more superficial injections. The subsequent steps of the operation were division of the trachea and its suture to the skin over the episternal notch. Division of the larynx in the middle line to learn the exact extent of the growth and involvement of the esophagus; this was found extensively involved on its anterior and left lateral surfaces.

The thyrohyoid membrane and esophagus at this level were divided; the esophagus was stripped up from the vertebral column and divided well below the growth; this removed the esophagus, larynx, and its attached muscles in block. The end of the esophagus was sutured to the skin in a separate opening some little distance away from the trachea; this was done as a precautionary measure, instead of closing it now, in the event that the gastrostomy opening should not prove satisfactory. The pharynx above was next closed, the skin flaps brought together, and the interval beneath lightly packed with iodoform gauze.

The operation represented a removal in block of all parts except the thyroid gland, from just above the sternum to the base of the tongue, and was entirely without pain. It had previously been arranged with the patient, who was holding an assistant's hand, that he was to squeeze it if he felt pain; this he did once very slightly, when working high up near the pharynx, but when asked if he felt pain he shook his head; however, slightly more solution was injected into the pharyngeal wall at this point.

There was no cough or other unpleasant reflexes throughout the operation; this had been prevented by the early injection of the superior and recurrent laryngeal nerves, and aspiration of blood or mucus was prevented by the early division of the trachea and its suture to the skin in the lower end of the incision out of the immediate field of operation; very little blood was lost, as all vessels were ligated before being divided, and the patient left the table in about the same condition as when the operation commenced.

The procedure was remarkably free from any unpleasant or annoying incidents, and progressed smoothly from start to finish, and impressed the writer, as well as others who witnessed it, with the feasibility and advantages of performing this operation under local anesthesia.

Tracheotomy, high or low, is easily performed by infiltration anesthesia in the midline of the neck, and needs no special description. It is unnecessary to infiltrate the trachea before opening it, as the mucous membrane is insensitive to pain, but will excite coughing as soon as instruments or the tracheal tube is placed within it; if for any reason this is to be avoided at the time, the opening may be retracted and a spray of cocain or novocain solution gently applied to the interior before the tube is inserted.

Alcohol Injections of the Internal Laryngeal Nerve in Tubercular Laryngitis.—By this method, first recommended by Hoffman, Roth has treated 33 cases and Levy 3 others. In Roth's series all had severe pain on swallowing, which had resisted all other methods of treatment. In these cases a painful pathognomonic spot is found between the hyoid bone and the thyroid cartilage corresponding to the point of entrance of the nerve.

After disinfection with alcohol (not ether, which causes coughing) an assistant makes pressure upon the opposite side. The painful point is then located with the finger, and with a somewhat blunt needle, though an ordinary hypodermic will do, the tissues are penetrated to a depth of about $1\frac{1}{2}$ cm.; the needle is then directed upward and outward (Fig. 59); when the nerve is reached the patient complains of pain radiating toward the ear. Then 1 to 2 c.c. of 85 per cent. alcohol, warmed slightly above body heat (45° C.) is slowly injected; some immediate discomfort is produced which soon subsides, and the resulting analgesia lasts from one to twenty-one days, one week being the average.

There is no loss of cough reflex or aspiration of food following. There seems no objection in repeating the injection as often as seems necessary, the patients often requesting that this be done; there seems no diminution of the effect in the repeated injections. Both sides may be injected as well as one, but when one injection is made it is always over the nerve which seems the tenderest on pressure.

GOITER

"One of the most convincing proofs of the great extension of local anesthesia in the surgery of the neck has been given by Kocher and his followers in their numerous operations for the cure of goiter. When we consider that the statistics of operations for goiter, as furnished by the clinics of Kocher, Roux, the Reverdins, Socin, Bruns, Mikulicz, Burkhardt, and other surgeons who practice in the great zone of goiter infection in Europe, amount to thousands of cases, and that since the value of cocain as an anesthetic was first established

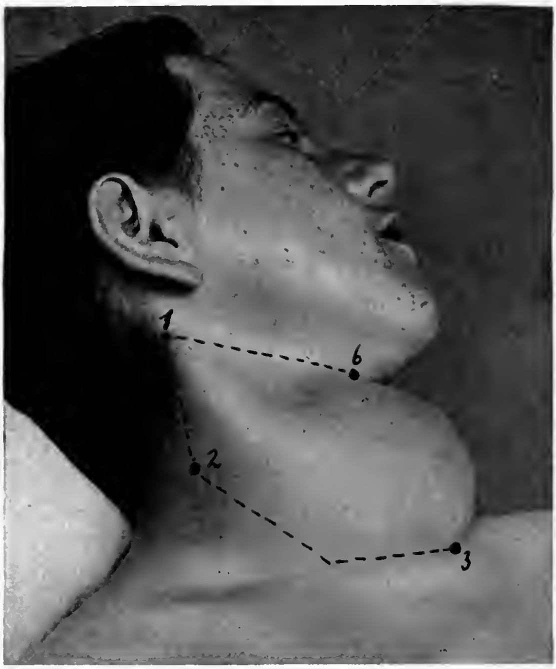


Fig. 62.—Points of injection and area of anesthesia for thyroidectomy. (From Braun.)

by Kocher (who alone claims a large majority of many thousand goiter cases as cocain operations) local anesthesia has become a routine practice in such cases, we will realize what a large slice of surgical territory has been wrested from the domain of general anesthesia in this region alone" (Matas).

Simple colloid goiter, unless excessively large, is comparatively easily removed by local anesthesia. Here we do not have the great nervous tension, with the psychic effect of fear, to contend with as seen in the exophthalmic type. These goiters may involve one or both lobes of the gland. The principal nerve-supply is from the cervical plexus, the nerves running forward from the posterior edge of the sternomastoid. Consequently, most of our anesthetic solution is distributed at this point, also creating a light zone of anesthesia around the gland (Figs. 62 and 63).

First produce a "station" in the skin on the outer side of the gland, then the long needle can be passed down to the posterior border of the sternomastoid and an area of infiltration created at this point, care being taken not to penetrate too deeply for fear of injury to the carotid and jugular, which lie just in front; from this point the

Fig. 63.—Points of injection and area of anesthesia for thyroidectomy. (From Braun.)

needle should be directed around, first above and then below, the margin of the tumor, injecting as you go. In case only one lobe is involved a station is now produced in the skin of the midline over the trachea, and a free injection made in this position from the skin down to the trachea as the nerves of the opposite side lap over the midline.

In the event of both lobes being involved this last injection can be very light and made principally in the deeper structures. An injection is then made on the outer side of the opposite lobe over the posterior border of the sternomastoid similar to the first side.

If the tumor is very large, stations may have to be established above and below to properly reach the entire circumference of the growth.

The skin incision is usually made across the most prominent part of the gland, either transverse or curved, according to the shape of the growth, and the muscles in the midline retracted. When working with local anesthesia it is better to attack the isthmus of the gland first; the capsule is peeled back and the isthmus divided, preferably, between clamps; a syringeful of solution may have to be injected thoroughly under the isthmus over the trachea before this can be done. After the isthmus is divided the gland is rolled out; this early division of the isthmus and its separation from the trachea relieves the traction upon this structure in manipulation elsewhere, which might otherwise cause the patient to complain. As the gland is rolled out the posterior capsule and underlying tissues will need infiltration, particularly at the upper pole.

The capsule is pushed back from the gland as it is delivered; the superior pole is caught between clamps and divided and later ligated, thus leaving a portion of the gland at this point with the capsule, which is left behind, containing the parathyroid bodies. The rest of the operation is simple. The opposite side, if involved, is removed the same way; if not, the isthmus is ligated.

In closing the wound the muscles in the midline should be replaced in nearly their same position and the platysma sutured separately, being careful not to include the platysma or any of the deeper muscles in the skin suture, as they will be bound together this way in the resulting cicatrix, which will later pull the skin up and down in an unpleasant way whenever these muscles act.

In making the first incision the skin and platysma can be divided at different levels, which further obviates the above result.

A small rubber drain is left in the wound.

Exophthalmic Goiter.—In this type of goiter we are concerned more especially with the condition the result of the hyperthyroidism than with the local condition itself.

The extremely nervous and psychic state of the patient often associated with grave cardiac changes makes the condition one of extreme danger when operating by any method of anesthesia. We believe, however, that many of these cases are better operated by local methods of anesthesia than by general inhalation narcosis, using in these cases a slightly larger preliminary dose of morphin and scopolamin, giving $\frac{1}{4}$ gr. of the former and $\frac{1}{100}$ gr. of the latter one hour beforehand.

This very effectually relieves the fear and dread so terrifying in these patients, and produces a state of apathy in which, if the operation is carefully and gently performed with a thorough observance of the anesthetic technic and no pain inflicted, the patient is enabled to leave the table in much better condition than after a general anesthetic.

The best method of dealing with these patients has been the subject of much thought and investigation on the part of many operators, and has resulted in a voluminous literature. Dr. Crile at one time advocated local methods of anesthesia exclusively, but now uses a combined method, not letting the patient know when operation is to be performed. Various aromatic substances are administered daily on an inhalation cone as a presumable part of the treatment, which is done in the patient's room; on the day of the operation anesthetics are gradually substituted without the patient's knowledge until narcosis is produced; the patient is then removed to the operating room. It is not necessary that this anesthesia be very profound, as the field is injected freely with local anesthetic solutions which prevent the transmission of painful impressions. The general anesthesia is used only to control the psychic state of the patient; it is, consequently, only necessary to produce a subconscious state. (See chapter on Combined Methods of Anesthesia for a further consideration of this method.)

The technic of the operation is the same as that given for colloid goiter.

We have not had occasion to resort to the combined method of anesthesia in these cases very often, as we have found local anesthesia alone was usually very satisfactory, but there is, of course, no objection to allowing a few whiffs of ether or chloroform or even alcohol on a cone should it appear advisable.

We do not mean to convey the impression that all these cases are operated on by us under local anesthesia, but the majority of them are. We could relate numerous clinical illustrations, but the following brief review of a rather severe case, operated on by the author, will suffice.

Exophthalmic goiter. Trahan, aged twenty-six. Entered Ward 9 July 26, 1908. Trouble of two years' duration. Markedly emaciated and weak; prominent, staring eyes, with a pulsating tumor as large as the fist in the thyroid region. Heart enormously dilated, weak, rapid, and irregular, with murmurs over the entire chest. Respiration rapid and irregular, pulse very irregular and weak, varied from 98 to 140. Temperature from 99° to 101° F. The right lobe and isthmus were removed; the left lobe, being but slightly affected, was not disturbed. Anesthesia was perfect (technic same as for colloid goiter). The patient conversed with us during the procedure, and rendered assistance by turning his head in different positions. He winced once or twice when we pulled on the trachea in lifting the gland from its bed. He left the table in good condition, apparently not affected by the operation. His progress for a few days was much disturbed by a weak and rapid heart, but he finally made a good recovery and left the hospital August 20th. He wrote me a letter later that he was entirely well.

These cases are particularly suited to local anesthesia, and I doubt if this particular one could have stood the operation with a general anesthetic.

It is hardly the purpose of a book of this kind to enter into a discussion of the many conditions arising in those patients which have to be considered in selecting the time for operation, also the preparatory and postoperative treatment, all of which are found in the general surgeries, and do not, as a rule, differ in any respect, whether the operation is done under general or local anesthesia.

There is, however, a procedure which I would like to speak of here, either as a palliative operation or as one preparatory to a radical procedure; namely, ligation of the thyroid vessels. This operation, while done before, owes much of its popularity to the Mayos. Following the ligation of the vessels a colloid degeneration takes place in the gland with subsidence of the symptoms of hyperthyroidism.

After two or three months' delay the radical removal of the parts of the glands affected can be undertaken with no greater difficulties than those attending ordinary goiter. As a preliminary step in the handling of all severe cases this should be borne in mind, as the procedure is very easily carried out and involves practically no risk under local anesthesia, offers quite a boon to these patients, and should prove a decided factor in reducing the mortality rate in these cases.

The following is from an article by Dr. Chas. H. Mayo, which appeared in the "Annals of Surgery," December, 1909:

"The earliest ligation of vessels as an operation for the relief of goiter is credited to Wölfler. Our experience with this procedure covers over 200 operations, and, with the results obtained by this method, we consider that the ligation of certain thyroid arteries and veins, and at times a portion of the gland, seems indicated in some cases of hyperthyroidism.

"First. In those suffering from mild symptoms of hyperthyroidism, and those in whom the diagnosis is made early, possibly before the less important eye symptoms or even goiter is present. In cases which are hardly severe enough to warrant a thyroidectomy the ligation of the vessels will often produce a cure in a few weeks with but little risk and without the necessity of special medication.

"Second. Ligation is indicated in that larger group of acute, severe exophthalmic goiters, and very sick patients, who, having exhausted all forms of treatment, are now suffering with various secondary symptoms—dilatation and degeneration of the heart, fatty liver, soft spleen, diseased kidneys, which have resulted from the chronic toxins, as seen in the later stages of Graves' disease—changes which, after all, are the final cause of death. This operation is of particular value in those cases with a marked pulsation and peculiar thrill of the superior thyroid arteries.

"All severe cases of hyperthyroidism when suffering from edema, ascites, dilatation of the heart, diarrhea, or gastric crisis of vomiting should be under observation for a short time at least, and some of them for a considerable period of time, to improve their condition, if possible, before even a ligation be attempted. There is a time in the progress of these cases when terminal degeneration of essential organs has advanced so far that they are no longer curable. When surgery is applied as a last resort it may be possible, by using some special great dexterity and care, to remove part of the gland without an immediate fatal result. While the disease may be checked, these patients are seldom sufficiently benefited to warrant the immoderate risk of an extirpation. On the other hand, at such times many cases, which have at first appeared to be unfavorable subjects, will so far improve under symptomatic treatment, aided by rest, hygiene, *x*-rays, etc., as to become suitable operative subjects at a later period. It is in this class of cases that ligation as a preliminary procedure is of great value. The relative safety of ligation, as compared with that of thyroidectomy, may lead the operator to accept as surgical risks patients so far advanced in the disease as to have but little prospect of cure. In operating upon these cases the surgeon should use his judgment as to the time and method of operation and the anesthesia to be used from observations, according to the improvement manifest under preparatory treatment.

"*Operation.*—A transverse incision gives the best working space as well as the least disfiguring scar. It is made $2\frac{1}{2}$ inches in length, crossing the central part of the thyroid cartilage. The incision should be made in a natural skin crease if possible, and should include the platysma myoides, this one incision being better than two lateral. The inner border of the sternomastoid is tracted laterally. This exposes the omohyoid muscle, which is tracted up and in toward the midline. Beneath this muscle is the upper pole of the gland with the superior thyroid artery and vein (Fig. 64).

"The ligating material is linen, passed by an aneurysm needle. Should a vein be pierced and a hemorrhage follow the placing of the

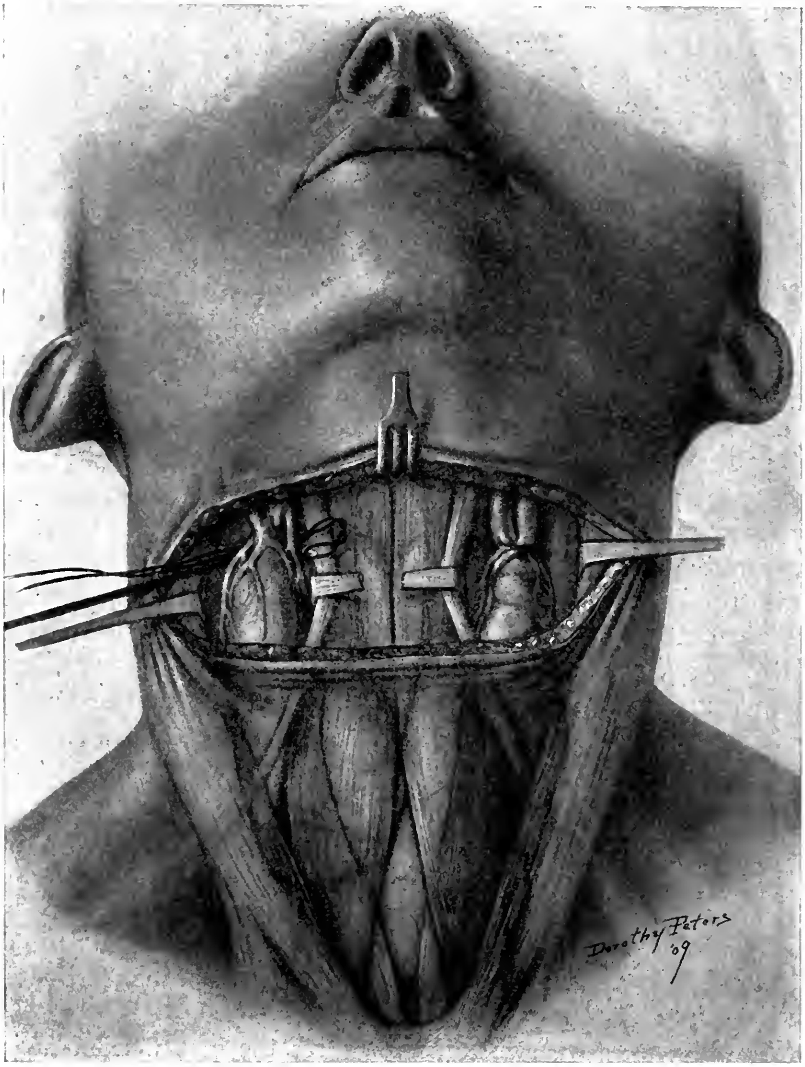


Fig. 64.—Ligation of the superior thyroid vessels. (C. H. Mayo.)

ligature, it is tracted upon, and a second loop is passed around including more tissue. In most cases this is preferable to a more generous incision with freer dissection. The veins are purposely included to secure venous obstruction, the free anastomosis within the gland capsule making this of advantage. One need not fear the ligation of a nerve in this location, as the inferior or recurrent laryngeal is below. The wound is closed by a subcuticular suture without drainage.

"The location of the ligation at the pole of the gland is important, as in one of our cases in which the superior thyroid arteries had been previously ligated at a point where they were given off from their origin at the external carotid there was but partial and temporary relief. At the second operation we found a reversal of the circulation in the large inner branch anastomosing with the inferior thyroid, and in the upper part of the gland the circulation was but little reduced.

"In the large hard glands of hyperthyroidism, where some reversion has occurred with colloid deposit, ligation is not indicated. The changes in the gland after ligation are most interesting. There is a change from the great increase in cell development back to the condition of simple goiter. This is produced by a simple exfoliation of cells, and does not resemble the degenerative changes which are found in the glands removed in the late stages of Basedow's disease or those in which serum treatment has been used. In both of these there is a true cytolysis or chemical destruction of the cell.

"While many patients reported indefinite gain in weight, there were 68 cases in which an accurate report was given, showing that 62 patients gained an average of 20½ pounds from three to five months after operation. If cases were excluded that were about normal weight at the time of operation the average gain would exceed this. Six patients lost an average of 6 pounds. Most of these were but little reduced at the time of the operation.

"In the majority of cases the ligation is made as a definite step in a graduated operation to reduce excessive secretion of the gland, and some of the reported cases are yet to be operated upon for the removal of part of the gland as a secondary procedure. Some of the patients in this series consider themselves too well at present to undergo another operation, and will probably do so only under the stress of a relapse of their symptoms, when it may be advisable to ligate the right inferior thyroid artery as a second step toward thyroidectomy. We found this procedure of value in 9 cases. On several occasions, because of the various seemingly urgent reasons involving the safety of the patient, we deemed it advisable to convert a thyroidectomy into a ligation of vessels."

For the ligation of the superior thyroid arteries the area of the superficial anesthesia is shown in Fig. 65. After the skin has been passed, deeper injections are made into the parts before their dissection, making these injections rather liberally around the superior poles, which must be well blocked before being ligated.

In the preceding pages I have endeavored to point out some of the uses of local anesthesia in the major surgery of the neck. It is only fair now to state that there still remains conditions in which it is an impracticable and unsatisfactory mode of anesthesia. This is particularly true of all atypical operations in which the lesions and the limits of the field of operation are ill-defined, as in multiple lymphatic

Fig. 65.—Line of infiltration anesthesia for double ligation of superior laryngeal artery. On each side the injection is made freely into the deep tissues.

tuberculosis, where the chains of infected glands are held fast to the periglandular tissues by dense adhesions.

In the removal of chains of malignant lymph-nodes the same objections hold with still greater force, and a general anesthetic becomes necessary. Malignant tumors, unless well defined, should rarely if ever be operated upon by infiltration in any region, and when done the Hackenbuch plan should be followed. These remarks do not refer to the application of regional methods for this purpose, which can always be employed.

CHAPTER XVI

THE THORAX AND BACK

In the major surgery of this region the local infiltration and neuroregional methods have yielded excellent results. Except in children and very nervous patients, many of the commonly performed operations can be as easily and often more safely performed by these methods than with general anesthesia. This is especially the case with empyema and hepatic abscess, where the patient is often exhausted by profound sepsis as well as the antecedent diseases (pneumonia, tuberculosis, or dysentery), and from dyspnea due to the encroachment upon the pulmonary area by these accumulations. In bad cases of this kind the administration of an anesthetic may be extremely hazardous or even absolutely contra-indicated. Here local anesthesia has proved of great value and should always be given the preference. The infiltration and operation must, however, be gently and delicately executed. Any undue traction or pressure on the surrounding sensitive parts will give pain and cause the patient to complain and lose confidence in the promise of a painless procedure.

The **nerves of the thorax** are principally the intercostals (anterior divisions of the dorsal nerves). The upper six, with the exception of the first and intercostohumeral branch of the second, supply the chest wall alone; the lower six, after being distributed to the parietes of the chest for the anterior half of their course, are distributed to the abdominal wall, the last one (twelfth dorsal) sending a filament as low down as the hip. In the intercostal spaces these nerves lie just below the arteries, near the lower border of the ribs, about the middle of their course, near the anterior axillary line; each gives off a lateral cutaneous branch, which pierces the muscles to the subcutaneous tissues and divides into anterior and posterior branches, the anterior branch running forward as far as the sternum, the posterior coursing backward in the skin of this region (Fig. 66). In the intercostal spaces the nerves lie first between the pleura and internal intercostal muscle, then between the two intercostals to near the middle of the ribs, when they continue their course between the fibers of the internal intercostal muscle. In the midline the nerves of each side overlap for some little distance. In the upper and lateroposterior

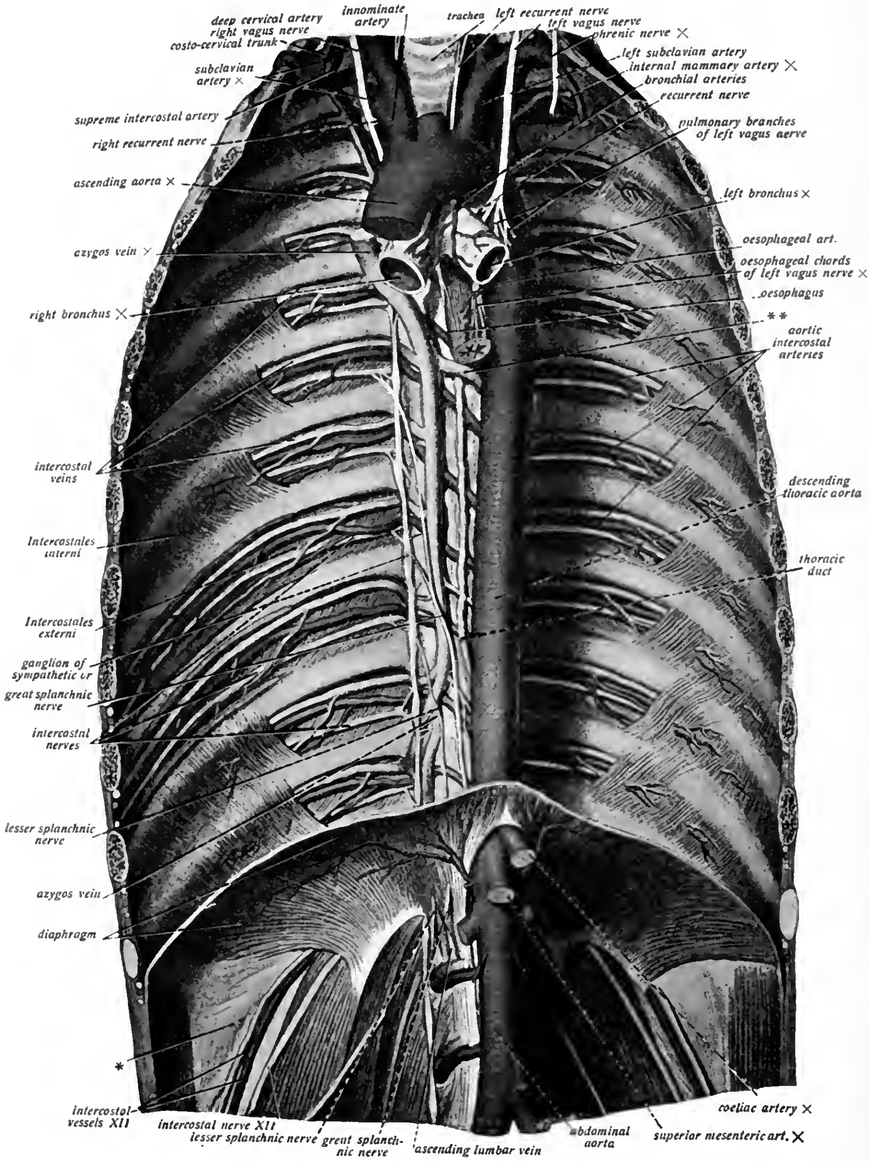


Fig. 66.—The large vascular and nervous trunks of the posterior thoracic wall as viewed from in front and somewhat from the right. * = Location of twelfth rib. ** = Communication between azygos and hemi-azygos veins. (Sobotta and McMurrich.)

regions of the thorax the branches of the brachial plexus and supraclavicular nerves are distributed to these parts.

In front the supraclavicular nerves send branches to the skin of the thorax nearly as far as the nipple; the external or supra-acromial branches supply the skin on the upper and back part of the shoulder; these branches pass obliquely across the outer surface of the trapezius and the acromion.

In addition to the above, branches of the anterior thoracic nerves supply the entire area covered by the pectoral muscles, though on a deeper plane; they send branches through to the surface.

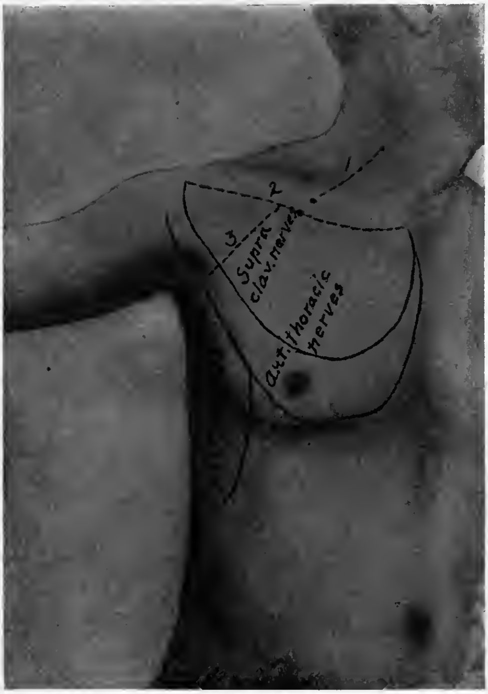


Fig. 67.—Areas of distribution of supraclavicular nerves overlapping field of anterior thoracic nerves. Area of postthoracic seen laterally: 1, Line of anesthesia for exposing brachial plexus; 2, line of anesthesia over clavicle for blocking supraclavicular nerves; long needle is entered over middle of the clavicle and directed subcutaneously toward each end of the bone; 3, deep infiltration of pectoral muscles from point near middle of clavicle to axillary margin.

On the side of the chest the posterior or long thoracic extends downward to the lowest digitations of the surratus magnus.

The typical course of an intercostal nerve is seen in Fig. 132, and in Fig. 67 is seen the area in which the supraclavicular anterior and posterior thoracic nerves intermingle in their distribution with branches from the intercostal.

In the scapula region behind the thoracic wall is overhung by this bone and its attached muscles, which will have to be dealt with in any procedure which involves the chest wall at this point; however, this is not often the site of surgical intervention.

It will be seen from the above and a study of Fig. 67, which represents diagramatically the intermingling of the areas of distribution of these nerves, that any methods of regional anesthesia, when applied to the anterior chest wall above or the lateral chest wall behind, must deal with nerves which enter the field from a variety of directions.

To *block the intercostal nerves* over a wide area of distribution is best done behind near the angle of the ribs, where they approach close

Fig. 68.—Shows line of anesthesia and points for entering long needle for blocking intercostal nerves at angle of ribs.

to the posterior wall and before the lateral branches are given off, though this can be done at any point of their course.

A vertical line of cutaneous anesthesia is carried down the back over the angle of the ribs, as seen in Fig. 68; the scapula is carried well forward and the finger locates the rib; a long fine needle is now passed down to the interval between the ribs; this is best done obliquely from below; with a finger pressed firmly on the rib, the needle is made to pass upward and inward, injecting as it is advanced until it strikes the bone; it is then pushed upward and inward for about 1 cm. further into the intercostal space above, and this freely infiltrated. This procedure is similarly carried out for as many spaces as indicated, taking in two or three spaces above and below the proposed field, as the lateral branches of these nerves freely overlap.

It must be remembered that the intercostal nerves lie deep down near the pleura, and the injections must be made well down in the intercostal spaces; this is best shown by a reference to Fig. 66; puncturing the pleura should be avoided, but if done no damage will result, only the solution is wasted.

To *anesthetize the anterior chest wall in front* an injection is made subcutaneously over the clavicle to block the branches of the supraclavicular nerves as they descend over this bone. This is best done by making an intradermal station over the middle of this bone, and passing the long needle subcutaneously in both directions, injecting as the needle is advanced until the entire area has been infiltrated. (See Fig. 67.)

A wall of anesthesia must then be established from the middle of this bone outward to block the branches of the anterior thoracic nerves as they descend beneath the pectoral muscles; this must extend from the skin to the chest wall, and outward as far as the axilla. (See Fig. 67.)

These two last injections, when combined with anesthesia of the upper intercostals, produce an area of anesthesia of the pectoral region and underlying chest wall including the pleura.

The **removal of a rib** along its entire course for tuberculosis, osteomyelitis, etc., is fairly satisfactorily done under local methods, except for the upper ribs, which underlie the shoulder girdle and are difficult of access, but any of the lower ribs can be easily removed from their angle forward by blocking the intercostal nerves for about two spaces above and below; this, combined with a fairly free subcutaneous infiltration along the course of the posterior thoracic, where this nerve crosses the rib, will be found to be sufficient. Where several ribs are involved this procedure will be found very satisfactory, but where only one is involved through but a part of its course it will be found that simple infiltration is to be preferred. Starting at the proximal end of the fields an intradermal station is made over the rib, and the long needle entered at this point and advanced in the deep tissues close to the rib, injecting as the needle is advanced, reentering it further on if necessary, until the entire subcutaneous field has been injected; we then return to the skin and finish the injection intradermally along the proposed line of incision over the rib. The object in making the deeper injections first is to allow ample time for the solution to diffuse while making the skin injection and thus save the necessity of having to wait later.

Less is known about the sensibility of the parts within the thorax than about the contents of any other cavity of the body, but it is believed that the same general rules governing the sensibility of the abdominal contents hold good here, that is, that the parietal pleura is sensitive and the visceral insensitive; the same with the pericardium. The lung is said to have no sensation. After the chest walls and parietal pleura have been anesthetized, an exploring needle can be passed freely within its substance without complaint, and it can

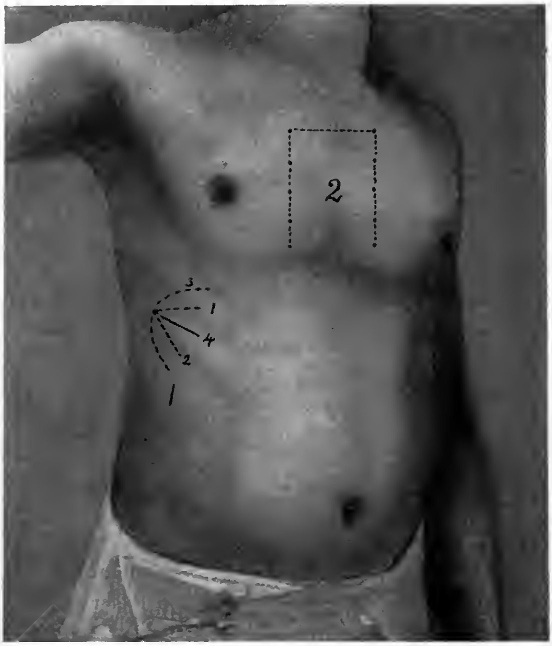


Fig. 69.—1, Method of injecting field for thoracotomy: 1 and 2, Direction of long needle to intercostal spaces above and below rib to be resected; 3, crescentic wall of anesthesia made subcutaneously embracing field; 4, line of incision. 2, Method of anesthetizing sternal region.

also be sutured to the chest wall without pain. The diaphragm is usually not sensitive.

The operation of **thoracotomy** is quite easily performed on almost any part of the thorax wall. After a consideration of the course of the nerves, it is seen that an injection proximal to the field of operation will block all nerves entering the area. Suppose we were to do a thoracotomy for empyema in the axillary line, with resection of the seventh rib, a point over this rib and just behind the field is selected and an intradermal injection made with fine needle. The large syringe and long needle is now taken, and the needle entered at this anesthetized point and passed down to the interval between the sixth and seventh rib, injecting lightly as it is advanced, until the plane between the intercostal muscles is reached. This can be fairly accurately determined by placing a finger firmly between the ribs and over the point of the advancing needle. It should be remembered that the nerve lies near the lower border of the rib. When the desired point is reached, about 1 or 2 drams of solution is injected. The needle is then slightly withdrawn and passed in the opposite direction, in the space between the seventh and eighth ribs, and a similar injection made. While we are waiting for the injection to act here, the infiltration of the skin is finished. This is done rather freely, in a crescentic-like course, over the sixth, seventh, and eighth ribs, the horns of the crescent turned toward the operative area (Fig. 69).

The anesthesia resulting from the above injection in the area just in front should be perfect, including the bone and pleura, and the

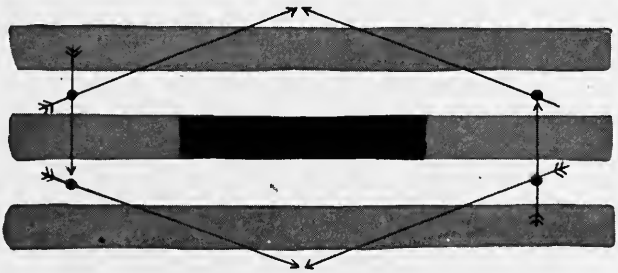


Fig. 70.—Schematic representation of method of anesthetizing rib for resection in thoracotomy. (From Braun.)

operation can be commenced by the time the skin infiltration is finished.

In the event that the operative field is slightly in front of the anterior axillary line a rather free subcutaneous injection is made, in addition to the above, to meet the anterior divisions of the lateral cutaneous branches of the intercostals given off at this point. If preferred, a rib may be resected in any part of its course by embracing the area by infiltration, which is carried well down into the intercostal spaces above and below (Fig. 70).

Transthoracic hepatotomy for abscess is quite satisfactory under local anesthesia; the larger and more superficial the abscess the easier is the procedure. It should not, however, be done without first positively locating the abscess with an exploring needle, and the needle left in position while the infiltration is being carried out. This is done the same as for thoracotomy, either by blocking the nerves or by massive infiltration. The rib next below the exploring needle is exposed and resected for about 2 or 3 inches. If it is found now that the diaphragmatic pleura is adherent to the parietal, the incision can be made at once down to the abscess, along the course of the exploring needle which has been left in position. The diaphragm is not usually sensitive, but, if it is found so, a few small syringes of solution, distributed along the course of the proposed incision, will suffice to control it. The liver itself is never sensitive. If it is found that the pleural space is still open at this point, the diaphragm must be sutured to the chest wall before the abscess is incised. In doing this, if pain is occasioned, the diaphragm is easily reached with a long needle and infiltrated. To illustrate the extensive procedures, which are possible under local anesthesia in this region, we quote the following from a paper by the author, which appeared in the "Transactions of the Orleans Parish Medical Society for 1909":

"The next case is rather unusual, and one of the most interesting upon which I have ever operated, and, owing to the rare combination of conditions found, I would like to put it upon record at this time:

"H., admitted to Ward 9, had been suffering from dysentery for several weeks, having frequent bloody stools, in which amebæ had been found. Medical treatment checked, but did not stop, the bloody evacuations. He shortly developed pain and swelling over the region of the liver; aspiration showed pus, which again showed the amebæ. He was prepared for operation and the liver again aspirated. No pus was located, but instead a large quantity of clear fluid was withdrawn from the pleural cavity; as the patient was very weak the chest was not opened, as I did not think thoracotomy justified for a serous accumulation. He continued to do badly, so on August 9, 1909, under local anesthesia, the eighth rib was resected and a large pleural effusion evacuated; the fluid was now of a sanguinous character. I felt this was not sufficient to account for the marked sepsis and effusion, as well as the physical signs we had obtained on examination, so explored further, enlarging the opening in the chest wall for inspection. The lung was seen bound down to the diaphragm in the middle line, some distance from the chest wall, and looked and felt boggy. An aspirating needle was passed into it a short distance and withdrew a thick, white creamy pus. A free incision was then made, opening an enormous pus cavity, which must have contained several pints, and extended in toward the median line about 8 inches. The incision in the lung caused no pain. Through this opening in the lung I explored the region of the diaphragm. At one point it felt distinctly fluctuating, and with my finger I broke through the diaphragm, opening a small pocket of pus of a chocolate color. It was of small size and at rather an inaccessible point, which explained our missing it the second time with the aspirator. We thus had in this case three distinct cavities, each yielding a different kind and color of pus. The openings into these several cavities were all enlarged and made to drain through the common opening in the chest wall by large-sized drainage-tubes. The operation was entirely without pain. The different specimens of pus were differently collected and examined and found to contain an organism resembling the Shiga bacillus, but no amebæ. It was possible he was suffering from a double infection. The only way I can account for this peculiar abscess combination is that the liver abscess ruptured into the lung, and when relieved of its tension the opening closed. The pleural effusion was a secondary phenomena.

Operations upon the breasts for galactocele, fibromas, or other benign growths, as well as mammary abscesses, when not too diffuse, can be quite satisfactorily operated by local anesthesia, but for the radical operation in malignant disease of this gland a general anesthetic should be given.

For removal of benign tumors of the breast, when well defined, the skin infiltration can be begun on the outer side at the base, and

Fig. 71.—For operations upon the base of the female breast, as in the removal of cysts and benign growths, a crescentic line of intradermal infiltration is produced around the base and outer side in the sulcus formed by the attachment of the breast with the chest wall. The breast is then raised, and with the long needle and large syringe the cellular space beneath the breast is infiltrated in all directions with the anesthetic solution. The incision is made in the sulcus and the breast turned up and operated upon from beneath; it is then dropped back in place and sutured, leaving very little scar visible. If the operative field involve the upper part of the breast near its cutaneous covering, this upper part should be surrounded by subcutaneous infiltration to block the supraclavicular nerves. The nerve-supply of the breast is from the intercostals, which approach it from the outer side and beneath, the anterior thoracic nerves from above and externally, and the supraclavicular nerves from above, these latter supplying only the skin and subcutaneous tissue as far down as the nipple.

carried around the base of the gland at its attachment to the chest wall on its outer and under surfaces (Fig. 71). Before commencing the skin injection it is well to infiltrate the tissues at the base of the gland, when the skin infiltration can be returned to and finished, allowing the other opportunity to act, thus saving time. This is done in the following manner: With a large syringe and long needle, or Matas infiltrator, the needle is advanced through the anesthetized skin and directed into the cellular tissue, well under the base of the gland and mass to be removed; while these are held up with one hand to better define this space, about 1 ounce of the solution is usually distributed here, but more may be necessary if the gland and mass are large. After the skin infiltration has been finished, an incision is made at the base of the gland, on its undersurface, at its attachment to the chest wall. The gland is then turned up, exposing its base, when the removal of the mass is accomplished from the undersurface and the gland dropped back in place and sutured, the resulting scar not being visible.

Where a simple growth or other lesion is superficially situated on the surface of the gland, a wall of infiltration anesthesia is created

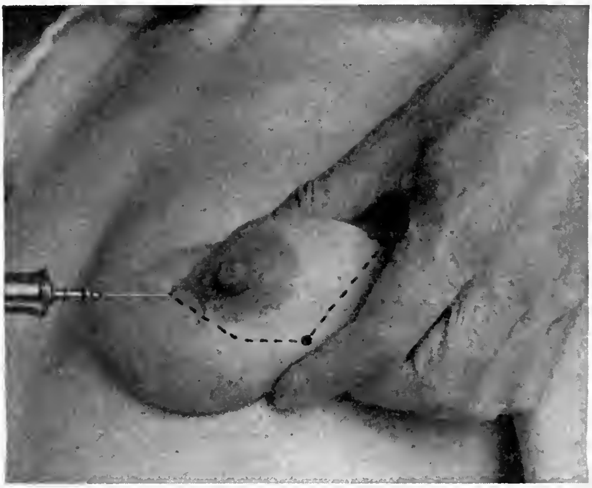


Fig. 72.—Method of creating a zone of anesthesia around a benign mammary tumor. (From Braun.)

around and beneath it in all directions after the Hackenbuch plan (Fig. 72).

The method of dealing with mammary abscesses will depend somewhat upon their location; but, as these usually point superficially, they are best opened by direct infiltration over their most prominent point.

THE STERNUM

This is blocked by making two vertical intradermal lines of anesthesia just to the outer side of the costochondral junction, to be away from the line of the internal mammary; these lines should meet above and be made subcutaneous here to block the suprasternal branches of the supraclavicular (see Fig. 69), the long fine needle is then used, and intercostal injections then made on each side in the same manner as already spoken of for blocking these nerves behind. This plan gives complete anesthesia of this region and the sternum can be resected if necessary.

Where the field of operation is limited to a small area, either of the overlying soft parts or of the chest wall, an area of anesthesia surrounding these parts is ample, as already described.

Operations on the thorax with the above technic have proved very satisfactory, and it is the procedure usually adopted by us, but where preferred simple massive infiltration can be employed, either directly in the line of the proposed incision or in a crescentic or circular manner, embracing the field and carried from the skin to the ribs, without regard to the course of the nerves. This procedure, while satisfactory, requires much more of the solution, which may be objectionable if the operative field is very large.

THE BACK

The surgical affections of this region are rather limited, and consist chiefly of carbuncles, furuncles, superficially situated growths, such as epitheliomas, moles, and the removal of an occasional bullet from beneath the skin; the back is also a favorite site for lipomas and fibrolipomas, the latter often attaining a large size and usually pedunculated.

Carbuncles, unless they penetrate too deeply, are quite satisfactorily operated upon by local anesthesia; the superficial extent of the lesion, unless enormous, is not usually a contra-indication, but the depth to which it extends, should it burrow down into the deep muscles and be situated over the midline of the back, may prevent our reaching the nerves at their exit from the spinal canal, except by going through diseased tissue, which is objectionable; however, the depth to which lesions penetrate is of no consequence if sufficiently removed from the midline to permit a long needle to be passed down through healthy tissue to reach the interval between the ribs.

In patients suffering from carbuncles we often have complicating constitutional conditions, such as diabetes, nephritis, or profound sepsis, which contra-indicate the safe employment of a general anesthesia. In these conditions local methods should be given the preference if it is possible to employ them.

The **nerves of the back** are divided into two sets of branches—anterior and posterior. The anterior branches (intercostals) run downward and forward.

To block the nerves of the back when to the side of the midline, the procedure is the same as for operations upon the thorax by blocking the intercostals. If the field is high up in the dorsal region, an additional wall of anesthesia will be necessary above the field, and should be made well down to the deep muscles to reach any nerves descending from above.

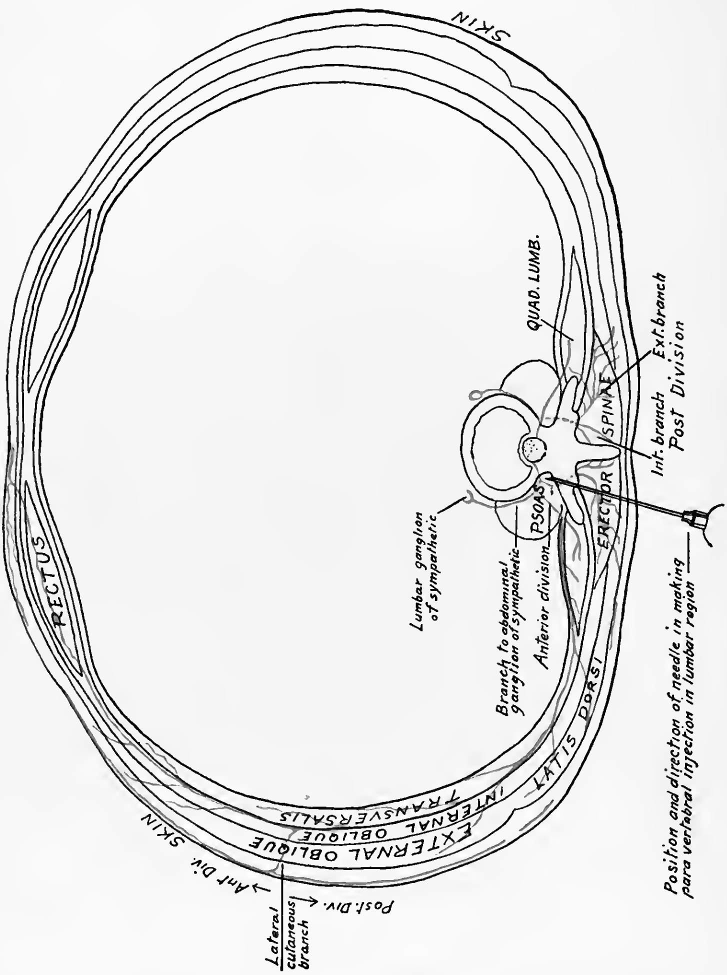


Fig. 73.—Diagrammatic arrangement of nerves in abdominal wall. In studying this diagram it must be borne in mind that while the arrangement at the vertebra represents the lumbar nerves, those in the abdominal wall represent the course and distribution of the lower intercostals, as the lumbar nerves have but a limited distribution to the lower part of the abdominal wall.

If over the midline, the procedure, as indicated in Fig. 74, may be carried out on the Hackenbuch plan (see Fig. 19), which may also be used to advantage in any region of the back.

In the lumbar region, except close to the spine, the exact point of the nerve cannot be determined; it is then necessary to create a wall of anesthesia in the deep muscles to meet the nerves as they come through, having the injections surround the field on its inner and upper parts to meet the nerves as they run downward and forward (Fig. 74) in the thorax between the ribs (see Nerve-supply of Thorax), in the lumbar region between the deep lumbar muscles (Fig. 73). The posterior nerves run backward, and are distributed to the soft parts lying on either side of the middle line. We

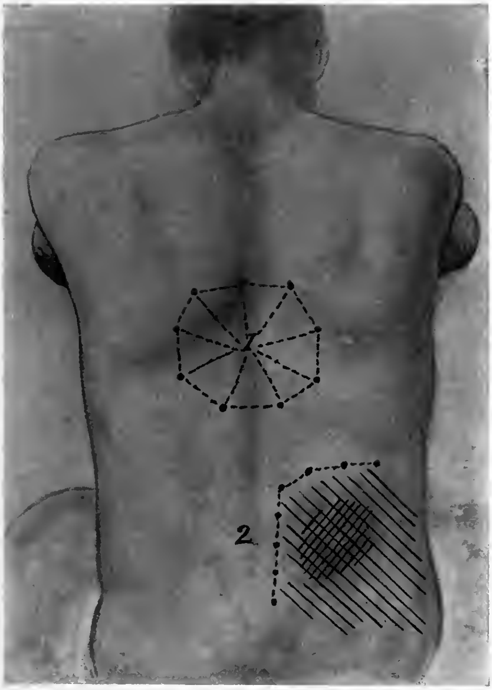


Fig. 74.—1, Hackenbuch plan of anesthesia embracing operative area: Circle of cutaneous anesthesia first surrounds field; long needle enters at several points on this circle and is directed obliquely downward and inward infiltrating deep planes. (See Fig. 19.) 2, Method of anesthetizing operative field in lumbar region: Dotted line—extent and direction of cutaneous anesthesia; heavy dots—points for inserting needle for deep injections into muscle walls; oblique lines—area of resulting anesthesia; dross-lines—operative field.

must remember that the area of distribution of any one nerve is overlapped by the nerves lying above and below it, and in some occasions, such as the upper part of the thorax, is crossed by nerves running in a different direction.

By operating in this way, procedures of considerable magnitude can be satisfactorily and painlessly performed, and often with comparatively little solution, but it is necessary, when making paraneural injections in this way, to allow a sufficient time to elapse (ten to fifteen minutes) for the anesthesia to become well established before beginning the operation. If the operation is near the midline of the back, a subcutaneous wall of anesthesia, made up and down the back near the line, will meet and block any overlapping branches from the opposite side.

This method of operating will be found very satisfactory in dealing with carbuncles and malignant growths when it is necessary that the infiltration should not be made into the diseased tissue.

Where the field of operation is somewhat removed from the midline, the depth of the tissues is much lessened and the procedure simplified. It is necessary here to create a somewhat crescentic-shaped wall of anesthesia on the proximal side from the surface to the deep parts, injecting between the ribs, and having the horns of the crescent to slightly embrace the field of operation, the same as has been suggested in Fig. 74.

By the above procedures, we have often operated large carbuncles or removed growths and have frequently resected ribs, and on one occasion removed an entire rib for tuberculous disease.

Large pedunculated fibrolipomas, common to the back, can be very easily removed by local anesthesia by injecting a collar of anesthesia in the skin around the base of the growth. After the skin injection has been started, a long needle is passed deep into the tissues at the base of the pedicle and from $\frac{1}{2}$ to 1 ounce or more of Solution No. 1 (plus adrenalin), according to the size of the growth, is distributed in the tissues at the base. While this is being allowed time to diffuse we can return to the skin injection and complete this, when the removal of the mass can be easily accomplished. In this way the author has removed a fibrolipoma about half the size of a water-bucket from between the shoulders of an elderly gentleman. Of latter years the size and unsightly appearance of the mass had kept him indoors, and more recently had almost anchored him to bed.

CHAPTER XVII

THE ABDOMEN

The question of the sensibility of the contents of this Pandora's box of the human body, in spite of the many experimental observations on animals and man and the many daily operations performed without general anesthesia, still remains largely in doubt, or at least a much disputed question between the followers of Lennander on the one side, and those who have arrived at their conclusion as the result of purely animal experimentation on the other.

Of one thing we are sure, there is nothing more certain or real than the existence of intra-abdominal pain—peritonitis, appendicitis, enteric, biliary and renal colic, etc. Such are daily observations in the routine of the physician's work; still, we are confronted with the statement, as the result of accumulated surgical evidence from reliable sources, that the intra-abdominal organs feel no pain, whether normal or inflamed.

While this subject has been investigated by earlier writers, both physiologists and surgeons, it had not been given the attention and study it merited until undertaken by the late K. G. Lennander, who made a most careful and thorough investigation, publishing his results in 1901, and since that date up to the time of his death. His conclusions were briefly that the parietal peritoneum is intensely sensitive to pain, but not to pressure, heat, or cold; this sensibility is increased by inflammation; the visceral peritoneum and abdominal organs are entirely devoid of any sense of pain, even when inflamed, and may be cut, crushed, torn, or burned without exciting pain; in other words, that all pain arising from disturbances within the abdomen is caused by irritation through spread of inflammation to the abdominal walls or pressure exerted upon these parts innervated by the cerebrospinal system, and that those parts supplied by the vagus and sympathetic system of nerves have no afferent fibers for the transmission of painful impressions. While Lennander's findings for the mesentery were not positive, he considered it also insensitive to any irritations or manipulations, except pulling upon it, which naturally exerted tension on the posterior abdominal wall and excited pain. Other investigators have stated that the occasional production of pain in the mesentery, as observed during operations upon man, may be due to the presence of an occasional cerebrospinal nerve, which may have found its way into these parts through an anomalous distribution. This view, however, is not satisfactory. Nothnagel has attributed the pain of intestinal colic to an anemia of the intestinal walls and pressure exerted upon the nerves of those parts through the violent muscular contractions; Wilms, on the other hand, accounts for the same pain by the violent peristalsis producing a stretching of the mesenteric attachments. Lennander, in investigating the same subject, found that he could stimulate a loop of the human intestine to such a degree that it became hard and anemic, without the production of pain until the mesentery was pulled upon. The last paper from Lennander's pen, which gives his views on this subject, was read at the meeting of the Amer. Med. Assoc., 1907, and is as follows:

"From my published works it may be gathered that I have not been able to find any abdominal organ, innervated only by the vagus or the sympathetic nerves, which is provided with the sense of pain. Sensations of pain within the abdominal cavity are, according to my experience, transmitted only by the phrenic nerve, the lower six intercostal, the lumbar, and the sacral nerves.

"My former pupil, M. Ramström, professor of anatomy at Upsala, has given us the first exact description of the course of these nerves within the diaphragm and the peritoneal lining of the anterior abdominal wall. He has shown that some of the older descriptions of the distribution of these nerves are incorrect.

"For instance, he has not seen any branches of the phrenic nerve running down from the diaphragm to the anterior abdominal wall, nor has he been able to trace a single branch of the phrenic nerve through the suspensory ligament to the capsule of the liver. Similarly, he has been unable to find any twigs from the intercostal nerves of the diaphragm which extend to the capsule of the liver.

"These anatomic observations of Ramström agree with my own experience in regard to the sensitiveness of the liver. Even a strong faradic of galvanic current, applied to the surface of the liver above the gall-bladder, does not excite pain. In some cases, in which the position of the liver was low, I have separated the attached surface of the gall-bladder as far as the cystic duct without causing any pain, whereas the patient complained as soon as I tilted the liver or dragged on the common bile-duct, thus putting the cerebrospinal nerves of the abdominal wall on the stretch. Not only the sense of pain, but also the other modalities of sensibility—pressure, cold, and heat—are absent from the liver and gall-bladder as well as from the stomach and intestines.

"We have often been able to ascertain that viscera involved in disease are quite as insensitive to operative measures and to electric stimuli as are sound ones. Thus, the old theory defended by Flourens has been destroyed.

"After many investigations—some of which have been attended by the well-known physiologist, Hj. Ohrvall, and several by Professor Ramström as recorder—we had come to the conclusion that the parietal peritoneum of the anterior abdominal wall possesses only the sense of pain, not the senses of pressure, cold, and heat. (In most cases it was the peritoneum behind the recti muscles, from a point 4 to 5 cm. above the umbilicus to a point midway between the umbilicus and the symphysis pubis, which had been examined.) Should this view of ours prove correct, it speaks decidedly in favor of the specific character of the nerves of pain. In other words, it goes to prove that the entire parietal peritoneum is provided only with nerves of pain—a condition previously known to exist in the cornea alone.

"It is my opinion that all painful sensations within the abdominal cavity are transmitted only by means of the parietal peritoneum and its subserous layer, both of which are richly supplied with cerebrospinal nerves around the whole of the abdominal cavity, possibly with the exception of a small area in front of the vertebral column lying below the crura of the diaphragm and between the two chains of sympathetic nerves. Here, as far as I am aware, no cerebrospinal nerves have as yet been demonstrated, and on a few occasions I have observed that within this area the patient does not respond to hard pressure with a finger or with an instrument; nor, furthermore, does he experience any sensation when a small portion of the mesenteric attachment at this point is put on the stretch.

"The opportunity is given during operations of observing that the manipulations which cause pain are those which occasion stretching of the parietal peritoneum as well as of the parietal attachments of the mesenteries. For example, pain is occasioned by the placing or removal of gauze compresses between the viscera and the parietal peritoneum, by the dragging forward of the cecum, of the vermiform appendix, or of any other organ whose normal attachment to the abdominal wall is put on the stretch; and the same principle applies to the stretching of any abdominal adhesions which may connect the viscera with the abdominal wall. On the other hand, should a compress lie between the viscera without coming in contact with the abdominal wall, the patient experiences no sensation when it is removed. Similarly, no sensation attends the stretching or breaking up of adhesions which have no connection with the abdominal parietes. As far as I can judge from my observations, the parietal peritoneum along the thoracic aperture and around the foramen of Winslow is especially sensitive to stretching, displacement, etc.

"A slow and gradual stretching of all the layers of the abdominal wall by ascites or meteorism occasions distress rather than pain, although a high degree of meteorism may be attended by great discomfort. If in a severe case of paresis of the bowel one succeeds in emptying the intestine by means of a typhilitic, a jejunal, or gastric fistula, the procedure is followed by such evident relief that the distress of the previous condition is emphasized. That a maximum degree of rapidly forming meteorism is an extremely painful condition, and one which may rapidly endanger life, I have witnessed in the case of a young student who had a coincident volvulus of the ileum and acute dilatation of the stomach. Four hours and a quarter after the appearance of the first symptoms he was pulseless from intense pain attended with a sensation of bursting.

"Infectious processes involving the abdominal viscera (ulcerations, acute inflammations, etc.) are attended by lymphangitis and lymphadenitis of the mesenteries. The infection spreads along the lymph-vessels to the subserous tissue of the abdominal wall, and, inasmuch as the lymph-vessels follow the course of the arteries, the lymphangitis very soon reaches the sides of the aorta, along which it then may continue up to the thoracic cavity. A lymphangitis of the parietal subserous connective tissue greatly increases the sensitiveness (excitability) of the cerebrospinal nerves to any manipulation which occasions pain even under normal circumstances.

"All that we know of lymphangitis and lymphadenitis attending affections of the mouth, of the pharynx, of the extremities, etc., applies equally well to corresponding processes within the abdominal cavity. We know, for example, that the severity of pain attending a lymphangitis and lymphadenitis of the above-named regions varies according to different infections, and the same thing is true for the abdominal cavity.

"The irritability of the nerves of pain of the parietal peritoneum is much increased even by the slight peritoneal inflammation. In the case of a serous peritonitis (peritonale, Reizung) the boundaries of the hyperemic zone of the parietal serosa can be mapped out almost to the centimeter by gentle palpation of the abdominal wall. With further increase of the hyperemia and of the inflammation the sensitiveness is at first almost proportionally increased. The fact that so many infectious processes within the abdominal cavity begin with diffuse abdominal pain may be explained by (1) an increased sensitiveness of a large portion of the parietal peritoneum, owing to the lymphangitis or peritonitis; (2) a considerably increased irregularity of peristaltic action which, in addition to pain, often produces a feeling of sickness, vomiting, and one or more actions of the bowels at the commencement of these illnesses. On account of the increased sensitiveness, the movements of the stomach and intestines against the parietal peritoneum and the stretching of their respective mesenteries are felt as severe pains. In most cases, however, the general peritoneal irritation soon passes off. Only the part more especially infected remains in a condition of inflammation, and the abdominal pain will become localized at this spot. In those cases where the infection spreads over a large portion of the peritoneal cavity, thus giving rise to a more or less general peritonitis, the pain will diminish as soon as the bowel becomes paretic and the nerve-endings of the parietal peritoneum have been more or less destroyed by the severe inflammation."

"**Pain in Connection with Perforation.**—In case of visceral perforation or of an abscess which ruptures into the free abdominal cavity, the primary pain is caused by the contents of the organ, or of the abscess, coming into contact with the parietal peritoneum. The severity and character of the pain depends on the nature and quantity of the escaping fluid, the extent to which it immediately comes into contact with the parietal peritoneum, and, lastly, on the intensity of the contractions of the stomach and bowels brought on by the irritation of the peritoneum.

"Many clinical observations are explicable if one bears in mind the fact that only the parietal peritoneum can transmit painful sensations. For example, the primary pain occasioned by a duodenal perforation may be referred to the iliac fossa. Again, the paroxysmal pains in connection with a gastric ulcer are elicited by the movements of the stomach; that is to say, by its dragging on a parietal serous membrane which is hyperesthetic on account of a lymphangitis from an infected ulcer. If the stomach is put at rest by the aid of a jejunostomy the pains cease. Further, in the case of a patient with an inflammatory focus, surrounded by small intestine and covered by a thick omentum, pressure on the abdomen will disclose no tenderness, whereas palpation per rectum may cause pain."

"The Hypotheses of Nothnagel as Regards Colic.—In human beings suffering from intestinal fistulæ, and to whom no anodyne has been given, sensation of pain cannot be evoked by means of chemical, thermic, mechanical, or electric stimuli applied to a portion of the gut lying outside the abdominal cavity as long as the stimulus or contractions which it causes only affect the bowel. When, on the other hand, the contracting bowel drags on adhesions connecting it with the abdominal wall it at once produces pain.

"Both theories of Nothnagel are hereby disproved, for the colicky pain cannot be due to pressure on the nerves of the bowel wall in consequence of a tonic spasm of its muscular coat, since the intestinal wall can be crushed with a strong pair of forceps without eliciting any sensation whatsoever. Further, the pain cannot be due to anemia of the intestinal wall due to a spasm of its muscular coat, since it is possible by means of electric stimulus to produce so powerful a contraction of the bowel that it becomes of tumor hardness and assumes a yellowish-white color from anemia, without the patient experiencing any sensation, even of being touched.

"Wilms, in an article and later in his splendid work on ileus (1906), tried to show that all those pains which we are accustomed to term 'intestinal colic' are entirely due to stretching of the mesenteric attachments. In my first publication (1901) I made the statement that every distention or contraction of a gut which is attended by a pull on its attachments to the abdominal wall is necessarily painful, as it involves a stretching of the cerebrospinal nerves of the parietal serous and subserous layers. With regard to the duodenum, the duodenojejunal flexure, the three flexures of the large intestine, and the most distal part of the ileum, it goes without saying that these portions of the bowel cannot contract on their contents in front of an obstruction without giving rise to a powerful dragging of their mesenteries, and at the same time a painful stretching of the nerves of sensibility of the parietal serosa. In similar fashion, powerful intestinal contractions are bound to involve a painful stretching of the parietal serosa in case the bowel has become fixed to the abdominal wall by adhesions, and there exists at the same time some obstruction at this point.

"The pains in connection with ileus, due to kinking, volvulus, etc., were thus easy to understand. On the other hand, it was my opinion that the stretching of a high and free mesentery of the small intestines or of the transverse colon could not account for the pain attending a stricture of these parts of the bowel when the stricture has not become adherent to the abdominal wall or in some way fixed, because I could not think that a contraction of the bowel around its contents in front of the stricture could drag on the parietal serosa and subserosa by that high and free mesenterium. Wilms also accounts for the pain in these cases as being only the result of the stretching of the mesentery proximal to the stricture. He considers that a loop of bowel, contracting on its contents at the proximal side of a constriction, endeavors to assume a straight form in the same way as does the gut in sausage-making. The mesentery, however, prevents the bowel from assuming the shape of a straight cylinder. The result is a stretching of the mesentery, and this is what causes the pain. In this connection, an observation was made a year ago in a case in which I had to resect more than 1 meter of the ileum, together with the cecum and a large portion of the colon, this portion of the intestine having been excluded some months previously by means of an ileocolostomy, on account of multiple fistulas and adhesions which could not be loosened.

"Under local and a short ether anesthesia the excluded portion of the bowel was completely freed from all adhesions, only the normal mesenteric attachment being left; the patient being awake, a piece of the ileum, about 40 cm. long, was clamped and inflated with air. The bowel straightened, the mesentery got stiff and assumed a fan-shaped form. While in this position, standing out from the vertebral column, the patient complained of pain, but this passed off as soon as the bowel was emptied of air and the mesentery was allowed to resume its normal position. The experiment was repeated with a considerably shorter piece of bowel. The result was the same, for the mesentery again became tight and stood out from the vertebral column, occasioning pain. Lastly, a piece of the intestine, only 5 or 6 cm. long, was shut off. Although it was inflated ad maximum, causing the serous membrane to burst and the bowel to sink between the two layers of the mesentery for fully 1 cm., the patient felt nothing. As soon, however, as the mesentery was stretched for a few moments with the fingers pain was felt. These observations are in full accordance with the above-mentioned view of Wilms as regards the stretching of the mesentery, a view which I believe to be correct.

"The pain in connection with a volvulus of the intestine or of an ovarian cyst naturally increases in proportion as the twisting comes on quickly and more parietal peritoneum is drawn into the pedicle."

"**Pain Caused by Displacement of the Serous Membrane of the Anterior Wall.**—On many occasions, when performing a laparotomy, I have passed into the abdominal cavity a finger, covered with a thin, smooth Indian rubber glove, dipped into saline solution, and exerted a slight pressure on the anterior abdominal wall. Of this the patient has no perception, but as soon as the serous membrane is displaced against the muscles or aponeuroses of the abdominal wall the patient has a feeling sometimes of touch, more often of pain, according to lesser or greater sensitiveness of the individual, and according to the degree of pressure and displacement employed. When asking the patient, 'Have you ever felt anything like this?' I have usually received such answers, 'It feels like colic'; 'It feels as if the bowel is being expanded by wind'; 'It's like bad griping pains'; 'It's worse than gripes.'

"Such sensations are occasioned by displacing a small, limited area of the serous membrane at nearly any point of the anterior abdominal wall. On account of these observations, I believe that a displacement of the serous lining takes place and gives rise to pain as soon as a loop of intestine contracts on its contents, hardens, rises, and presses against the parietal peritoneum. According to my opinion, these pains occur not only in connection with ileus, but also in connection with temporary irregularities of the peristaltic movement of the bowels in people not suffering from abdominal diseases. I have myself felt these griping pains, and I have been strongly inclined to localize the same at the anterior abdominal wall, most often to the left lower quadrant. As a rule, I have attributed them to the contractions of the sigmoid flexure.

"Here I may mention a case illustrating the displacement of the serous membrane of the anterior abdominal wall at the thoracic aperture. It was brought about by a subserous myoma of the uteri of about the size of a mandarin in a woman eight or nine months pregnant. She had suddenly been taken ill with severe pains, vomiting, and inability to pass flatus. A diagnosis was made by her medical attendant of a twisted ovarian cyst. As soon as the myoma had been removed under the local anesthesia all symptoms disappeared. The ovaries were normal. The pregnancy went on to its normal termination. I have record of another patient, who had a small subserous myoma of the uterus, and in whom, after the seventh month of pregnancy, abdominal pains were produced by any movement. They were felt as a very painful friction, and disappeared as soon as the tumor was removed.

"If the bowel wall on the proximal side of an obstruction is considerably thickened and the serous coat rough, the 'Darmsteifung' is naturally attended by a much more extensive displacement of the parietal peritoneum than in the case of a normal intestinal wall. Contrary to Wilms, I consider this factor also to be the cause of the colicky pain which attends intestinal obstruction. I have, consequently, come to the conclusion that 'gripes' are due partly to a stretching of the parietal attachments of the bowel and partly to a displacement of the serous lining of the abdominal wall."

"**Reflex Rigidity of the Abdominal Muscles.**—The normal response of the abdominal muscles to an acute sensation of pain which originates in the parietal peritoneum or subserous tissue lies in a reflex contraction (défense musculaire). In case of violent and very extensive irritation (hyperemia, slight edema) the abdomen assumes a board-like rigidity and the respiration becomes costal in type, for the abdominal muscles and the diaphragm are in a state of tonic contraction. In this way the range of movement of the abdominal organs is greatly diminished, and consequently the abdominal pain is greatly lessened. Compare with this the endeavor of patients suffering from severe abdominal pains to get relief by lying on the 'belly,' or by fixing something tightly round the abdomen. The extension of the reflex muscular rigidity corresponds closely to the area of peritoneal irritation of the parietal serosa. We know little as yet about défense musculaire in connection with a mechanical ileus before the onset of peritonitis. It is necessary to observe with care every case of severe colicky pain attending an intestinal obstruction, in order to see whether a tonic contraction of the abdominal muscles and diaphragm takes place, with the object of diminishing the movements of the bowels and indirectly the severity of the pains.

"In acute inflammatory diseases of the abdomen I have not observed the presence of cutaneous hyperalgesia so often as one might expect, especially in consideration of the 'triade douloureuse' of Dieulafoy (1899), which he regarded as necessary for the diagnosis of an acute appendicitis—cutaneous hyperalgesia, reflex muscular rigidity, tenderness on pressure. Before applying Head's theory of cutaneous hyperalgesia to a given case, one ought to consider the question whether in that special case an infectious lymphangitis, along the posterior abdominal wall and around the vertebral column, might not cause a hyperesthesia of the sensitive nerve-trunks and spinal ganglia of that region.

"It will, of course, be clear to every one that this is only a working hypothesis. In those few cases of acute appendicitis with cutaneous hyperalgesia, which have come under my care since I began to pay more attention to this matter, I have observed co-existing tenderness on deep pressure in the angle between the twelfth rib and the erector spinea or somewhat lower down at the border of this muscle.

"When considering the pains connected with infectious diseases of the liver and gall-bladder, one has to remember that well-known embryologic facts, as well as my own researches and the investigations of Ramström, all lead to the assumption that the liver, the gall-bladder, and the extrahepatic bile-passage do not possess nerves of pain. One has further to consider the distribution of the lymph-vessels from these organs to the posterior abdominal wall and diaphragm, as well as their anastomoses with the lymphatics of the duodenum and pancreas. One can then easily understand that infectious diseases of the liver and gall-bladder are apt to be followed by spasms of the diaphragm, and that the movements of the common bile-duct, the duodenum, and stomach may be attended by pain. When the gall-bladder contracts spasmodically in order to expel its contents there results a stretching of the cystic and common bile-ducts, and consequently a displacement of the parietal peritoneum and the extremely sensitive retroperitoneal connective tissue around the common bile-duct. If a tube has been fixed (water-tight) into the gall-bladder in a case of cystotomy for cholecystitis, 100 c.c. or more of saline solution may be made to pass from the gall-bladder into the duodenum (the biliary passage being free) without the patient feeling anything so long as the solution is being slowly injected into the gall-bladder. If the injection is made with a little greater force, the patient almost immediately complains of colicky pain in the back.

"With a shrunken gall-bladder and very wide common bile-duct, biliary colic, due to the stretching or distension of the common bile-duct, is inconceivable.

"It is quite necessary to consider carefully the account which the patient gives of his pain. Lately a patient of mine, suffering from an acute hemorrhagic pancreatitis, stated that the attack of pain began with a sensation as if the large blood-vessel at the back had burst near the pit of the stomach. The autopsy showed, in addition to the pancreatic hemorrhages, a large retroperitoneal extravasation around the celiac artery and the aorta. One must never forget how difficult it is to localize pain, and how great an extent a correct interpretation of the site of painful sensation is a matter of practice."

"**Summary.**—In estimating abdominal pain, and especially in connection with illnesses giving the symptoms of 'ileus,' we must bear in mind, briefly, that:

"(1) Pains do not originate within the abdominal organs, which are supplied only by sympathetic fibers and the vagus nerves.

"(2) All pains originate in the abdominal wall, more especially in the parietal serous membrane and subserous connective-tissue structures which are innervated by the cerebrospinal nerves.

"(3) Stretching of the parietal (mesenteric) attachments of the stomach and intestines, as well as of string- or band-like adhesions to the abdominal parietes, invariably elicits pain.

"(4) The same thing holds true for the displacement of the parietal serosa from its normal relation to the muscles or aponeuroses of the abdominal wall.

"(5) Most of the diseases connected with ileus are, at their commencement, attended by increased and, as a rule, irregular peristalsis.

"(6) Chemically different substances, such as the contents of the stomach, gall-bladder, intestine, or abscesses, give rise to severe pains when they come into contact with a healthy or hyperemic parietal peritoneum (pain due to perforation).

"(7) Even that form of acute peritonitis which goes under the name of peritoneal irritation (peritoneale, Reizung) greatly increases the sensitiveness of the parietal serous membrane.

"(8) The sensitiveness of the parietal peritoneum at first increases *pari passu* with the inflammation, but later decreases again when the inflammation has reached a certain high degree, and in many cases may ultimately cease altogether. (Compare herewith erysipelas of the skin, more especially the gangrenous kind.)

"I believe, finally, that we are on the way to completely understand the pains of ileus, though a great amount of work still remains to be done. I consider it to be a very happy thought to bring together anatomists, physiologists, physicians, and surgeons for the discussion of this question, and I feel not only greatly honored, but also deeply grateful, for the invitation to contribute this introductory paper."

Lennander's views have been largely confirmed and accepted by many surgeons the world over, although there still remains some observations which cannot be satisfactorily explained from his standpoint. On the other hand, the character and standing of those opposing these views, and the highly scientific nature of these experiments, safeguarded by controlling or eliminating every possible avenue of chance, accident, or doubt in their experiments, almost forces conviction.

The latest investigations in this direction have been by Kast and Meltzer, at the Rockefeller Institute, New York. In a large number of experiments, mostly upon dogs (but also cats and rabbits), they have proved in a most convincing way that Lennander's views are in error on almost every point, at least in so far as they concern these animals. They further made the astounding revelation that the amount of cocain used in the infiltrating solution for operations upon animals (most previous observations, both on animals and men, had been made after exposing the abdominal contents under local anesthesia) was sufficient in animals to control through its central action all sensation of intra-abdominal pain. This observation becomes the more important and interesting when it is remembered that the general sensibility over the entire body has been so inhibited, through the central action of cocain, as to permit the painless or almost painless performance of operations. (See chapter on General Anesthesia with Cocain.) Kast and Meltzer also found that through the injection of a moderate dose of cocain given in any convenient part of the body the whinnying, restlessness, and excitement of the animal following the operations under general anesthesia were at once stopped, the animal becoming quiet, and to all appearances remaining in a normal condition.

A thorough appreciation of this subject by the reader, as well as the difficulties in drawing conclusions from the conflicting evidence, can best be obtained after a review of the facts presented by each side. The following, "On the Sensibility of the Abdominal Organs," by Kast and Meltzer, appeared in the "Medical Record," December 29, 1906.

The animals were well narcotized by ether, the abdomen opened, and immediately closed by temporary ligatures held together by clamps, and when the animal was partly out of the anesthesia one or more of the clamps were taken off, thus permitting one or more of the intestinal coils to come out. These, as a rule, were kept moist and covered with towels saturated in warm saline solution. In other cases the entire animal was kept in a saline bath at 39° C., the viscera being well covered with a warm saline solution. In still other animals the abdomen was opened under local (cocain) anesthesia.

The presence of sensation of pain was tested by pressing the organs with the fingers or with thumb forceps, by touching them with heated test-tubes, and by stimulating with the faradic current, and watching the reaction of the animal to these irritations.

In all stimulations great care was taken to avoid pulling the mesentery or touching the parietal peritoneum. They write:

"We have tested the various parts of the gastro-intestinal canal—the spleen, the kidneys, uterus, bladder, etc.—but our present statement refers essentially to the gastro-intestinal canal, which we have studied mostly.

"All experiments lead up to one unmistakable result, which can be stated in a few words—the normal gastro-intestinal canal possesses the sensation of pain. But, besides the difference in the subject of observations, there was a difference in the condition under which both observations were made. Lennander operated essentially under Schleich's infiltration anesthesia. Schleich's mixture, as Lennander employed it, consisted of 5 cg. of cocain, 1 cg. of morphin, and 200 c.c. of a normal salt solution.

"It seems advisable to us as a further step in our investigation to study the possible effects of these ingredients upon the sensation of pain in the abdominal organs.

"We began with cocain. The hitherto known effect of this drug was its local anesthetic effect.

"Lennander and other surgeons employed it for this very quality to deaden the pain during the incision, apparently without the remotest idea that the drug could also effect the sensibility of the distant isolated gut.

"We nevertheless decided to test it. After establishing the undoubted sensitiveness of the intestines, etc., 2 cg. of cocain were injected into the tissues of the abdominal walls near the incision. We were then surprised, indeed, when we discovered that a short time after the injection all sensation disappeared from the intestines. Even a very strong electric stimulus no longer produced any reaction or effect. After thirty or forty minutes the sensation returned. Such observations were then repeatedly made, and invariably with the same results.

"Now, we could hardly think that the cocain crept over by capillarity or by some other manner to the intestines, and the observed anesthetic effect was a local one. Neither did it seem probable that the cocain crept along the spinal nerves to the spinal cord, and then came in contact with the pain-carrying nerve-fibers from the intestines. The most reasonable explanation was that the anesthetic effect was produced through the circulation. That would mean that cocain had not only a local but also a general anesthetic effect. This assumption was easily tested.

"The cocain was now injected in parts distant from the abdominal cavity, in the thigh, arms, pectoral muscles, etc. The anesthetic effect upon the intestines was prompt and complete just the same.

"In further experiments, we have established that 1 cg. was sufficient to bring about the desired effect, and this even in large dogs weighing 14 kilos.

"We have, then, thus far established two facts: that the gastro-intestinal canal possesses the sensation of pain, and that the subcutaneous or intramuscular injection of a comparatively small dose of cocain is capable of abolishing this sensation for some time.

"We believe that we are now justified in offering the following interpretation of the surgical observations: While we have not the slightest doubt of the correctness of the facts, namely, that when operating under Schleich's infiltration anesthesia the abdominal organs are completely anesthetized, we suggest that this anesthesia is due essentially to the general effect of the cocain employed, and not to a normal absence of sensation in these organs.

"In the course of the investigations we exposed some intestinal coils to the drying effect of the air in order to bring on some inflammation, and we then found that inflamed organs are distinctly more sensitive than normal ones. In fact, the sensitiveness is often greater than that of the skin.

"Now, Lennander and other surgical observers stated that in their experiences also inflamed organs are completely anesthetic. We have, therefore, tested the effect of cocain upon the exaggerated sensitiveness of inflamed intestines, and found that a somewhat larger dose of cocain, say 3 cg., will completely abolish all sensations also from inflamed organs.

"Another interesting point is the observation that the parietal peritoneum also loses its sensation by a hypodermic injection in any part of the body, but the anesthesia sets in here later and disappears earlier than in the internal organs.

"It is possible also that the degree of the anesthesia is less, but we are not yet ready to make any positive assertion on that point.

"An interesting and new fact is the observation which we made on the effect which the injection of a small dose of cocain exerts upon the psychic condition of the animal—it promptly quiets excitement. The animals, which were very restless, howling and crying, became perfectly quiet one or two minutes after an intramuscular injection of cocain. It may be claimed that the quietness was due to the abolition of the pain.

"We have tested it on etherized, but not operated, dogs. On awakening from ether they howl just as much as operated animals; the howling is not due to pain, but to the ether intoxication. An injection of cocain quiets them promptly.

"The psychic effect seems to last longer than the anesthesia of internal organs. The injection has no narcotic effect; the animal is apparently wide awake and follows one with his eyes. The lid reflex is not abolished, but the cornea is anesthetic and the pupil is widely dilated.

"Whether the general sensibility is also reduced, that question we are not yet ready to answer."

Still more disquieting than the foregoing to the earlier accepted views of Lennander appears a later paper by the same careful, thorough, and painstaking investigators on the sensibility of the abdominal organs, which appeared in the "Mitteilungen aus den Grenzgebieten der Medizin und Chirurgie" for 1909. As this most interesting and instructive paper is a highly valuable contribution to this, as well as collateral subjects, we hope the reader will pardon our quoting from it at length in the author's own words:

"The surgery of our day denies the sensibility of all the abdominal organs, notwithstanding numerous daily experiences to the contrary; this question of normal sensibility belongs to the domain of physiology. But we find here that for a decade nobody has paid any attention to the subject, and most text-books do not mention a single word on the subject. But it was not always thus—in the first half of the last century many prominent physiologists had contributed to the solution of this question. The sympathetic ganglions and the nerves distributed from them were studied in the range of the examinations. The results were far from satisfactory and full of contradiction. Many observers asserted in a positive manner that no kind of irritation of the sympathetic ganglions, their nerve-fibers, or the intestines was capable of producing pain. Other authors, on the contrary, equally well known in the history of physiology, asserted that strong irritation of these parts was followed by severe pain.

"Megendie stated that cutting, tearing, etc., of the ganglions made no impression upon the animal.

"Bichat has also reported that a dog had eaten its own exposed intestines, and many other well-known authors have reported similar observations. Bichat further reported irritating the celiac plexus and intestines of a dog by cutting or with acid without producing pain. Johannes Müller, on the other hand, states that mechanical and chemical irritation of the celiac plexus or the connective tissue of the renal vessels in the guinea-pig undoubtedly caused pain. Similar observations were made by Budge, Gianuzzi, and others. Again, other investigators, among them such brilliant names as Flourens, Longet, Brachet, and Valentine, take a middle ground. Some stated that only very strong or long-continual irritation caused pain, and then of a mild degree. Others had pointed out that immediately after the exposure of the ganglion by no kinds of stimuli could pain be produced, but that, on the contrary, after longer exposure, when it had become red or 'otherwise irritated,' the same stimuli were followed by manifestations of pain.

"Since the middle of the last century, since which time practical surgery as well as physiologic experiments have made use of general anesthesia, we scarcely meet a report on investigation which deals with our subject. They deal principally in consideration of other problems in relation to the sympathetic nervous system of the abdomen, in which occasionally observations are mentioned which show that even in narcosis the cutting, crushing, or tearing out of the splanchnic nerves or the celiac ganglion always cause pain (Haffter, Nasse, Braam-Heuckgeest, etc.).

"In numerous examinations, undertaken without regard to sensibility, afferent nerve-fibers of the sympathetic were demonstrated which serve many reflex purposes, as vasomotor, cardiac inhibition, respiratory, etc. In relation to the sensibility to pain of the abdominal organs we find the physiologic literature of the last decades, as far as we are acquainted with it, to contain not even occasional observations. Some authors, as Buch, Richet, etc., who have concerned themselves with our problems, admit that these organs normally possess no sensibility, but that these organs can become the seat of intense pain when inflamed or otherwise in a condition of abnormal irritability.

"In recent times the study of the sensation of the abdominal organs has been undertaken by surgeons. An occasional clinical statement regarding the lack of sensibility of the abdominal contents is met in the older literature here and there.

"Such observations were: the apparent lack of sensibility of the contents of herniæ to mechanical or electric irritation; or of loops of the bowel fixed outside the abdominal wall for the purpose of creating an artificial anus; also of prolapsed portions of intestines.

"Since the introduction of local anesthesia and Schleich's infiltration method numerous extensive abdominal operations have been undertaken without general anesthesia; these offered apparently a very favorable opportunity for the study of our problems. In fact, many surgeons have made the occasional observations that the abdominal contents appear devoid of any sensation.

"Bier has stated that the intestines can be cut, squeezed, burned, etc., without producing pain, but in a later contribution he adds that tearing the intestines or the connective tissue of the mesentery or separating adhesions will occasion pain.

"The question was gone into systematically and studied with greater care by K. G. Lennander. The results of his investigations were that the intestine, stomach, omentum, mesentery, spleen, liver, gall-bladder and bile-passages, etc., in short, all organs which received their nerve-supply exclusively from the sympathetic, possess neither pain nor tactile or thermic sensations; and this applied not only to the normal condition, but to the inflamed state as well.

"These organs, asserts Lennander, possess simply no fibers for the transmission of touch, temperature, or pain. Only the parietal peritoneum feels pain, and this because it is supplied with spinal nerves. Inflammation increases the irritability of the nerves in general, and increases, therefore, the sensibility of those in the parietal peritoneum. Lennander refers the origin of the different kinds of pain which occur in the abdomen to the parietal peritoneum and to the spinal nerves in general.

"Therefore, would a distention of the intestines and intensive peristalsis produce pressure and rubbing upon the parietal peritoneum, or by producing a stretching of the mesentery which is felt on the spinal nerves or the root of the mesentery?

"In consequence of the inflammation of the abdominal organs there occurs, as Lennander also assumes, not only an increased irritability of the spinal nerves, but also the production of lymphangitis, which later extends to the tissues which are richly provided with spinal nerves.

"Infectious, toxic, or chemically irritating materials, therefore, occasion pain; they are absorbed through the lymph-vessels, and are immediately transported to parts supplied by the afferent spinal nerves.

"Lennander's views are at present shared by many prominent surgeons, among others von Wilms, who, on the contrary, sees in the stretching of the mesentery the essential factor in the production of abdominal pains.

"The most essential and most striking feature in Lennander's views are that the abdominal organs, which receive their nerve-supply exclusively from the sympathetic, are entirely incapable of feeling the sensations of pain, pressure, heat, or cold.

"This view has recently obtained physiologic sanction, and has been completely accepted by Thunberg in the chapter on Tactile Temperature and Painful Sensation in Nagel's 'Handbook of Physiology.'

"Some time ago we began a series of experiments on animals to determine the sensation of pain in the abdominal organs. Our observations led us to the following conclusion: The abdominal organs are capable of painful sensation in the normal condition as well as in the presence of inflammation. At the same time we made the observation that this pain disappears after an injection of cocain given in any convenient part of the body. In publishing a preliminary report on these facts we consider our ability to put the question, whether or not in operations on man the cocain plays an essential share in the comparative analgesia as it is observed by the surgeon?"

"The Experimental Facts.—*Methods of Examination.*—Experiments were carried out on dogs, cats, and rabbits, the greater number on dogs, of which we used more than 60, and our report will consist principally of the findings in these animals. In the greater number of our examinations the animals were etherized, the abdominal cavity in the linea alba opened, and immediately closed with temporary ligatures held together with clamps. The laparotomy was carried out step by step; as the incision was lengthened, the wound was closed. In this manner it was possible to carry the incision almost the entire length of the abdomen without permitting the intestines to protrude, and we were especially careful to touch them as little as possible.

"Before beginning the essential part of the experiment the animal was permitted to come more or less out of the influence of the ether. In some cases the laparotomy was done under local anesthesia with cocain, beta-eucain, or tropococain; again, in other cases the laparotomy was performed by infiltration of the skin with 0.9 per cent. salt solution. As reactions of the animals, such decided irritation was necessary as would produce distinct symptoms of active pain, such as crying out, whining, pulling or actual movements of the body, sudden wagging of the tail, when the onset or commencement of these symptoms began abruptly, commencing with the beginning of the irritation and stopping with its cessation. The pulling or turning of the body and the quick wagging of the tail were accepted as sufficient symptoms of pain where whining, etc., were prevented by tracheotomy. Rapidity of respiration or stretching of the abdominal muscles without the other symptoms of pain were considered as reflex symptoms, which possibly were not accompanied by pain.

"The ether naturally prevented painful sensation. Reactions which we encountered in experiments before the animal was completely awake from the ether do not represent as much relatively as those which occurred in a normal condition. However, it appeared sometimes desirable, especially in restless animals, to apply the irritation while the animal was still moderately under the influence of the anesthetic; at these times it was rather a qualitative than a quantitative test. The contrast from the repose of the animal was so distinct before the irritation was applied as to leave no doubt, and bore a direct relation between cause and effect.

"On the other hand, it appeared without a doubt in restless, continually whining animals that the irritation caused pain, as all symptoms of pain increased so suddenly after the application of the irritation. Especially after some experience with these kind of experiments one seldom remained in doubt as to whether a definite reaction caused pain or not. We may, however, add that we drew our conclusions from such reactions that left no doubt and, for the most part, after the agreement of two or more independent observations.

"We, therefore, lay especial emphasis upon this point, as one or the other observer, possibly after several earlier examinations, may have become confused or disgusted; and, indeed, in view of the possible difficulties, to doubt the reaction at times when the animal was of an especially restless character.

"We will further state that the irritation as well as the reaction which was produced was only of short duration, and the animal evidently suffered very little under it.

"We examined along with the intestines also the stomach, liver, spleen, omentum, mesentery, and kidney. In the greater number of our experiments we confined ourselves to the intestines, and used mechanical, electric, and thermic irritation.

"Mechanical irritation consisted for the most part in pressing the intestines either between the fingers or between the blades of surgical forceps. Sometimes the intestines were irritated by incisions or by sticking with a needle. For electric irritation we used the faradic current, and for heat, a test-tube filled with hot water.

"The intestine was tested for sensibility, either within the cavity or after it had been delivered outside. In the latter cases all or a greater part of the ligatures were opened, and a more or less larger part of the intestine brought forward and kept covered by towels wet in warm salt solution, or only a single ligature was loosened and a short loop of intestine brought forward; in these cases the delivery of the intestine was aided by a silk thread, lightly drawn around the bowels at the time of laparotomy, the ends knotted and retained outside. The single intestinal loop was either immediately replaced in the cavity after the irritation or allowed to remain outside and kept moist and warm with towels. Organs like the liver, kidney, etc., which could either not be delivered at all or only by pulling upon their mesentery, were tested within the cavity.

"In numerous experiments the intestines were tested only within the cavity, and then after the following special method: During the laparotomy the intestine was loosely fixed between the blades of an artery forceps covered with soft rubber, and allowed to remain in the cavity with the handles projecting through the incision. Thus, pressure on the handles of the forceps outside of the cavity was transmitted to the loop of bowel lying between the blades on the inside.

"In experiments in which the laparotomy was done with local anesthesia we often irritated the intestines with a forceps, which was passed through a proportionally small opening immediately after the incision. Some other details shall be mentioned in the protocol.

"While Lennander and other surgeons accept all pain arising in the peritoneal cavity as coming either from pulling upon the mesentery or through rubbing the parietal peritoneum, we especially emphasize that in our experiments on the abdominal contents we particularly avoided pulling on the mesentery or irritating the parietal peritoneum. Moreover, after mechanically irritating the intestines, we often obtained an equally pronounced positive reaction by pulling on the mesentery or rubbing the parietal peritoneum."

"**Results.**—By far the most important part of our problem was the question from the physiologic standpoint: Are the organs which are supplied exclusively by sympathetic nerves provided with afferent fibers for the impression of painful sensation? We were, therefore, first concerned with this question. To which our answer, in so far as the abdominal organs are concerned, is decidedly in the affirmative. In about 60 dogs, on which we experimented, we missed in only a single case in the entire number a distinct reaction after irritating the intestines. The probable cause of the analgesia of that one animal we intend to discuss later. Under reactions we understand, as mentioned above, the aforementioned symptoms in the animal—symptoms manifesting pains. The measure of these reactions was different in the several experiments, and was repeatedly even different during the course of one and the same experiment. We intend to return later to the conditions occasioning these variations, but in each one of our dogs, with the exception of one, there existed a more or less long period, during the course of the experiment, in which an irritation of the intestines produced a stronger or weaker unmistakable reaction indicating pain. To illustrate this, we may quote some experiments from our records:

"Experiment 1, dog No. 14, 4 kg. Laparotomy done under ether, the larger part of the wound was then closed with sutures except a few centimeters at the anterior end. Through this part a loop of intestine was allowed to protrude. The loop of small intestine was kept covered with absorbent cotton wet in salt solution.

"Operation ended at 11:10 A. M. 11:25 the exposed loop was tested. Pressure with dull forceps produced a decided reaction; pulling on the mesentery or rubbing on the wound was carefully avoided.

"Faradization produced the same result. During the faradization the intestinal loop was carefully lifted from the abdominal wall. Application of a glass tube filled with hot water produced an undoubted reaction, although after a delay of several seconds another short loop of intestine was brought forward, and the same three tests repeated with a similar result as before. The intestines were replaced and the wound closed. (The experiment was later continued under different conditions.)

"Experiment No. 2, young dog, No. 23, 2.8 kg. Laparotomized under ether; wound closed with sutures. Operation finished at 12:10 A. M.; 12:40 the dog was placed in a sodium chlorid bath (39° C.).

"Abdomen opened by loosening the ligatures; the intestine came forward, but all remained under water. Tested twice; pressure with the fingers and faradization both caused pain. Reaction undoubted. (During the faradization the intestine was lifted for several seconds above the surface of the water. Experiment was continued.)

"Experiment 3, dog No 44, 7 kg. Ether. Laparotomy, closed with ligatures. Femoral artery prepared for measuring the blood-pressure. Finished at 10:45 A. M.; 11:30 wound opened, intestine came forward under the water. Pulse 120, pressure 140. Cautious pressure on the intestine causes prompt and strong reaction; irritating the skin caused only little reaction. In these three experiments as well as in many others under similar conditions in which the animal had recovered from the ether narcosis, and the intestine was still in fresh, comparatively normal condition. Strong pressure with the finger or forceps caused unmistakable evidences of pain. The same after faradization or touching the intestine with hot test-tubes.

"Experiment 4, dog No. 37, 5.3 kg. The abdominal skin in the lower half of the linea alba for several centimeters was infiltrated with 0.9 per cent. sodium chlorid solution. Cutting through the abdominal wall at this point caused only slight pain. A loop of intestine came forward spontaneously. Careful testing with firm finger pressure caused undoubted strong reaction."

In all of our experiments in which only sodium chlorid solution was used for infiltration we could, without exception, immediately after the opening of the abdomen obtain an unmistakable reaction by pressure upon the intestines.

"The following protocol serves as an illustration of a series of experiments in which pressure was made upon the intestines within the abdominal cavity:

"Experiment 5, young dog, No. 32, 4.3 kg. Ether; abdomen opened in the lower part of the linea alba; a loop of intestine was lightly fixed between the rubber-covered blades of a long curved forceps, with the intestinal loop replaced in the abdomen and wound closed, except for an opening where the handle of the forceps protruded.

"Ether narcosis stopped. Somewhat later, when the animal was still moderately in the ether narcosis, we pressed together the forcep handles (this pressure naturally squeezed the loop of intestine lying between the blades in the abdominal cavity); each time it produced an unmistakable reaction in the still sleeping animal; simply pulling on the forceps, which produced a pull on the mesentery, produced only little effect. The blades of our forceps was lightly bent; the point could, therefore, easily be directed against the peritoneum within the cavity. In this way rubbing on the parietal peirtoneum produced a reaction, which was quite moderate in comparison to the effect produced by pressing together the blades of the forceps.

"With the method which we describe in this experiment we could always produce a prompt reaction and have demonstrated it by many different observations.

"In the following experiment we have attempted, in a certain sense, to imitate a hernia. The experiment is at the same time a good illustration of the influence of inflammation upon the sensibility of the intestines:

"Experiment 6, November 8, 10 A. M., young dog, No. 10, 4 kg. Ether; abdomen opened; a loop of small intestine brought forward and sunk in a pouch between the muscle and skin, fixed in position with a stitch. The pouch was situated in the lower left side of the abdomen. The rest of the wound was completely closed. November 9, 3 P. M., the animal in good condition; the stitch divided, and the intestinal loop brought forward.

"It appeared moderately inflamed, relaxed, and distended with gas; no visible peristalsis. Pressure with the fingers produced clearly more pain than would have been produced by similar pressure on any other part of the normal skin.

"Heat applied to the intestine produced an equally marked reaction as an application to the skin. Faradization was followed by a marked reaction, which was at least as active as that following faradization of the skin.

"We observed at different occasions that a striking hypersensibility occurs, ordinarily in parts of the bowel in which, in the course of a long-continued examination distinct symptoms of inflammation develop. A needle stick, simply touching these parts with an instrument, or by merely blowing upon them, is sufficient to produce a marked reaction.

"What we have stated here in relation to the existence of pain in the intestines, including the colon, applies also to the stomach, and appears to apply equally to the liver, spleen, and kidney, but our experience on these organs has been very little when compared to our extensive experience on the intestines.

"Therefore, from our experience with the dog we may state that the abdominal organs are supplied with nerve-fibers for the transmission of painful impressions. If the existence of such nerve-fibers appear to have been proved, if only on a few dogs, and only occasionally distinct expressions of pain had been indicated, then it is highly improbable that in a single individual of the same species such a wide variation should exist in such a fundamental fact as the occurrence of definite important nerve-fibers.

"As already mentioned, the existence of pain, we can say, in all dogs on which we experimented and submitting all of our experiments was the appearance of painful reaction in no way an occasional reaction.

"Our experiments have further shown that in inflamed conditions the sensibility of the abdominal organs is much increased. It was further frequently apparent that the pain produced by direct irritation of the intestines was more severe than that caused by pulling upon the mesentery or rubbing the parietal peritoneum. The last procedure (pulling on the mesentery or rubbing the parietal peritoneum) cannot be accepted from this standpoint as the only cause of intra-abdominal pain in the dog, as Lennander and other authors assume for the human subject.

"While the total of our numerous and manifold experiments does not permit of any other interpretation than the one given above, we must admit that the interpretation of some single experiments is not a simple problem. It especially appears to us that the manner of experimentation as it usually was, and still is, carried on by the free exposure of the abdominal viscera after a large abdominal incision gives changing and apparently contradictory results.

"The reaction to irritation of the freely exposed intestine was always non-uniform, according to the conditions, as to whether the intestines remained uncovered or covered with moist cloths or the whole animal with the exposed intestines placed in warm saline or Ringer's solution. At times the reactions were positive or even violent, at other times doubtful and sometimes decidedly negative. We will again illustrate this statement through an abbreviated protocol:

"First we want to quote the record of an experiment in which during no stage of the experiment irritation of the intestine seemed to have produced an undoubted manifestation of pain.

"Experiment 7, dog No. 28, 3.6 kg. Ether; tracheotomy; abdomen appears distended; laparotomy. Wound provisionally closed with ligatures. About twenty minutes after stopping the ether the animal was placed in a sodium chlorid bath, maintained at a temperature of 40° C. The tracheotomy cannula was connected with a rather wide rubber tube, about 30 cm. long, so that the animal could breathe when the wound in the neck was under the water-level (the free end of the tube was placed for a few seconds under the level of the water; the animal would not aspirate the water, but breathed out vigorously). The ligatures were loosened, and the abdomen opened under the level of the water; the stomach and intestines gushed out of the cavity, both markedly distended with gas. The intestines were irritated by pressure and faradization. Both irritations caused 'very little pain,' but a certain degree of sensation existed. Several minutes later no kind of irritation produced any reaction. This complete analgesia lasted through the entire continuance of the experiment. Strong sudden irritation (mechanical and electric) produced no reaction either on the outer skin, nose, or lips, etc. The analgesia was complete for the entire body. Respiration regular, about 40 per minute; pulse weak, between 110 and 120; blood-pressure not measured. Corneal reflex rather good. The animal remained in the condition of deep apathy for more than an hour, when it was killed by sinking the end of the tube in the water. No symptoms of asphyxia, convulsions, or spasmodic respiration appeared.

"In the experiment the protocol reports only a 'little pain,' and that but for a short time. During a full hour afterward there were no symptoms whatever of any sensation in the intestines. We, therefore, regard this as a negative result. There was at the same time complete analgesia of the entire body and the animal remained in a condition of deep apathy.

"When drowned the usual symptoms of asphyxia, such as respiratory convulsions, were lacking.

"The condition of the animal is recorded in our protocol as 'shock'; however, we will not here discuss further the correctness of this record.

"As already repeatedly mentioned, we met only once such a case of total intestinal analgesia during the whole number of experiments. On the other hand, we possess the records of a fair number of experiments in which a passing analgesia appeared once or several times during the experiment. To illustrate this state we shall quote the continuation of Experiment No. 1:

"Experiment 1 (continued), dog No. 14. After determining that the intestines reacted plainly to pain they were replaced in the abdomen, the wound closed, and abdomen kept warm. Finished 11 : 50 A. M.; 12 : 10 the animal was quiet, respirations superficial. Corneal reflex dull. Pulse 110. Reacted only lightly to mechanical and electric irritation of the skin. Wound then uncovered, and a loop of intestine pressed out between the ligatures and allowed to lie outside.

"This loop was distended, cyanotic, and gave scarcely any reaction to irritation; it was replaced in the cavity and the ligatures tightened. The dog remained completely quiet. 1 : 10 P. M., dog begins to move; 1 : 40, ligatures at the lower end of the wound loosened, a loop of intestine comes forward. Pressure with forceps and faradization gives painful reaction. Soon after the intestinal loop became distended and cyanotic, when the reaction to pressure, heat, and the electric current gradually became weaker and finally disappeared. Also irritation of the skin showed scarcely any effect.

"The animal was quiet, pulse 110, intestines replaced in cavity, and wound closed.

"2 : 22 P. M. Ligatures opened and an intestinal loop brought forward. Irritation of this loop caused strong reaction. The intestine replaced and wound again closed. (The experiment was continued with cocain injections.)

"In this experiment it happened twice that the intestine after coming forward became analgesic, while before a quite long and distinct reaction to pain had been produced. The sensibility to pain, however, returned after the intestine had been replaced in the cavity and allowed to remain there for a while.

"The sensibility of the gut was not lessened if this was brought out of the cavity for only a short time. At the same time with the intestinal analgesia occurred a lessening of the general sensibility over the entire body. In short, the condition was very similar to that which we have observed during the entire progress of previous experiments, only that here the condition was temporary and reversible. It is to be noted, however, that in the previous experiments almost all the intestine was brought out of the cavity and not replaced.

"Experiment 8, dog No. 20, 5.2 kg. Ether (it required very much to anesthetize the animal); laparotomy; incisions closed with ligatures. Narcosis and operation finished at 11 A. M.; 11: 15, the animal awake, moving, and squeezes a loop of intestine out between the ligatures. Immediate reposition of the loop causes strong reaction of pain of short duration, after which the animal immediately became quiet.

"He lay without making a sound or moving, pulse small and very rapid. After some minutes the pulse again became normal, the animal continuing quiet.

"11 : 30 A. M. A loop of intestine was carefully drawn forward. Pressure produced a positive reaction. The reaction is so active that the animal gets his head out of the halter, the ligatures stretched, and the abdominal contents were forced out. Scarcely had the head been secured again when the animal became quiet; irritation of the intestine with strong pressure and with faradization remained negative; no reaction was produced. The intestines were now covered with wet towels, with the exception of a loop, which remained uncovered and was not moistened.

"12 M. Intestine (the covered portion) shows no reaction to pressure. Faradization, however, is followed by a mild but certain reaction. The skin was also tested for confirmation; it was negative for pressure, but positive for faradization. 12 : 02 P. M. The uncovered and dry loop of intestine appeared hyperemic. Pressure gave positive reaction; faradization by weak currents was positive. 12 : 10 P. M. Faradization of the intestines;

reaction doubtful; equally strong faradization of the skin showed active reaction. 12 : 25 P. M. Pressure on the covered and uncovered portion shows positive reaction; even a needle stick shows positive reaction.

"12 : 30 P. M. Pressure, needle stick, and hot test-tubes show distinct reaction. 12 : 45 P. M. Pressure, positive reaction faradization even with very weak currents shows pronounced reaction. No proportional difference between the covered and uncovered portions of the intestine.

"Also in the experiment the sudden delivery of a large part of the intestine caused temporary analgesia, accompanied by an unmistakable depression of the cutaneous sensibility.

"The sensibility of the intestine, as well as the skin, returned after the intestines had been covered, warmed, and moistened.

"The sensibility not only returned, but seemed so much increased that even a needle stick caused pain.

"Experiment 9, dog No. 27 (weight not noted). Ether; laparotomy. Around a loop of intestine a silk thread was drawn, abdomen closed, narcosis and operation finished at 11 A. M. 11 : 25 A. M. The loop of intestine on the thread cautiously drawn forward; positive reaction to pressure; intestine replaced; some minutes after all the intestines were brought forward; soon thereafter pressure and faradization were without effect. Faradization of the ears showed little reaction.

"11 : 45 A. M. Intestines replaced and abdomen closed; 11 : 55 A. M., faradization of ears, positive reaction; 12 : 55 P. M., a loop again drawn forward. Pressure shows positive reaction. All ligatures were quickly opened and the stomach, intestines, and spleen brought forward, remaining uncovered and not moistened. For two minutes the intestine remained sensitive to pressure; after that there was a negative reaction to pressure and faradization, later even very strong faradization is negative. Gradually, the parietal peritoneum and mesentery completely lose their sensibility. The previously much-disturbed animal had become quiet; 1 : 15 P. M., all organs replaced, abdomen closed; 1 : 40 P. M., a single loop of intestines brought forward; faradization caused very strong reaction. The intestine replaced; 1 : 55 P. M., again all ligatures were opened, immediate faradization of the intestine gave a distinct reaction; soon after stronger faradization is without effect. Pupils wide, corneal reflex present, and faradization of the ears gives positive reaction.

"Also in the examination was the sensibility of the intestine abolished, through the delivery of all or a greater part of their length, and appeared again after replacing them in the cavity and closing the wound. This was done three times during the same examination. After each delivery of the bowel the dog was quiet and apathetic; the skin, however, did not lose much of its sensibility. The delivery of a single loop of intestine did not lessen the sensibility.

"Experiment 10, dog No. 38, 5.1 kg. The skin of the abdomen in the middle line was infiltrated with salt solution, the abdominal wall for 2 cm. was opened; till now very little sensibility. Seizing a loop of intestine with forceps was answered by an unmistakable reaction. Pulling on the mesentery and touching the parietal peritoneum was carefully avoided. Ether narcosis begun; both femoral arteries were prepared for measuring the blood-pressure. Abdominal incision increased about 20 cm.; a loop of intestine was lightly fixed between the blades of a forceps. Abdomen closed about 11 : 15 A. M. The animal is awake, but quiet, lid reflex present. 12 : 25 and 12 : 40 P. M., light pressure with the forceps causes immediate distinct reaction.; 1 : 00 P. M., blood-pressure wavers around 140 mm. mercury. After opening the entire wound all the intestines were brought forward. Pressure on the forceps at first causes a quick reaction, but later no response at all. Blood-pressure at first increased; the arrow, however, soon fell back and remained around 140 mm. The intestines were soon covered with warm sodii chlor. compresses. Lid reflex normal, respiration slow and regular, the animal was remarkable quiet. 1 : 55 P. M., pressure on intestines, active reaction; 2 : 10 P. M., reaction to pressure still active.

"Intestines replaced in the abdomen and after some minutes again brought forward. The sensibility of the intestines disappeared almost completely and the animal was again strikingly apathetic.

"Blood-pressure remained in the same tube about 140 mm.; 2 : 50 P. M., strong pressure on the intestines (which had remained out) produced again a little reaction.

"A noteworthy observation in this experiment is the fact that the lessening of the sensibility of the intestines and the apathetic condition of the animal was in no way accompanied by a fall in blood-pressure.

"Experiment 11, dog No. 39, 9 kg. After infiltration with salt solution a small incision was made, and the sensibility of the intestines within the cavity was tested. Reaction distinctly positive. Etherization. The animal slowly entered narcosis. Both femoral arteries prepared for measuring the blood-pressure, abdomen widely opened, and a loop of intestine fastened between the blades of the forceps. Abdomen closed and ether stopped about 10 : 55 A. M.

"From 11 : 15 to 11 : 35 A. M. the animal remained completely quiet. Light pressure on the forceps produced a distinct reaction, which was tested several times with similar result; 11 : 40 A. M. all ligatures quickly loosened, the intestines gushed out; now light pressure on the forceps on the same part of the bowel produced no reaction, stronger pressure producing only little expression of pain.

"The animal begins to be excited, moving quickly, respiration slow, pulse rapid, blood-pressure about 140 mm. The sensibility of the intestines soon began to return again, slowly but surely. The intestines remained covered with salt solution compresses.

"12 : 30 P. M., the intestines were manipulated in different ways. The sensibility was distinctly lessened by these manipulations, but soon returned. The examination was repeated four times with similar results. The sensibility was each time apparently diminished, but did not completely disappear, and soon returned to its original intensity. Blood-pressure remained about 140 mm. 1 : 10 P. M., sensibility pronounced, even light pressure producing an active reaction. After replacing intestines and repeating the eventration, the sensibility almost completely disappeared; blood-pressure remained about the same.

"From this experiment it is evident, aside from the repetition of facts from former experiments, that the reposition of the intestines in the abdominal cavity and their manipulation produce a reduction of the sensibility, but this reduction was not so great as in former experiments and not so lasting.

"The animal was by nature very sensitive and reacted to ether extraordinarily. During the variations in the sensibility in this experiment there was no corresponding variation in the blood-pressure.

"The contrast between the sensibility and the variability of the blood-pressure was clearly shown in many of our experiments. Especially striking was this in the cases where the animal was kept in a warm bath of salt solution or Ringer's solution. The blood-pressure remained moderately high while the animal was apathetic, and the intestines and skin either lessened or lost their sensibility. In some cases, however, the blood-pressure began finally to fall, and the animal passed into a condition of true shock. Similar experiments were also conducted on cats and rabbits, but the results were unsatisfactory, as it was often difficult to tell when these animals suffered. They were further very easily affected by laparotomy, showing pronounced depression and inhibition early in the course of the experiment."

"**Review of the Facts.**—When the sensibility was tested within the closed abdominal cavity with the help of a forceps, after the animal had completely or partially come out of the anesthetic, moderate pressure caused each time an unmistakable—at the same time active—reaction. We met in this relation no single exception. If the abdomen was opened through the analgesic action of local infiltration, and immediately moderate pressure made upon an intestine loop by means of a forceps introduced into the cavity, it showed in each case a distinct unmistakable reaction without a single exception. In these, as in other cases, was especial care exercised to avoid pulling on the mesentery or rubbing the parietal peritoneum. Moreover, in these cases was it frequently observed that pulling on the mesentery or rubbing the parietal peritoneum caused less pain than pressure upon the intestine.

"When a small loop of intestine was carefully drawn out of the cavity by means of a thread and pressure made upon it, we were each time able to demonstrate a positive painful reaction, but this, as a rule, was always less than when the intestine was tested within the cavity. On the other hand, there was not a single case in which the sensibility was not absent for a longer or shorter time, or at least materially lessened if the entire abdominal contents or a large part of them were drawn out of the cavity through a large incision. As a rule, the diminution of sensibility began after two or three minutes free exposure. At the same time with the depression of the intestinal sensibility the animal developed a general apathy. The restlessness and movements of the animal, noticeable before the cavity was widely opened, ceased suddenly, and the animal sank into a condition of deep apathy after the symptoms incident to the evisceration had ceased.

The animal lay without making a sound, with wide open eyes and more or less prompt lid reflex. This condition was frequently accompanied by a more or less pronounced depression of the cutaneous sensibility. As a rule the blood-pressure first rose, but soon fell back to its original point; it was never less than before the delivery of the intestines, providing that their exposure and the condition of apathy was not continued too long. The respiration was frequently rather slow and sometimes of a Cheyne-Stokes type. The pulse was often rapid, yet only temporarily; it would soon slow down and remain at the normal frequency. When the eventration was quickly done the loss of sensibility of the intestines was clearly marked, yet even when slowly and gradually done a distinct loss of sensibility always followed; if the eventration itself clearly caused pain or it was produced through quickly replacing the organs in the cavity, this loss of sensibility both within and out of the cavity was hastened and seemed to be more pronounced. On the other hand, evisceration seemed to reduce the sensibility much less if ether had been given for a short time.

"It was manifested that the general condition of the animal played an influence in the development of this condition of loss of sensibility. In strong, sound, lusty animals, as well as in those which in general reacted quickly to irritation, this loss of sensibility appeared less quickly, was less marked, and disappeared quicker than in weak dogs. The duration of this condition lasted longest if the animal was placed in a warm salt bath, and lasted perhaps still longer if a bath of Ringer's solution was used; often, however, the sensibility did not return and the animal passed into a condition of veritable shock, with rapid pulse and falling blood-pressure. But this condition during the relatively short duration of our experiment never led to the death of the animal; each one had to be specially killed.

"If the animal was not placed in a water bath, and the intestines were exposed to moist or dry air, the sensibility of the intestines returned sooner or later, though only rarely, to the original degree, except those parts which clearly showed inflammation. On these the sensibility frequently exceeded the sensibility of the normal conditions. The return of the sensibility was completed when all the intestines were returned to the abdominal cavity, the wound closed, and the animal covered and a sufficiently long period of rest allowed. If after this a single loop was withdrawn for testing, it was frequently found to have returned to the normal degree of sensibility.

"As a rule, the animal did not recover from the general condition of apathy before the return of the intestinal sensibility. As long as the intestines remained out of the cavity and appeared insensible to irritation the condition of general apathy continued. After the reposition of the intestines and closure of the abdominal cavity the animal usually remained completely quiet for a while, but later became restless and began to whine. If now a short loop of intestine was tested, it showed that the sensibility had already returned.

"In certain cases when, for example, a part of the intestines was inflamed, it appeared to be even hyperesthetic, although the animal in general still appeared indifferent. But here there existed an apparent difference between strong naturally sensitive animals and weak quiet ones. The former showed less deep apathy, and came out of this state earlier than the latter.

"These are, in general, the facts from which we arrived at the conclusions from our experiments. It can briefly be stated that the abdominal organs of the dog, without exception, are distinctly sensitive to pain as long as they remain in the closed abdomen. Extensive laparotomy, on the other hand, a free exposure of the abdominal organs influence to a high degree their sensibility, frequently to such a degree as to lose all sensibility, and this either temporarily or permanently."

"**Old Experiences in a New Light.**—In the last-named condition is no doubt to be found an explanation of the contradictions in the statements of earlier investigators. In the field of the sensibility of the abdominal organs almost all investigations were carried out after free opening of the abdominal cavity, thereby depriving the sensitive intestines of the protection which the closed abdomen afforded. The results could, therefore, differ according to different conditions.

"They may be differently manifested according to the individual differences in the sensitiveness and state of health of the animal; according to the time after the incision in which the observation was made, or according to the treatment to which the free exposed organs have been subjected; the variations may yet correspond to many other factors. We take, for example, one of our experiments in which the intestines were brought forward, and we can easily understand how three or four different observers, who would make examinations in the different states, would arrive at different conclusions. One observer would perhaps examine them immediately after their delivery and would find pronounced sensibility; the other would decide to wait 'until the animal was quiet,' and is then not in a condition to be sensitive. The third would wait perhaps somewhat longer before testing the sensibility, and would then confirm the return of sensibility to a moderate degree. And still somewhat later, after a part of the intestine had been sufficiently exposed to have become clearly inflamed, a fourth observer would find a condition of hypersensibility.

"**Inhibition of the Sensibility Produced by Laparotomy.**—The lessening or complete loss of sensibility can occur either through a depression of the power of perception of the peripheral endings of afferent nerves in the abdominal organs or through inhibition of their central endings. In other words, the inhibitory effect can either be of a peripheral or central nature, when, after the loss of intestinal sensation, there is a more or less marked depression of the cutaneous sensibility, it is evident that at least in this way laparotomy may exercise a central inhibitory influence. It is, therefore, very probable that the loss of intestinal sensibility is essentially of central origin.

"In conclusion, we can therefore say that extensive opening of the abdominal cavity, manipulation of the intestines, eventration, etc., exercises a profound inhibitory influence on the motor and sensory mechanism of the intestinal tract, whereby the wave of inhibition spreads within the central nervous system to other sensitive and sensory mechanisms."

"**General Information.**—Along with the statement that the abdominal organs are innervated with sensory fibers, the above statements also convey other information which is of general significance. For examinations of processes in organs that are lying in serous cavities in surgery, as well as in experimental physiology, the simplest method seems to be to open the cavity and thus directly to inspect the organ. The above-mentioned facts teach, on the contrary, that the opening as such considerably influences the motility as well as the sensory process, and what one sees are not the normal but the considerably altered conditions of the internal organs. For the investigation of a noise in a closed room it is not always the best method to look for the cause through the open door; the opening of the door often will suddenly stop the noise; here, as well as in biology, one often arrives at the best result by observing the process through the keyhole.

"Before we conclude this part, we will again especially emphasize, that the general condition of the animal is an essential factor in influencing the sensibility through laparotomy. The weaker the animal the greater the influence, so that in quite depressed animals the simple opening of the abdomen not only leads to a pronounced depression of the sensibility of the abdominal organs, but may even be followed by veritable shock."

"**Conclusions.**—The abdominal organs of the dog, examined through a small opening in the otherwise closed abdominal cavity, are undoubtedly sensitive to pain, and are also sensitive outside of the cavity, if only a small loop is brought out and tested immediately after its exposure. Inflammation undoubtedly increases the sensitiveness of the abdominal organs of the dog. If all the intestines or a greater part are eventrated or otherwise freely exposed, there appears a more or less marked depression of the sensibility, which is more complete the weaker the animal is; at the same time the animal becomes more or less markedly apathetic with lessening of the cutaneous sensibility. Laparotomy also depresses the motor activity of the gastro-intestinal canal. This motor and sensory depression is a reflex inhibition of central nature, and can also extend to other centers.

"In weak animals and in prolonged procedures this inhibition may extend to the vital centers in the medulla oblongata, and may often lead to fatal shock.

"It also appears that the peripheral mechanism in the intestinal canal may also be inhibited to a certain degree. It is evident, also, that the intestines of cats and rabbits possess sensory nerves, but they are easily exhausted and are very early and strongly influenced by laparotomy; the intestines are affected much quicker and more profoundly than the mesentery. The surgical experience on the human subject does not at all prove that the intestines normally in the normal closed abdomen possess no pain-conducting fibers. Until exact proofs are brought forward that the sensory innervation of the human abdominal organs differs radically from that of other animals it will have to be assumed that as with animals, so also with man, the abdominal organs are provided with special nerve-fibers, and that the sensation of these organs can be increased by inflammation as we see it in animals.

"This theory explains in a simple way the well-known occurrence of all kinds of violent pain in the human abdomen."

After reading the preceding, one is almost forced to conviction of these views were it not for the daily repeated observations at the operating-table upon the human subject, when it becomes self-evident that they cannot be unreservedly accepted for the human body without further observations, and we realize that on this perplexing subject the last word has not yet been spoken.

It is very probable that in the highly organized human body conditions of sensibility differ from those found to exist in the animal in accordance with the well-known law that the higher we ascend in the animal scale the more highly organized, complex, and sensitive becomes the nervous system. The fact that moderate doses of cocain, 1 to 3 cg., is sufficient to abolish all intra-abdominal sensation in dogs, and that large doses are capable of producing general anesthesia in man, must be taken into consideration in arriving at any conclusions regarding intra-abdominal sensations during operations upon man under local anesthesia, where it is also possible that the acuteness of the sensibility of these parts may be somewhat lessened; also the fact, demonstrated by Kast and Meltzer, that free exposure of the abdominal contents inhibits or completely abolishes all local as well as general sensibility; the fact that such exposure if prolonged leads to shock has been recognized in man, but observations on the sensibility, either local or general, long before shock appeared had not been reported; it is, however, well known that during shock all painful sensations are either greatly lessened or entirely abolished. The "apathetic state" reported by Kast and Meltzer, even without any fall of blood-pressure, must be recognized as a condition which immediately precedes shock, as indicated by the blood-pressure.

The question of the lessened intra-abdominal sensibility through the use of cocain or its substitutes, and the depression of sensibility through exposure of the abdominal organs in man, must now remain an open question until proved by further observation on the human subject made with this end in view.

In considering some of the above questions in the light of information already obtained from operations performed on man, it has been proved that the existence of adhesions between movable intestinal coils does not excite pain as a symptom; other disturbances may arise, but when adhesions have existed between the intestine and the abdominal wall pain has always been complained of. In operating upon such cases under local anesthesia, the separation of the adhesions between the several loops of intestines, no noteworthy complaint is made by the patient provided the mesentery is not pulled upon, but in separating adhesion between the intestines and the abdominal wall pain is always complained of.

If a finger is introduced into the abdominal cavity and firm pressure made against the parietal peritoneum no pain is produced, as the parietal peritoneum is insensitive to pressure, but by sliding the finger about over the surface, traction is made on the delicate and sensitive subperitoneal tissue and pain produced. In this way Lennander believes that the pain of some forms of colic not explained by pulling on the mesentery may be accounted for. The gradual and general distention occurring in ascites, large tumors, pregnancy, etc., may not cause pain, but the unequal distention and violent peristalsis of a small loop may, by a sliding motion on the parietal peritoneum, excite acute pain.

The withdrawal of packs and drainage-tubes from between coils of intestines excites very little pain, provided the mesentery is not pulled on, in comparison to the pain produced by removing them when in contact with the abdominal wall. In operations under local anesthesia the careful, gentle application of packs around the field and in contact with the parietal peritoneum does not excite any complaint, but when being removed if they are roughly dragged out the patient will always give unmistakable evidence of decided pain.

Investigations under similar conditions to those employed by Kast and Meltzer have been undertaken by Müller, but he did not obtain the same results; also by Hotz, but here the observations were made under morphin narcosis, and are, consequently, not of the same value; however, he states that irritations of violent kinds, even in inflamed conditions, do not excite pain unless the mesentery is pulled upon.

Ritter, on the other hand, tried similar experiments, and was able to completely confirm Kast's and Meltzer's findings and oppose those of Lennander. In 1909 he brought forth an entirely new theory. He believes that the sympathetic nerves are capable of the transmission of painful impressions, but associates such sensation directly with the blood-supply, and found that the more vascular parts were the more sensitive, the non-vascular, less so; the vessels themselves are most sensitive, and in every instance were painful when ligated. He thinks that this means of testing the sensibility of these parts is the only one that eliminates all possibility of error. Pulling upon the mesentery was eliminated by a series of double ligatures; in placing these, if the proximal was tied first it alone caused pain, the application of the distal one being painless; but if the distal one was tied first, then both caused pain. He found that cocain injected around the blood-vessels renders anesthetic the viscera supplied by them, and thinks that injury to the vessels is important in the production of shock, and advises that when working under local anesthesia all vessels of any size should be cocainized before ligation and division.

He does not think that the cocain used in performing laparotomy has had so much to do with the negative findings of many surgeons as the inhibition of sensation brought about by the exposure of the delicate nerve-fibers in the abdominal cavity.

These later findings by Ritter have attracted the favorable attention of some observers; further investigations may prove their value, but we must bear in mind two points: first, that cutting off the blood-supply always lessens the sensibility of the parts; second, that the sympathetic nerves (if they have been proved to contain pain-conducting fibers) are largely distributed upon the blood-vessels, and the ligation of these vessels may completely block their power of conduction.

In another publication Ritter has stated that the free exposure of the intestines in non-anesthetized patients, as well as pinching them with forceps, causes pain. Mitchell reports 2 cases and Haim 1 case operated without narcosis and without cocain, and they state that the lack of sensibility of the intestines was similar to that observed in similar operations under cocain. Two of these cases had carcinoma of the stomach and the third an irreducible hernia. While these examinations were more to the point, the cases must have been very ill to have been operated without any form of anesthesia, and this condition must have had some effect in shocking or inhibiting the sensibility; however, the number is too small from which to draw any definite conclusions. Nystroem, a former assistant of Lennander, in a recent paper champions the theories of his former chief, and questions the value of experimentation upon animals in settling these points, and calls attention to the widely different results obtained by different investigators in the same experiment. He tried the same experiments carried on by Kast and Meltzer, and obtained exactly opposite results, and could excite no pain unless the mesentery was pulled upon or the parietal peritoneum irritated. He then experimented upon a case of hernia in a man: the abdomen was first opened by a small incision under ether narcosis, the peritoneum was then temporarily closed, and the patient allowed to recover. The parietal peritoneum was then tested and found very sensitive, but the irritation of a loop of intestine which was found presenting at the opening gave no evidence of sensation until the mesentery was pulled upon. From these and other observations Nystroem concludes that the contradiction of Lennander's work is not to be unhesitatingly accepted. While he admits the existence of many points which cannot be satisfactorily explained by these views at present, it is wise to withhold judgment until further observations can be made.

Kast and Meltzer, in discussing the opposing views given by some of the above-mentioned investigators, state the following:

"Now we will try to solve the question on the ground of our experimental experiences. In dogs we have almost, without exception, confirmed the sensibility of the abdominal organs; we have found that by the free exposure of the intestines their sensibility is reduced and that this reduction is more pronounced the weaker the operated animal. We have further found that in cats and rabbits the abdominal contents are sensitive, but that in these animals the opening of the abdomen exercises a much stronger influence upon the sensibility than with dogs, and that often a single exposure and irritation suffices to suspend reaction. The sensibility of the intestines is yet more fleeting than that of the mesentery, and with rabbits more fleeting than with cats. How does it stand now with the sensibility of the abdominal organs of man? Here we have essentially the principal question in view: Do the abdominal organs of man possess pain-conducting fibers?

"This has been positively denied by competent surgeons. If one, however, considers how such a denial involves theoretically and practically very important assumptions, and if one considers still further how such an assumption must now appear even more important, since it establishes a radical difference in the innervation between man and other mammals, it is, therefore, clear that such a statement can only be accepted when based on exact proofs. But are there such exact proofs? We have first the large number of observations which have been made under cocain anesthesia, but we have proved that a cocain injection, even without touching the intestine, is able to temporarily abolish this sensibility. The surgeons who have not sufficiently investigated it doubt this statement. But it is a certain fact, and it has also, as above mentioned, been recently confirmed by Ritter. Here one must consider that to reply to our question in the affirmative it is not at all necessary to assume that the sensibility must be intense.

"It may appear in man after opening the abdomen as weak as we have found it in cats and rabbits, and the small doses of cocain which are ordinarily used may, therefore, completely suffice to suspend this slight sensibility. Also the surgical observations which have been made with the use of cocain are absolutely not such convincing proofs. May the few recent observations which have been made without the use of cocain in these cases be accepted as such positive proof? Certainly not. Again, have we seen that other observations speak for the contrary that the human intestines have painful sensations. We must further mention that the above-cited three negative observations were made upon very sick patients, and here we must remember our experimental experiences that the weaker the animal the more profoundly was the sensibility reduced by laparotomy; and yet, again, may we add that as regards the sensibility of the abdominal organs of man after laparotomy they may behave as in cats and rabbits.

"To recapitulate, the observations which were made under the use of cocain are on account of the cocain not of proportionate value. The observations which were made without cocain are quite small in number, are not without contradiction, and were made on very weak patients. Moreover, laparotomy depresses the sensibility considerably, and in quite weakened animals, also in several kinds of animals in rather normal condition, was the sensibility completely suspended. The surgical observations contain, therefore, not only no kind of positive proof, but contain in general no proof at all that the abdominal organs of the normal man in the normal closed abdomen are unable to feel painful sensations.

"As we have no proof to offer, we are justified in accepting that the visceral innervation of normal man in the normal closed abdomen does not differ essentially from that of other mammals, and that the abdominal organs are more or less richly provided with pain-conducting nerve-fibers. We are further justified in accepting that as with animals, so also with man, a marked inflammation strongly increases the sensibility.

"Based on the above assumptions, the most widely different intense pain that the human in his normal closed abdomen often has to bear find their simple explanation, and do not need any interpretation by forced hypothesis."

Investigations have been undertaken with a view of determining the sensibility of the mucous membrane at various points along the alimentary canal, and, while the results of these investigations agree on nearly all points, there are still some dissenting opinions. These tests were made through gastric and intestinal fistula or artificial ani, or by passing instruments into the stomach through a stomach-tube, or into the rectum through a speculum; the results of these examinations have been that the mucous membrane of these parts has no sense of touch, pain, heat, or cold. In 1909 Zimmerman published the results of an extensive series of experiments upon himself and on patients. These experiments were principally upon the stomach and rectum, and were performed without any anesthesia; the mucous membrane of these parts was irritated in a variety of ways—by pinching with forceps, by electrodes, and by the cautery. In the stomach there was no response to any form of irritation, but decided pressure gave rise to a sense of fulness. In the rectum, 6 cm. above the external sphincter, there was no sense of any kind except for pressure and differences in pressure could be noted.

The esophagus was sensitive to both heat, cold, and pressure. Regarding these experiments upon the rectum, the author has tested the sensibility of the rectal mucosa and found that above the anal canal there is practically no sense of pain to superficial irritation, and the mucous membrane can be cut and cauterized without any complaint. On one occasion a polypus was removed by cutting, with cauterization of its attachments, with an electrode without any complaint from the patient, although this region felt sore for several days afterward. Schwenkenbecker in 1908 described his sensations after taking large doses of menthol, which produced on the sensitive mucous membrane of the mouth an intense feeling somewhat between burning and cold. After the drug had passed the level of the larynx there was no sensation until the anal canal was reached, when the feeling of cold was again produced. He concludes from this observation that the mucous membrane of the alimentary canal is insensitive except at its upper and lower ends.

We know that certain affections of the stomach, notably ulcer, give rise to pain, although they may exist for long periods of time without the patient's knowledge, and intestinal ulcers may go on to perforation without the patient having been aware of their existence; similarly, the ulcers of typhoid fever seem to excite no pain. Lennander maintains that a gastric ulcer excites no pain unless accompanied by a lymphangitis, and that hyperacidity excites pain when the irritating or chemical substances are carried by the lymphatics to the sensitive abdominal wall (posteriorly). Mueller, in discussing this point, admits that the stomach shows no reaction to touch, cold, or heat, as far as external stimulation is concerned, but asserts that it does react to certain internal irritations. He believes that the abdominal organs do possess certain sensations necessary for protection from toxic or chemically irritating substances, and are capable of mechanical irritation by overdistention. The sensations thus produced he attributes to the sympathetic nerves, which, under ordinary normal conditions, do not transmit painful impressions, but become capable of feeling pain under the irritation of abnormal or diseased conditions. When all the evidence, pro and con, regarding the sensibility of the abdominal organs has been gathered and carefully sifted down, we have to admit that the crucial test must be the application of these findings by the practical surgeon at the operating-table upon the human subject, and here, so far, Lennander's views have largely been substantiated. In the experience of the writer the intestines are devoid of sensation unless the mesentery is pulled upon; after extensive manipulations the patient may complain of a peculiar visceral sense, hardly a pain, but at times sufficient to excite some complaint. We have frequently explored limited parts of the abdominal cavity by introduction of the fingers or hand, and when carefully done, avoiding friction on the parietal peritoneum, it caused no complaint, except in the region of the foramen of Winslow over the celiac plexus; here the parts seem particularly sensitive. The parietal peritoneum and mesentery have always been found sensitive, except when controlled by the injections of the anesthetic solutions; it is certain that only those parts controlled by the injections would stand operation; that the solution used may have had some controlling or lessening effect upon the sensibility of other parts may be possible, but we have never observed the general analgesia, such as that reported by Kast and Meltzer upon dogs, when using cocain or any other local anesthetic agent, and any extension of the incisions to the recognized sensitive parts, if unanesthetized, has always excited pain and required additional infiltration. In some few very extensive intra-abdominal operations undertaken with local anesthesia, where large quantities of the anesthetic solution were used and large parts of the intestines and other organs exposed, the prolongation of the operation, instead of lessening the sensibility, seemed rather to increase it.

In numerous operations for artificial anus where a loop of bowel, usually the descending colon, has been fixed outside the abdominal wall, either under local or general anesthesia, and opened several days later without any form of anesthesia, I can remember no case where any complaint was made. This opening was made either with knife, scissors, or cautery, and later, after retraction had taken place, the excess of tissue was trimmed down level with the abdominal wall. Whether the long exposure and changes occurring on the surface of the bowel was sufficient to destroy the sensibility of the part or not is possible, but it is certain that these cases have not, as a rule, required any form of anesthesia for the opening of the bowel. The same may be said about the stomach in operations for gastrostomy, as in the Ssabanajew-Frank operation, where the stomach is opened a few days later, after adhesions have taken place.

A careful study of the preceding pages should prove particularly interesting to the practical surgeon who attempts to deal with intra-abdominal conditions under local anesthesia. Nowhere better than in the abdominal cavity is the fact demonstrated that the skilful use of local anesthesia is in itself an art. What one operator does with ease seems to another impossible, and he may even discredit the statements of the other. Here, in addition to a thorough knowledge of technic, it is absolutely essential to possess an accurate knowledge of the manipulations which cause pain, the parts most susceptible of painful impressions, and the conditions which intensify these impressions, such as inflammation.

We all agree that certain of the intra-abdominal contents possess painful sensations; these are especially all blood-vessels except the smallest divisions (and this rule holds good elsewhere in the body), and the mesenteries and attachments of the viscera to the abdominal wall. As the blood-vessels almost invariably lie within the folds of the mesentery, this limits the areas of sensibility under ordinary conditions (the absence of inflammation) to the mesentery and the parietal peritoneum. I have never found that incision, clamping, or suture of the stomach, large or small intestines, gall-bladder, or uterus upon which I have operated ever gave pain, providing the surrounding parts were not disturbed by rough manipulations that would make traction upon the mesentery, and when it was necessary to include the mesentery in the field of operation, as in resections, a moderate injection of anesthetic solution between its folds and at some distance proximal to the field always sufficed to control these sensations, providing there was no traction.

It is essential for these reasons that rather free incisions be made to permit the ready manipulation of the parts as much within the cavity as possible and render unnecessary undue traction and displacement.

We should now, for a thorough understanding of our subject, be able to account for the pain-conducting nerve-fibers within the cavity.

We know that all the abdominal organs are innervated almost exclusively by the sympathetic system, and that all the sympathetic ganglia as they lie against the vertebral column, both within the abdomen and above, receive fibers from the spinal nerves just after emerging from the vertebral foramina (Figs. 73–75). It has been impossible to trace these nerve-fibers to their ultimate distribution—most are soon lost in the intermingling of nerve-fibers of that region, some few have been traced to the mesentery, but could not be followed further, as it is impossible by any known methods to distinguish between sensory and other nerve-fibers. As all painful impressions must come through the cerebrospinal nerves, it is in fibers supplied by these communicating branches that we must look for the paths of these sensations.

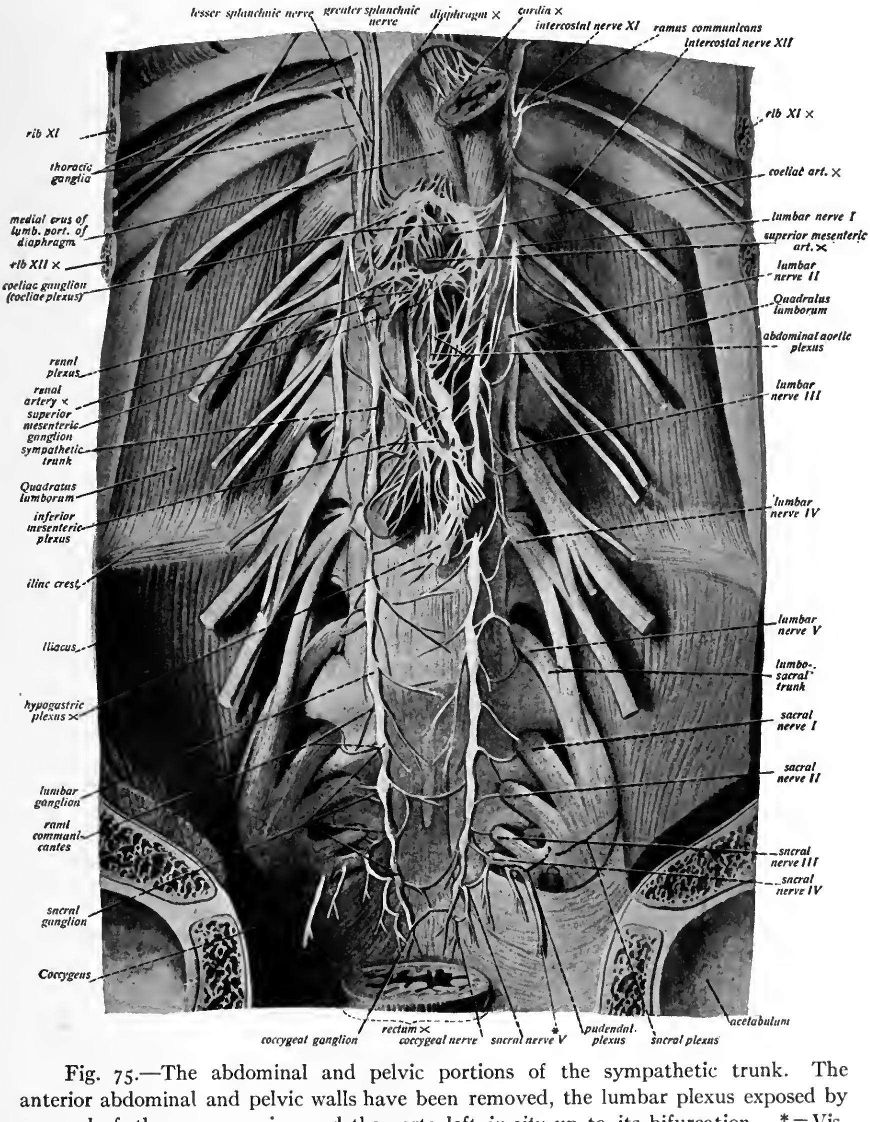


Fig. 75.—The abdominal and pelvic portions of the sympathetic trunk. The anterior abdominal and pelvic walls have been removed, the lumbar plexus exposed by removal of the psoas major, and the aorta left *in situ* up to its bifurcation. * = Visceral branches of the pudendal plexus. (Sobotta and McMurrich.)

An effort has more recently been made to reach these rami communicantes, and at the same time block the parent trunk by reaching these nerves just as they emerge from the vertebral foramina; thus, by a paravertebral injection (by one injection) securing both visceral as well as parietal anesthesia of the entire distribution of the nerve. This method is spoken of more in detail under this heading.

As a general proposition, it may be said that in operations upon any intra-abdominal part a thorough infiltration of the abdominal wall in the line of incision is the first essential feature. Should the operation be upon the fundus of a part or at some distance from its mesenteric attachment, no further anesthesia may be required, but should the field of operation involve the cervix, hilum, or mesenteric attachment of the part, these must be thoroughly blocked. These principles, when properly applied to the various parts, are the essentials of the anesthetizing process.

Braun, in infiltrating the abdominal wall preparatory to its incision, makes the injection around the field in more or less rhombus shape. This is best illustrated by making an injection around the middle line—we will say, for an operation upon the stomach. A line of cutaneous anesthesia is established on each side two or three fingers-breadth from the middle line; starting on this line at two or more points, depending upon the extent of the proposed incision, the long needle is entered and directed obliquely outward, injecting as it is advanced, piercing the rectus sheath, which is recognized by its slight resistance to the needle, and advancing some little distance within this muscle until it is quite freely injected; the needle is then partially withdrawn, when it is advanced again in two or more directions above and below, slightly increasing the angle each time, thus making the injection in something of a fan-like shape; this is done along the line of cutaneous anesthesia at two or more points, having the fan-like areas of infiltration come in contact with the one above or below. The same procedure is repeated on the opposite side. These two lateral lines of infiltration are joined above and below by subcutaneous infiltration, as shown in Fig. 76.

While the above method of Braun is certainly found useful in thin subjects, in thick abdominal walls heavily overlaid with fat it is unsatisfactory, takes longer to carry out, and requires some little delay before the solution has thoroughly diffused in all directions and anesthesia established. I usually prefer to establish a wall of anesthesia along the proposed line of incision from the skin to the peritoneum, and have not found that muscular contractions interfere if anesthesia has been perfect, and no pain excited either in the incision or operation on the deeper parts, the muscles usually being quite relaxed. The method of procedure is usually as follows: An intradermal wheal is established midway along the line of the proposed incision; the long needle with 10 c.c. syringe is entered at this point and directed up and then down, without withdrawing the needle, along the proposed line of incision in the subcutaneous tissues, injecting freely as the needle is advanced, detaching and refilling the syringe as occasion requires; without withdrawing the needle from the skin its direction is now changed, and it is passed inward toward the rectal sheath; this is the first plane of decided resistance which the needle encounters; this is gently pierced, injecting as the needle is advanced

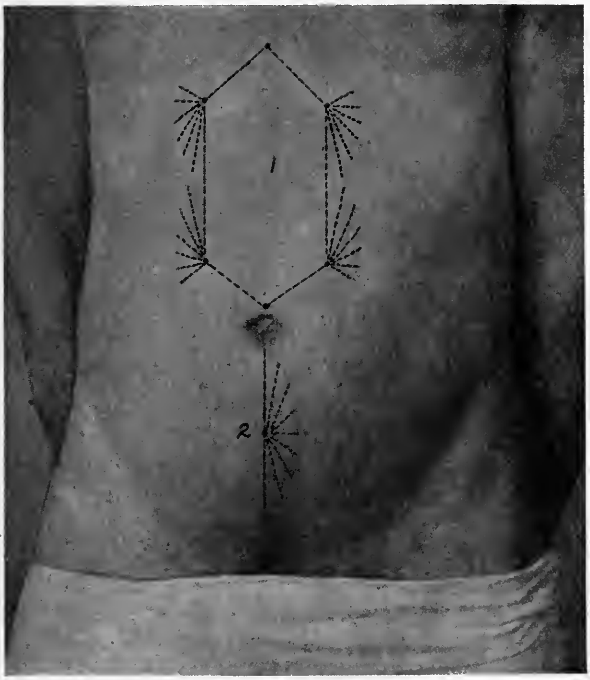


Fig. 76.—1, Braun's method of anesthetizing abdominal wall around area of incision; 2, author's method: infiltration of line of incision from one midpoint.

to about 1 cm. within the sheath; the needle is then partially withdrawn and redirected within the sheath at several points above and below in a similar manner (Fig. 76). Returning now to the skin, the intradermal infiltration is completed along the proposed line of incision. The deeper injections thus made first have ample time to diffuse. Having completed the skin infiltration, the incision is made down to the rectus sheath without need of further delay; with the rectal sheath now within plain view, further injections can be made within it if necessary. At this point the superficial vessels are ligated, getting rid of the forceps, and allowing the deeper injections more time to diffuse during this interval. The rectal sheath is now slit up and the muscle-fibers separated, exposing the posterior sheath; this is now penetrated at several points with the needle and freely infiltrated posteriorly in the retroperitoneal tissue, this last injection freely diffusing to the peritoneum; the posterior sheath and peritoneum are now opened.

This method I have found to be highly satisfactory and quickly executed, and employ it almost invariably for incisions through any part of the abdominal walls.

The solution usually preferred for these incisions, as well as for all work within the cavity, is No. 2 (0.50 per cent. novocain in 0.04 per cent. NaCl), adding about 10 drops of adrenalin to every 3 or 4 ounces of the solution used.

The nerve-supply of the abdominal walls is given in the chapter on Hernia.

POSSIBLE SCOPE OF OPERATIONS WITHIN THE ABDOMEN

All simple operations, such as gastrostomy, gastrotomy, colostomy, appendectomy, and gall-bladder drainage, are quite satisfactorily performed on suitable subjects (when not too nervous or apprehensive) when the parts are fairly easily accessible, and not matted down by inflammation or adhesions to the parietal peritoneum or surrounding organs; consequently, only such operations should be undertaken when it is known beforehand that favorable conditions exist. A fairly satisfactory exploration can be done under local anesthesia by making a free incision to permit the easy introduction of the hand, when, if it is gently insinuated without pressure or traction, a rather thorough examination of the entire cavity can be made. The sensations experienced by a patient during a carefully made examination of this kind is that of a vague intra-abdominal sensation, variously described as a weight or fulness, becoming cramp-like if traction or pressure is exerted.

It may often be found satisfactory to make such an exploration under local means, then resorting to a light general anesthesia if conditions are met with which cannot be easily undertaken by local means alone.

Local anesthesia is not the method for routine work within the abdomen, although in the interest of the patient many of the more serious operations may be undertaken by these methods alone; here it should always be borne in mind that no traction upon a viscus is ever tolerated.

If, on exploring through a midline incision, an appendix or diseased gall-bladder is encountered, separate incisions should be made over these parts rather than attempt to displace them toward the midline.

Many conditions of the patient may contra-indicate general anesthesia; it may then be advisable to attempt the more serious and complicated procedures when the indications are urgent. Very ill patients, and those suffering from the toxic effect of disease, often have their general sensibility so reduced that they make favorable subjects, provided they are not dangerously weakened or the field of operation is not actively involved in inflammation; even in some greatly weakened and reduced patients the danger of a general anesthesia may be greater than the difficulties likely to be encountered with local anesthesia; it may, therefore, be advisable to proceed by these methods. In some cases the combined method of operating is advisable, using infiltration with light or superficial narcosis (see chapter on this subject). In all intra-abdominal operations of any severity the preliminary hypodermic of morphin, $\frac{1}{6}$ to $\frac{1}{4}$ gr. with scopolamin $\frac{1}{150}$ to $\frac{1}{100}$ gr., should always be given one hour before operation.

The Stomach.—Simple operations upon the anterior wall of the stomach when uncomplicated are quite easily performed under local anesthesia by infiltration of the entire abdominal wall and subperitoneal tissue in the line of the proposed incision, as already explained, making the incisions slightly longer than under a general anesthetic; the cavity is opened, the wound lightly retracted, and the stomach operated upon in position, or the viscus caught with a sponge-holder or the fingers and gently drawn out; if care is exercised not to pull upon its attachments, no pain is produced. In this way we have operated in many cases, and always with perfect satisfaction. It is quite easy to perform gastrotomy for the removal of foreign bodies or the examination of the interior of the stomach; also gastrostomy by the Ssabanajew-Frank or other methods, or the Heinecke-Mikulicz operation for hour-glass contraction, when unaccompanied by surrounding complicating conditions.

Gastro-enterostomy and gastric resections are now no longer novelties under local anesthesia. The early and extensive work done by Mikulicz, and later by Braun, Läwen, Bakes, and a host of others, especially Finsterer with his classic contributions upon this subject, have placed this method of operating upon a firmly established foundation, and secures for it a recognition among other accepted procedures.

In posterior gastro-enterostomy by the "no-loop method," the operation now generally performed, the posterior stomach wall is as tolerant of operative intervention without discomfort as is the anterior; to secure access to it the mesocolon, in the usually selected non-vascular area, is first freely infiltrated between its layers before it is divided and the stomach seized. In drawing the omentum and transverse colon out of the field and displacing it above, as is usually done, they

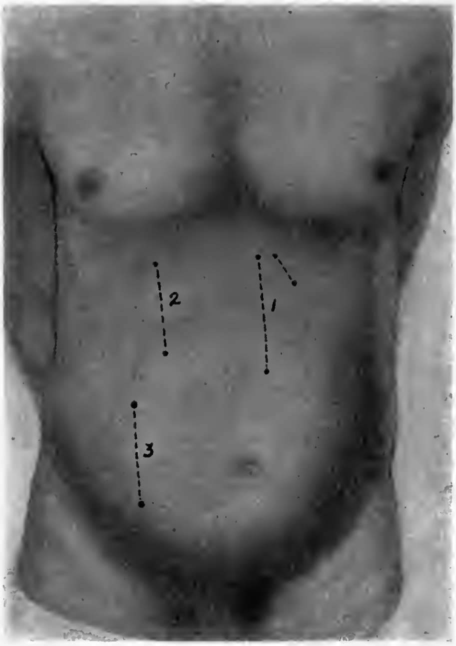


Fig. 77.—1, Line of anesthesia for exposing stomach. Upper oblique line is for additional incision for Ssabanajew-Frank gastrostomy; 2, for exposure of gall-bladder; 3, appendectomy through straight rectus incision.

should be carefully covered with wet towels (saline solution), as their prolonged contact with the air may excite some complaint. After infiltration of the mesocolon no further infiltration is necessary, and the various steps of the operation are carried out the same as under a general anesthetic.

For gastric resections the gastrocolic and lesser omentums must be freely infiltrated between their folds for an area some little distance beyond the proposed field of resection; this should not be undertaken by local anesthesia alone, except under conditions of free mobility of the stomach.

Finsterer, in his latest contribution to this subject in the "Beiträge zur Klin. Chir.," 1912, cites in detail a large number of resections and gastro-enterostomies performed by purely local means. The notable differences observed between such operations and similar ones performed under general anesthesia was the marked absence from shock, lung, and renal complications, and almost a total absence of postoperative vomiting and gastric distention, viscious circle, etc., as there is not that paralysis of the stomach walls which follow such operations under general anesthesia.

In **colostomy** for the establishment of an artificial anus the same may be said here as for the stomach—the operation is quite easy and satisfactory where the mesentery is not pulled upon. The later opening of the bowel after a day or two, when adhesions have taken place, we have never found accompanied by any pain; the excess of tissue can be trimmed down level with the abdominal wall by either knife, scissors, or cautery.

The Appendix.—The opening of a simple appendicular abscess when in contact with the abdominal wall involves no greater difficulties than an abscess situated elsewhere, and is always suitable for operations under local anesthesia. The removal of the appendix is a different matter; in the presence of inflammation or extensive adhesions the operation is never suitable for local measures alone; again, we never know where the appendix will be found, whether lying loose on the intestines in its usual position, bound down to the surrounding structures, attached in the pelvis, embedded in the posterior abdominal wall or retrocecal. The ease with which the appendix can be removed in non-inflammatory cases depends entirely upon its position; when lying loose and easily accessible we have quite frequently removed it without any difficulties or pain to the patient, but always infiltrate lightly the meso-appendix, as its ligation will cause pain, taking care not to enter a vein in making the injection; when lying in other less accessible positions, by sufficiently enlarging the abdominal incision to permit free access, it can be fairly satisfactorily separated from other attachments, when not too extensive, by lightly infiltrating these lines of attachment with the anesthetic solution. On one occasion the author removed, with but very moderate discomfort to the patient, a retrocolic appendix by infiltration of the attachments of the cecum and colon to the abdominal wall as well as the retrocolic space, then divided these attachments and rolled the colon inward. Similar methods of procedure can be resorted to elsewhere.

Gall-bladder.—Operations upon the fundus of the gall-bladder for purposes of drainage in cholecystitis, or for the removal of stones, are quite easily and painlessly performed when the bladder is fairly accessible and not contracted or bound down by adhesions.

As traction will cause pain this should be carefully avoided; scooping out stones or passing in forceps to extract them if cautiously done will excite no complaint. Where stones are found in the cystic or common duct, or the bladder small and contracted or badly adherent, the case is hardly suitable for local anesthesia alone.

The Liver.—Operations upon the right lobe for abscess are best operated by the transthoracic route, which has been described in operations upon the thorax. Abscesses of the left lobe are quite easily operated over their most prominent points; in these cases the liver is usually already adherent to the abdominal wall, and a simple incision under infiltration is all that is necessary; when it is not adherent, it is first secured by sutures through its capsule before opening; this is not, as a rule, painful, but should complaint be made light infiltration of the capsule will be sufficient to control it.

Intestines.—Resection of the bowel has been done satisfactorily under local anesthesia. In typhoid perforation Dr. Harvey Cushing reviews 5 cases, and notes their decidedly favorable postoperative condition when compared with such cases (perforation or suspected perforation) operated on with a general anesthesia, and comes to the following conclusions:

"In consideration of the inevitable fatality of intestinal perforation in typhoid fever, and in the face of extreme difficulties of diagnosis which often attend this complication in its early, and from the surgical standpoint its elective, stage, it can be understood that a prompt exploration, could it be unattended by risk, would be most desirable. From the discussion and reports of these cases it would appear that in certain surroundings such an exploration under local anesthesia can be satisfactorily accomplished painlessly and without exposing the patient to danger."

Dr. Mitchell, in discussing the same condition, has the following to say: "The danger is practically eliminated by the use of local anesthesia, and at the same time the necessity for a hurried operation is practically done away with. The knowledge that a cocain exploration is without danger must lead one to explore, without hesitation, many cases where a positive diagnosis would be demanded before subjecting these patients to a general narcosis. Typhoid patients, as a rule, are ideal subjects for local anesthesia."

It will be seen after a study of the above that the clinical test on the human subject agrees rather with the findings of Lennander than with those of the animal experimenters, but without discrediting the value of the latter. What effect in man the anesthetic solution, infiltrated in the abdominal wall, has upon the sensibility of the intra-abdominal organs through its central action must indeed be very slight, if any, and, at least for the present, has not been demonstrated in man. It will also be seen from the range of operations mentioned that the abdominal cavity is in many ways a free field for exploration under local anesthesia, which is often limited as much by skill, dexterity, and gentleness of the operator as well as by the fundamental principles and limitations already laid down.

Lipectomy.—This operation is quite easily, quickly, and satisfactorily performed under local anesthesia. The procedure, however, is more often done as a final step following laparotomy, hernia, or other abdominal operations performed under general anesthesia. Many stout people seek relief for excessive abdominal fat who are in apparently good health, but to whom one may hesitate to administer a general anesthetic owing to their excessive obesity; in these the operation is particularly inviting under local anesthesia, and becomes more so in the presence of any organic lesion.

The length of the incision and mass of tissue to be removed may, in the minds of the uninitiated, preclude the possibility of its being satisfactorily done under purely local methods; this, however, is not the case.

The procedure should be undertaken as follows: Select any point along the proposed line of incision, and with the small hypodermic syringe produce an intradermal wheal, using solution No. 1 (0.25 per cent. novocain with 2 or 3 drops of adrenalin to the ounce) then with the large 10 c.c. syringe and long fine needle enter at this point, directing it subcutaneously along the line of the proposed incision, injecting the solution as the needle is advanced; another introdermal wheal is now made, just over the point where the long needle stopped; the long needle is inserted at this point and continued as before (Fig. 78). The above is repeated until the entire circumference of the mass to be removed has been infiltrated along the proposed line of incision. (See illustrations in chapter on Principles of Technic; also Hackenbuch, Plan of Anesthesia, same chapter.) Having completed the above the long needle is now directed down into the depths of the mass, at almost right angles to the surface, through the line of infiltration, and the depths of the mass freely infiltrated, inserting the needle at intervals of every few inches. Fat itself has no sensation, but many nerves come through the mass on their way to the skin, and these should be blocked by this deep infiltration. As the fatty layers are divided these nerves can often be seen in the glistening mass before they are cut, and should receive additional injections if any question exists regarding the thoroughness of the infiltration.

These nerves often accompany blood-vessels, which aids in their more ready recognition. Blood-vessels, except the smallest, when unaccompanied by demonstrable nerves should also be blocked, as nerve-fibers exist in their sheaths and walls.

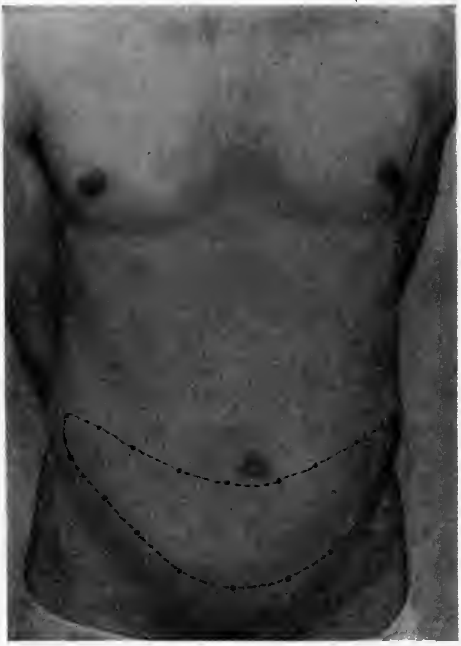


Fig. 78.—Line of cutaneous anesthesia and points for making deep injections down to abdominal muscles for lipectomy.

Large amounts of solution are often needed for the removal of the fatty masses, and for this reason the content of adrenalin should be somewhat reduced from that usually employed for smaller operations, 2 or 3 drops to the ounce being sufficient.

The possibility of such low-grade tissue as fat suppurating following its infiltration, as in the above operation, has been advanced by some as an objection to its use; this, however, I have not found to be the case in my hands.

The following case illustrates the possibilities in this direction:

Mrs. L., rather short, middle-aged woman, weighing 285 pounds, with cardiac and renal lesions. For many years the abdominal fat had been accumulating, until for some time prior to operation a large fatty fold hung from the abdomen over the pubes, producing an unsightly appearance, seriously interfering with her movements and comfort. She had long sought relief, but being an unfavorable surgical subject had been refused operation.

She was operated on June 16, 1913, by the method outlined above and a mass of fat, weighing 13½ pounds, 29 inches long and 14 inches wide by 4½ inches thick, was removed. One quart of 0.25 per cent. novocain solution being required for the procedure no pain or shock was experienced by the patient. Recovery, except for some gastro-intestinal disturbance, was free from incident, the wound healing very satisfactorily. Specimen shown in Fig. 79.

As a final proposition, it may be stated that where the intra-abdominal condition presents inflammation with adhesions that a resort may be had to the paravertebral method of anesthesia discussed under

Fig. 79.—Fatty mass: weight, 13½ pounds, 29 inches long, 14 inches wide, and 4½ inches thick, removed under local anesthesia.

this heading; or, where it is desirable to lessen or reduce to a minimum the general anesthetic, the abdomen can first be opened by local anesthesia, determining just what is to be done, when resort may then be had to light general anesthesia, combining infiltration of the region operated upon to block all afferent nerves preventing shock or other reflexes, as discussed in the chapter on Anoci-association.

Many procedures not discussed in these pages may be carried out by an application of the principles laid down in the general remarks on this subject.

CHAPTER XVIII

HERNIA

"One of the most notable benefits that surgery has derived from the introduction of cocain has been the successful local anesthesia of the hernial regions, notably the inguinal region.

"One of the earliest applications of local anesthesia by the use of cocain for the relief of strangulated hernia was made by an American surgeon (Hewlett, 1887). Since that time the reports from German, French, Italian, and American clinics have so steadily increased that it would be difficult to even mention the names of the operators without the risk of serious omission.

"It would be difficult to trace the history of cocain to its first application in the radical cure of hernia, but it is evident that many operators in this country and Europe began to resort to this mode of practice even in the early days of cocain technic. Reclus, in his book on 'Cocain in Surgery' (1895), describes his method of infiltration (with 1 per cent. solution) for the cure of hernia, which he has performed as a typical procedure many times. Ceci, of Pisa, in a contribution ('Semaine Medicale,' Paris, as early as 1899, vol. xix, p. 41), states that by combining the statistics of his clinics in Genoa and Pisa (1885–1899) he had collected 543 radical operations for hernia, of which 363 were anesthetized with cocain alone. Ceci made use of a 5 per cent. cocain prepared with 3 per cent. boric acid solution. He believed in deep infiltrations, including the hypoderm and the subaponeurotic layers in his primary injections, without reference to a separate analgesia of individual nerves of the region. The large number of personal observations reported by Ceci alone indicate that, up to 1899, great success had already been attained in the radical cure of hernia by the earlier methods of direct local infiltration" (Matas).

Since these early days these contributions have been too numerous to mention, and the performance of this operation under local anesthesia is now no longer a novelty.

The value of the neuroregional method had not been tested in this operation until 1897, and it remained for Dr. Harvey Cushing, of Johns Hopkins University (Prof. Halsted's Clinic), to do so.

And again, in 1900, in the "Annals of Surgery," he thoroughly discusses this method, which has been tried and accepted the world over by all who resort to local anesthesia for this operation.

INGUINAL HERNIA

There is probably no commonly performed major operation that is more inviting to local or regional methods of anesthesia than inguinal herniotomy. This is so on account of the superficial position of the parts, the anatomic arrangement, and the course and distribution of the nerves involved.

Such operations under local methods require a thorough knowledge of anatomy; often a more accurate knowledge than is required for the same operations under general anesthesia. It, above all, makes of us nerve anatomists, and forces us to respect and preserve from injury all nerves encountered. While during the operation we are principally concerned with the sensory functions of the nerves, we must not lose sight of the fact that most nerves are motor and trophic, as well as sensory.

Division of an important nerve may be followed by muscular atony and relaxation of the parts, and, in the case of herniotomy, be followed by a recurrence of the trouble or an unpleasant sagging of the scrotum in case the cremaster muscle is paralyzed by division of the genital branch of the genitocrural, or a possible atrophy of the testicle. Of course, such injuries should not occur in the hands of careful operators even under general anesthesia, but under local anesthesia there are greater precautions taken, as we are forced to recognize and respect each individual nerve.

One of the many advantages of local over general anesthesia, as mentioned elsewhere, is particularly emphasized here in the absence of vomiting; these efforts, if prolonged or severe, may compromise the results of the operation by loosening sutures and favor a recurrence of the trouble. This is particularly likely to be the case in large or complicated herniæ, where often extensive plastic resections are necessary to secure a satisfactory closure. For this, if for no other reason, should the local method be preferred, and I believe that a comparison of statistics will show a lesser percentage of recurrences following closure in this way.

The size of the hernia is no contra-indication for this method, nor is the age of the patient, providing he is enjoying fairly good health; in fact, old age is particularly favorable to all local anesthetic procedures. Many of these old subjects may be refused operation by general anesthesia, when they can be safely and easily operated upon by this method. It is advisable that these old patients should be put to bed for a day or two before operation to see how they stand confinement, and to enable them to learn to empty their bladder and bowels in the recumbent position.

Another important consideration which applies to all cases, but more particularly to the aged, is that nutrition is not interfered with, as there is no disturbance of the gastro-intestinal tract. A light meal is always preferred just before operation, but nourishment should be restricted to liquids after operation, excluding milk for the first day or two. If the subject is very feeble, stimulating drinks, such as coffee, toddy, or hot tea, can be administered during the progress of the operation. By handling feeble and aged subjects in this way—by local anesthesia—many can be safely carried through an operation for hernia without any operative or postoperative disturbance whatever, who would most probably succumb, if not to the operation, at least to the necessary postoperative disturbances following general anesthesia.

Nerves.—There are three nerves with which we are principally concerned in inguinal hernia—the iliohypogastric, ilio-inguinal, and genitocrural.

The skin over this region receives branches from several of the surrounding nerves, especially the last dorsal, but, as it is infiltrated directly, these do not especially interest us (Figs. 80, 81).

The *iliohypogastric nerve* perforates the transversalis muscle at its posterior part, near the crest of the ilium, and gives off its iliac branch, which descends; the hypogastric branch continues forward between the transversalis and internal oblique, perforating the internal oblique just above and a little to the outer side of the internal ring. It then runs transversely inward toward the middle line on the surface of the internal oblique, and just above and a little to the outer side of the external ring pierces the aponeurosis of the external oblique, and is distributed to the skin of the hypogastric region.

The *ilio-inguinal nerve* appears in the field after perforating the internal oblique at or near the internal ring and descends along the lower part of the inguinal canal; it terminates by distributing fibers to the side of the scrotum and thigh. This nerve is not constant, and occasionally is found joined to the genital branch of the genitocrural to form the external spermatic nerve.

The *genitocrural nerve*, its genital branch, appears at the internal ring and passes down the back part of the spermatic cord into the

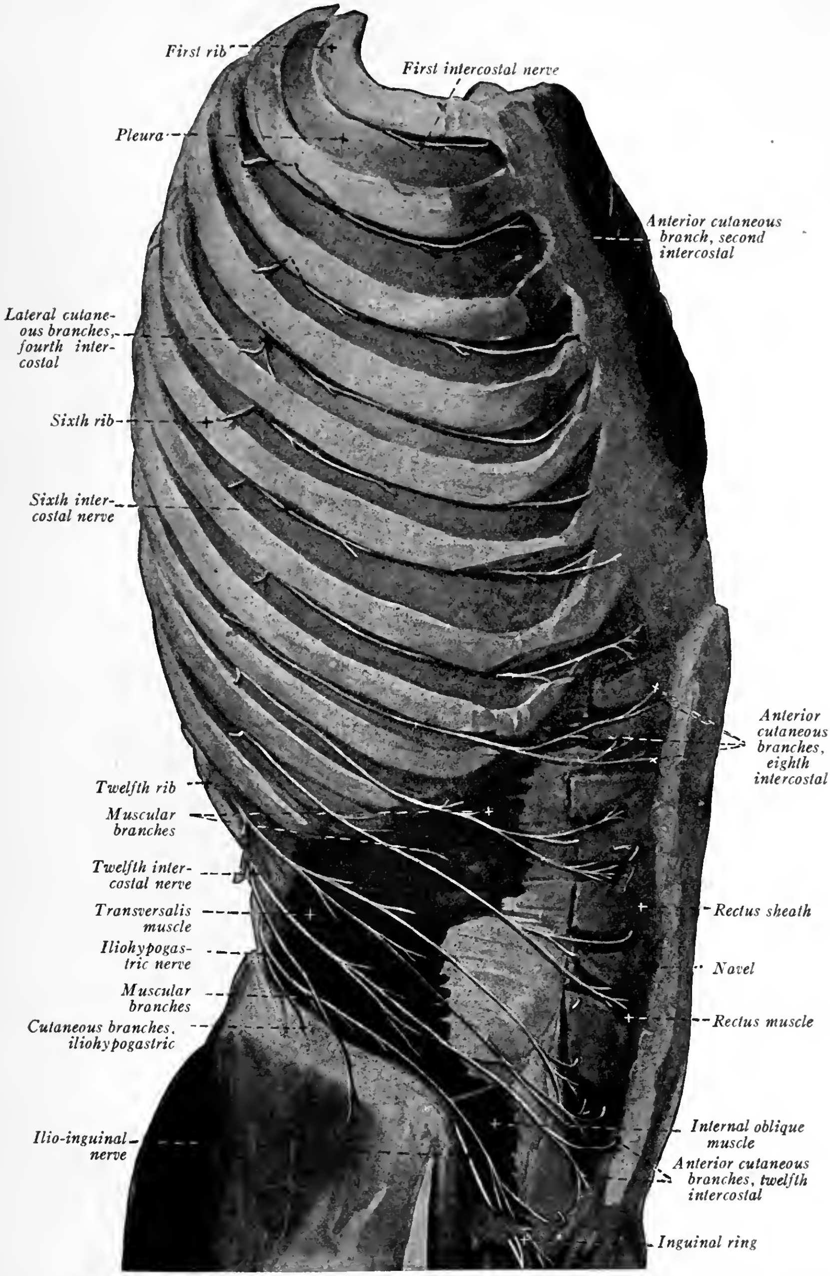


Fig. 80.—Course and distribution of the intercostal nerves. (After Spalteholz.) The intercostal and oblique abdominal muscles are removed. (From Braun.)

scrotum, where it supplies the cremaster muscle, testicle, and other contents of the scrotum. The skin of the scrotum receives fibers from the inferior pudendal branch of the small sciatic and from the superficial perineal branch of the pudic, in addition to the ilio-inguinal nerve already mentioned.

It will be seen from a study of the above that after the skin is passed all nerves entering the field emerge at or near the internal ring, and it is consequently here that we inject most of our solutions.

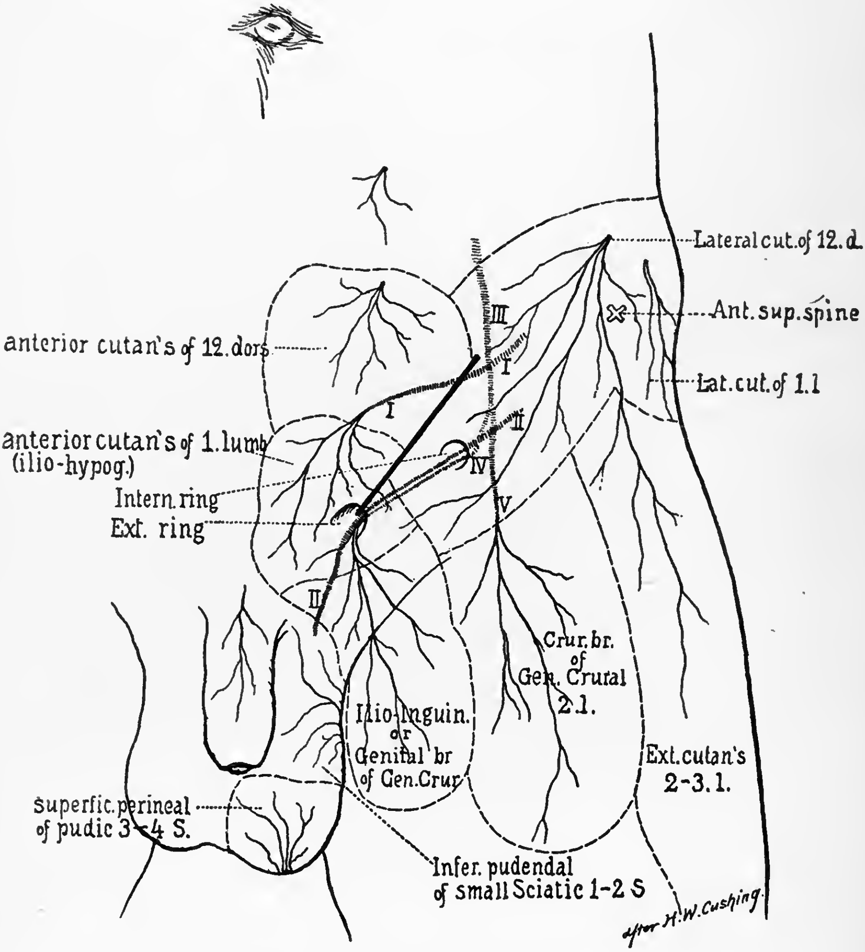


Fig. 81—Sites for local anesthesia in the inguinal region. (After Cushing.)

Preparation for the Operation.—Preliminary hypodermic or morphin, $\frac{1}{6}$ gr., with scopolamin, $\frac{1}{150}$ gr., one hour beforehand.

Four ounces of solution No. 1 (novocain, 0.25 per cent.; sodium chlorid, 0.04 per cent.), to which add 15 drops of adrenalin solution (1 : 1000). If the hernia is very large, it is well to have on hand more than the 4 ounces. Small hernias may not require this much, but it is well to have an ample supply.

Two small hypodermic syringes and one large 10 c.c. syringe, with long fine needles, or a Matas' infiltration apparatus—all well tested beforehand to be sure they are in good working order.

Some operators prefer to inject the cases about fifteen minutes to one-half hour beforehand, and allow them to wait for the solution to diffuse and become fixed in the tissues. This practice, while advisable elsewhere, we do not find necessary here, and proceed at once with the operation. Also some prefer to use a 1 per cent. novocain

Fig. 82.—Long needle passed through intradermal station to reach position of iliohypogastric nerve beneath tendon of external oblique.

solution to infiltrate the nerves as they are encountered, but, as all the nerves concerned are very small, it is unnecessary to use any but the ordinary infiltration solution (No. 1).

Begin the injection with the small hypodermic syringe at the highest point of the proposed incision, at the upper and outer part of the field, about 1½ inches internal and slightly below the anterior spine of ilium. Make the injection intradermally. With the large syringe and long needle enter at this point, directing the needle downward to the subcutaneous tissues (Fig. 82), and inject about ½ ounce in this position; another ½ ounce is injected subcutaneously along the proposed line of incision by advancing the needle in this direction (Fig. 83), injecting as the needle is advanced. If the patient is very stout and there is much subcutaneous fatty tissue, more than this may be needed, but in the ordinary case the above is sufficient.

While we are waiting for these subcutaneous injections to diffuse, the infiltration of the skin is finished by starting at the already injected point on the skin, proceeding downward and inward intradermally the full length of the proposed incision. After this had been done, the incision can be made at once and carried down to the aponeurosis of the external oblique. Expose this freely over the site of the internal ring, and with the large syringe inject about ½ ounce of solution just under the aponeurosis at this point. Now, while waiting for this to

Fig. 83.—Needle is partially withdrawn from position shown in Fig. 81 and directed subcutaneously toward pubes.

act, here secure and tie any superficial vessels that may be necessary, and expose the rest of the field by gauze dissection. Then, slit up the aponeurosis of the external oblique to above the internal ring, retract, and you bring into view the iliohypogastric nerve. This has probably already been anesthetized by the last injection, but if there is any doubt it can be injected intraneurally or perineurally with the small hypodermic syringe.

Retract upward the internal oblique and transversalis to better expose the internal ring. If the ilio-inguinal nerve is seen on the lower side of the cord (Fig. 84), infiltrate it at once high up; if not seen, inject circumferentially around the neck of the cord several small syringefuls of solution. This will permit it to be freely handled and the ilio-inguinal and genitocrural nerves looked for—the ilio-inguinal on the lower side of the cord and the genitocrural behind. If any trouble is encountered in finding them, and it is likely that the cord or scrotal contents will be handled, then a free infiltration of about $\frac{1}{2}$ oz. around the neck of the cord will suffice and will reach both nerves involved. If such an injection is made, care should be exercised not to enter any veins. It is, of course, far preferable to locate the nerves. The sac is now picked up and opened and any contents replaced in the cavity. If they are adherent, their separation does not cause pain.

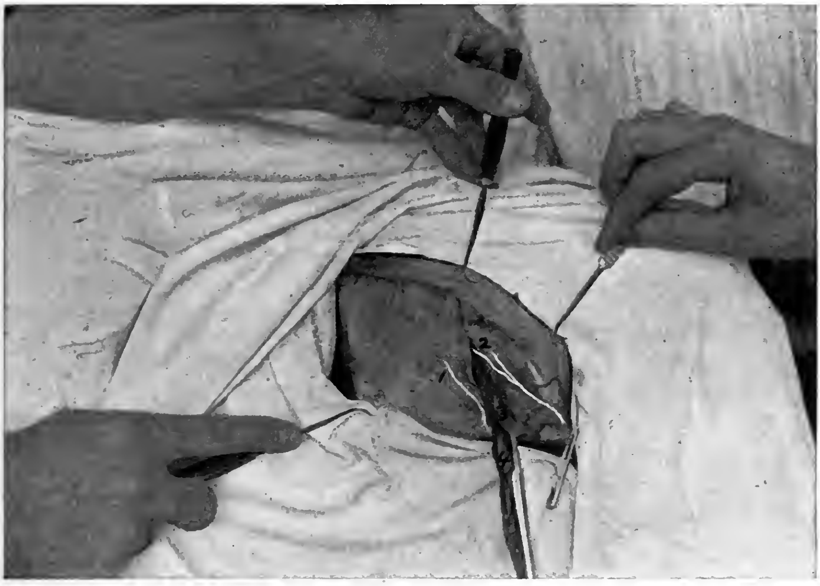


Fig. 84.—1, Iliohypogastric nerve; 2, ilio-inguinal nerve; 3, spermatic cord; 4, hernial sac dissected free. The genitocrural nerve is not seen, as it lies within the cord on its posterior aspect.

Omentum may be resected, if necessary, without pain.[1] A finger is now passed into the cavity through the neck of the sac, and two or three small hypodermics of the solution distributed subperitoneally around the neck, either from within the sac or by passing the needle down around it from the outside (Figs. 85, 86). The sac can now be dealt with by any method preferred—if small, excised; if large and adherent, it can be divided, slit up, and left *in situ*, to be eventually absorbed, or it may be entirely removed.

[1] Any large vessels encountered in extensive resections of the omentum should be blocked, as these are sensitive; otherwise the omentum has no sensation.

Fig. 85.—Method of making injections around neck of sac, with finger within sac.

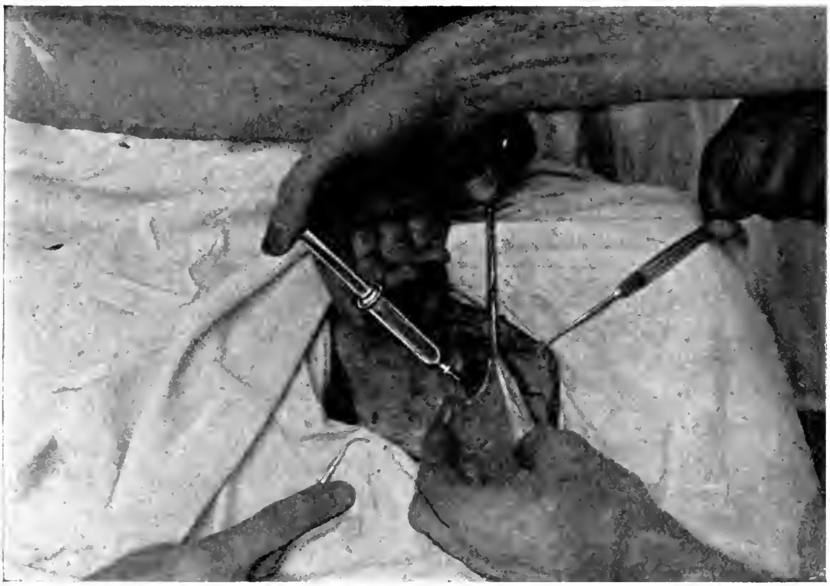


Fig. 86 —Method of making subperitoneal injections around neck of sac. Sac slit up and held open and injected from within.

An existing varicocele or any other complication should be dealt with now and requires no further infiltration. The testicle may also be exposed and handled if necessary. It should be borne in mind, however, that any undue traction upon the cord by pulling upon the parts within the cavity will cause pain, but none is otherwise experienced. The neck of the sac can now be closed—by crushing, if large, and ligated; or sutured, if preferred.

The operation usually performed by Professor Matas and his staff is the Ferguson-Andrews. Here the cord is not disturbed, and consequently may require less preliminary injection, as it is left in its bed and all structures sutured over it, the aponeurosis of the external oblique being overlapped. However, the operation can now be completed by any of the accepted methods—the Bassini or any of its modifications.

If the above technic is followed absolutely no pain should be felt by the patient; where pain is inflicted the technic is at fault. In the hands of a skilful operator an ordinary hernia can be closed by using not over 3 oz. of solution (we often use much less), and the time consumed is not over five or ten minutes longer than would have been required with general anesthesia.

The following histories may prove interesting:

Flood, aged seventy-five, Ward 9, an old and feeble man. Entered the service for the removal of epithelioma of right temporal region, and while convalescing from the operation, which was done with local anesthesia, a large inguinal hernia of the left side, of fifteen years' duration, became incarcerated and irreducible. He was operated on June 26, 1908, by the method described above, and was discharged cured in two weeks, with no recurrence since. This was a particularly satisfactory case, in view of the extreme feebleness of the patient.

Pear, aged sixty-four (Fig. 87). Left inguinal hernia of thirty-four years' duration with enormous sac, extending to near the knee. The contents of the sac had not been reduced for years; the photograph gives a good idea of the condition. The inguinal ring was large enough to admit three fingers. In view of marked arteriosclerosis, with renal and cardiac lesions, the operation was performed by the above-mentioned method on August 27, 1908. A large part of the omentum was adherent to the sac and much thickened and had to be resected. A portion of the rectus muscle was transplanted to close the inguinal opening. Some of the redundant skin of the parts was resected. The operation was entirely painless, with union by first intention, and the patient was up in two weeks. This case was a bad hernia and a severe test of the method, and clearly demonstrated its usefulness and feasibility in these cases. I have recently seen the case, and he had remained well, with no sign of recurrence.

In case the hernial ring is very large, it may be necessary to loosen the internal oblique and transversalis from the edge of the rectus so as to enable the conjoined tendon to be brought down; in case this is necessary, and the dissection be carried very high, some additional infiltration at this point may be needed, and should be made directly into the tissues to be dissected.

In the event that the hernia sac contains a large amount of intra-abdominal contents that cannot be replaced before operation, this can often be done, after the sac is freely exposed and liberated and the internal ring enlarged, by taking the sac up in the hands and resorting to manipulation. If the contents are not readily replaced do not open the sac too freely at once, as the too long exposure of a large length of bowel may cause unpleasant intra-abdominal discomfort and some complaint on the part of the patient, but make a small slit near the neck of the sac and explore its contents with the finger. The contents of these large hernia sacs are, as a rule, mostly omentum,

Fig. 87.—Large irreducible hernia operated on by author under local anesthesia. Sac contained omentum and intestines; large part of omentum was resected.

with a small loop of bowel. If much bowel is encountered, it can be replaced in this way usually without much difficulty, unless adherent. If the omentum is found hard and fibrous from its long sojourn in the sac it will require resection, but, unless badly damaged, it should not be sacrificed, as it is an organ of many valuable functions.

The exposure of the omentum never gives rise to any discomfort, and its resection causes no complaint, as it has no sensation; but large vessels within it are sensitive, and should first be blocked before ligation or division.

In the case of very large herniæ, where it is necessary to carry the skin incision well down over the scrotum, the skin must be infiltrated all the way.

In strangulated hernia, general anesthesia is contra-indicated, and should rarely, if ever, be used. In very severe and prostrated cases the general anesthetic may add sufficient additional depression to cause a fatal issue. The sac should here be exposed and opened under infiltration. If the patient is very weak a radical operation should not be attempted at the time, but the bowel, if gangrenous, opened and drainage permitted. It will here frequently be found that the bowel is adherent around the ring and the general cavity walled off. If this is not the case, a few sutures and packing can be resorted to to close off the cavity and the bowel at once opened. The improvement permitted by this procedure revives the patient and, after all gangrenous material has come away, the ends of the bowel can be approximated by the Murphy button or suture.

We then wait for good union to take place and the wound to become clean and covered with healthy granulation, when it can be closed with a small drain. The following case illustrates this type:

Mr. S., aged seventy-two. Had had a large inguinal hernia since he was seventeen. It had frequently become incarcerated, but he was always able to reduce it until a few days prior to my seeing him, when it again became incarcerated and all efforts at reduction failed, strangulation following. Patient was very feeble, pulse almost imperceptible, temperature subnormal with cold extremities, and almost constant stercoraceous vomiting. Under local anesthesia the sac was opened. The bowel and fat attached to it were found gangrenous, with a large quantity of foul fluid in the sac. The neck of the sac was securely protected with sutures, packs, and rubber tissue, the gangrenous fat cut away, and the loop of bowel opened at the distal end. The patient revived at once, all vomiting ceasing, next day was in a rolling chair on the gallery, and in a few days was sitting up.

Nourishment had been at once resumed, and his improvement was noticeable daily. In ten days the bowel was closed by suture, and two weeks later the wound, now being quite healthy, closure under local anesthesia was performed. The bowel, freed from the old sac, dropped back into the cavity, the wound enlarged until the anatomy became apparent, and the parts then closed with two rubber-tissue drains, one within the cavity and one subcutaneously. The Fowler position was used for twenty four hours, then discontinued, and the drain removed in three or four days. Recovery was without incident, the patient being discharged about three weeks later. This illustrates a type of case which, I believe, if handled any other way would have resulted fatally.

Reclus very justly refers to operations for strangulated hernia as "the triumph of cocain." In strangulation it is the anesthetic of election, and it is only in special conditions, such as in herniæ of unusually large size, with eventration of the abdominal contents and when extensive adhesions exist, that he would prefer a general anesthetic. In advanced strangulations, with vomiting of intestinal contents, the dangers of septic pneumonia and secondary renal complications from chloroform and ether are specially to be feared, and more particularly in the aged. Then, again, colostomy for strangulation is an urgent operation which, in country practice, frequently compels the surgeon to depend upon unskilled assistants. Under these circumstances the value of a local anesthetic entirely under the control of the operator becomes especially apparent. It is not surprising, therefore, that Mehler enthusiastically asserts that he who has tried local anesthesia in these conditions will never feel inclined to return to general anesthesia, unless compelled to by pressure of unusual circumstances.

FEMORAL HERNIA

This hernia, except in very fat people, is easily operated upon with local anesthesia, and is best suited to the infiltration method. Regional anesthesia cannot be employed, as the nerve-supply is from

Fig. 88.—Line of cutaneous anesthesia for femoral hernia.

many sources and reaches the field from several directions, all being small branches. This method of procedure will likely vary, according as to whether or not the patient is stout or thin, and whether the hernial sac can be readily defined from the surrounding tissues.

In stout persons or in poorly defined sacs an incision had best be made in the long axis of the tumor, infiltrating layer after layer, and cutting as we go (Fig. 88). After the sac has been reached and defined the tissues at its sides and neck can be infiltrated, care being taken to locate and avoid the femoral vein which lies just to its outer side, and, on account of the sac rising forward, often a little behind. In case the patient is thin and the sac well defined a more satisfactory plan can be followed by making a circumferential injection around the sac subcutaneously; or, as recommended in umbilical hernia, the sac can be opened early in the operation and a finger passed down within, which is used as a guide to the needle which is passed down along the outer wall infiltrating the tissues as far as the neck.

First anesthetize a point in the skin near the edge of the sac with a small hypodermic syringe. If the Matas infiltration apparatus with a curved needle is convenient, it will be found very useful here; if not, the large syringe with a long needle will answer. The advantage here of the Matas apparatus with the curved needle is that the entire circumference of the sac, unless very large, can be reached and infiltrated from a single point of puncture of the skin; if a straight needle is used several punctures will have to be made.

First advance the needle closely under the skin, then through the deeper subcutaneous tissues in all directions around the sac on the outer side, taking care not to penetrate beneath the fascia lata for fear of injuring the femoral vein, but on the inner side a much greater depth can be penetrated without fear of injury.

It may be necessary to avoid the saphenous vein at the lower portion. The precaution mentioned elsewhere, when injecting in the neighborhood of large veins, should here be observed, of injecting only when the needle is being advanced or withdrawn, and never when the point is stationary, as a vein may be entered and a large quantity of the solution thrown directly into the circulation. If a vein should be pierced with a fine needle no serious consequences will result.

The injection by the above method is made very quickly, and all nerves entering the field from any direction are bathed in the solution and anesthetized. It is unnecessary to inject the skin along the proposed line of incision if a few minutes' delay is permitted for the solution to diffuse. This plan of Lennander, of waiting fifteen to twenty minutes after the injection, is of advantage here. But in case it is desirable to proceed at once, and the skin in the middle line is not anesthetic, it can be infiltrated intradermally and the incision made at once, as the deeper parts will be found well anesthetized.

Before opening the hernial sac it should be observed whether or not it is the bladder, which is very common in these herniæ, and may be opened in looking for the peritoneal investment.

The neck of the sac is freed and Gimbernat's ligament divided, when reduction is usually easy. Closure can then be accomplished by any recognized method, after first anesthetizing the neck of the sac.

The solution used here is the same as for inguinal hernia (No. 1, novocain, 0.25 per cent.; sodium chlorid, 0.04 per cent; and adrenalin, 10 to 15 drops).

UMBILICAL HERNIA

In very fat individuals with large herniæ and many adhesions and tense abdominal walls this operation may be difficult under local

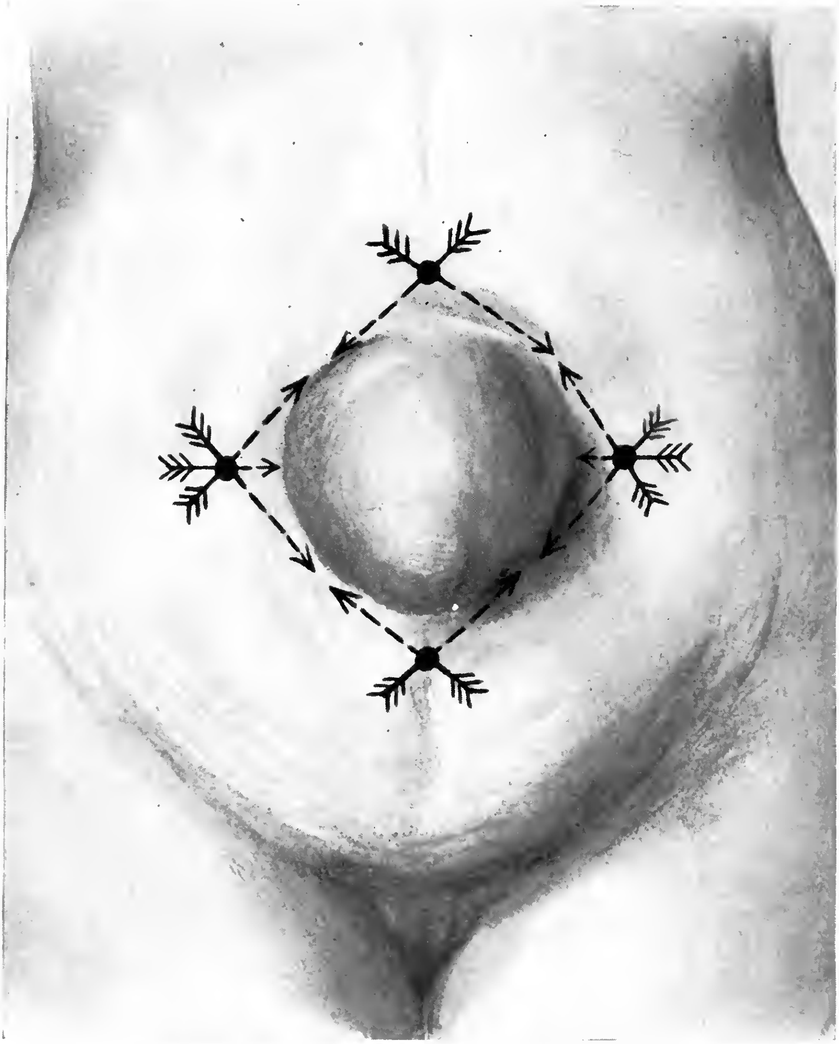


Fig. 89.—Method of injection around umbilical hernia. (From Braun.)

anesthesia, nevertheless it can be performed; but in thin or moderately stout patients, unless the condition is very severe, it can be quite satisfactorily performed.

In all these operations the mechanical difficulties are very much lessened by putting the patient to bed for a few days, on restricted diet, with daily laxatives. This relaxes the abdominal walls and relieves the intra-abdominal tension, and approximation of the gap can be much more easily obtained.

With Solution No. 1 several stations in the skin are anesthetized; if the hernia is small, one on each side; if large, one above and one below, in the median line, in addition (Figs. 89, 90). By entering at these points (Matas' infiltration apparatus or large syringe with long needle) and passing the needle in all directions, a circumferential injection is made into all the subcutaneous tissues, thus creating a zone

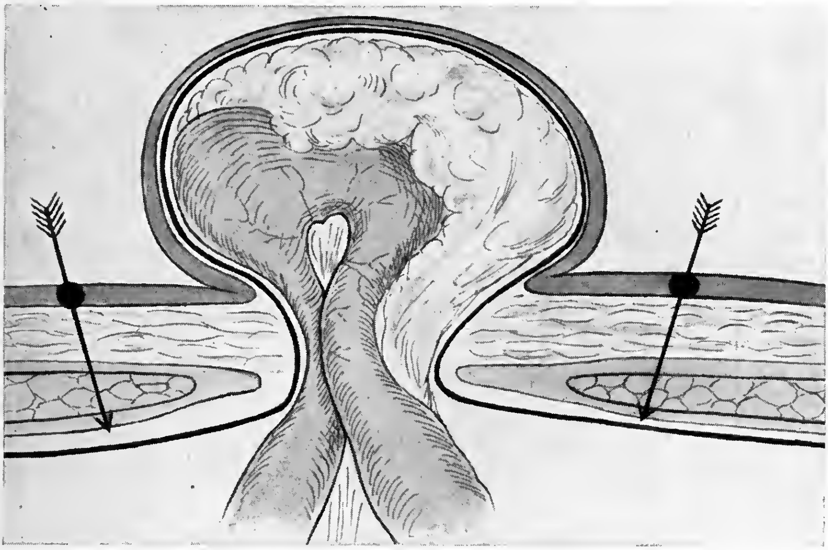


Fig. 90.—Cross-section through umbilical hernia, showing method of making deep injections through abdominal walls. (From Braun.)

of anesthesia. If the underlying muscles are clearly outlined, and there is no danger of going through them, these may be infiltrated at the same time; otherwise this had better be delayed until they are exposed. After a delay of from ten to fifteen minutes, to allow the solution time to diffuse, the incision can be made. First, expose the muscles and thoroughly infiltrate them down to the peritoneum, if this has not already been done. While we are waiting for the last injection to diffuse, bleeding points can be ligated and the sac opened and its contents dealt with. By now the parietal peritoneum will probably have become anesthetized, and the sac can be cut away around the margin of the gap; if the peritoneum is still sensitive, a long needle is passed through the opening into the subperitoneal tissue and a moderate injection made in all directions. There will then be no further sensation.

In dealing with the contents of the sac omental adhesions cause no trouble, and can be separated or divided without sensation. If the intestines are adherent any very extensive manipulation may give rise to cramps, but this can be avoided by infiltrating with a fine needle the points of adhesion, care being taken not to enter the bowel.

In closing these herniæ the Mayo operation of overlapping is usually considered the best, and can here be easily done.

It may often be found advisable to open the sac early in the operation after the circumferential injection and pass a finger down through the ring; this is held under the edge of the muscle while the long needle is passed down from without through the tissues, injecting the several planes as it is advanced until it reaches the tissues just above the palpating finger within the cavity. In this way the injection of the entire field is made before the operation is well advanced without danger of injuring the bowel by penetrating through the abdominal walls, and will often be found the more preferable method of handling these cases. The same procedure is used in postoperative herniæ.

POSTOPERATIVE HERNIA

In selecting these herniæ for operation by local anesthesia one should be guided by the same general observations made regarding umbilical hernia. In some of these cases the gap in the muscle wall is considerable, often ragged and irregular, and difficult to close by general anesthesia. Under local anesthesia these difficulties are not increased, but often lessened, as you do not have the straining so often encountered under general anesthesia. The patient can also better take a position favorable to relaxation of the muscles, but particularly valuable afterward is the absence of vomiting, which if severe or protracted may often jeopardize the results of the work. It is here often highly valuable to have the patient remain perfectly quiet after operation, as he is able to do following the use of local anesthesia. These remarks apply equally to all herniæ.

One difficulty encountered in postoperative herniæ is the large amount of fibrous tissue encountered, which mats all the structures together, but if a zone of anesthesia is created just outside of the area no special difficulties are encountered.

Herniæ in the midline should be dealt with the same as umbilical herniæ, by a complete circumferential injection around the gap, thus sequestering all nerve-endings within the area.

Herniæ just to either side of the midline will also require a circumferential injection, as the nerve-fibers from the other side lap over the midline some little distance; but where the hernia is some distance removed, as is the case of those resulting from appendicular operations, a circumferential injection is not necessary. As all the nerves in the anterior abdominal wall proceed downward and forward be-

Fig. 91.—Method of making crescentic line of anesthesia around postappendicular hernia. Deep injections made through heavy dots.

tween the muscle planes, it is only necessary to make the injection in such a way as to block these. Consequently, a crescentic-like area of anesthesia on the outer side of the hernia will prove sufficient, having the horns of the crescent to embrace the upper and lower extremities of the gap and carried as a wall of anesthesia from the skin to the peritoneum. (See Figs. 80 and 91.) I have often closed large postappendicular herniæ in this way, and have found it very satisfactory.

CHAPTER XIX

GENITO-URINARY, ANORECTAL, AND GYNECOLOGIC OPERATIONS

GENITO-URINARY ORGANS

While the pudic nerve is the principal source of innervation of the deeper parts of these organs (Fig. 92) and is capable of a fairly accurate blocking for regional anesthesia, the skin of these parts receives its nerve-supply from a variety of sources and cannot be dealt with collectively except by such more or less central methods as parasacral or epidural injections, thus blocking at one time the entire innervation of the pelvis and a large part of the lower extremity.

The pudic nerve leaves the pelvis through the great sacrosciatic foramen, crosses the spine of the ischium with the pudic artery, and re-enters the pelvis through the lesser sacrosciatic foramen. Accompanying the pudic vessels, it runs downward, forward, and inward along the outer wall of the ischiorectal fossa. In this position it is about 1 inch internal to the tuberosity of the ischium. Here it gives off its perineal and inferior hemorrhoidal nerves, then continues as the dorsal nerve of the penis.

The inferior hemorrhoidal nerves, several in number, pass downward, inward, and slightly forward from the above position, and are distributed to the sphincters of the rectum and anal canal.

The perineal branches pass downward and forward to the perineum, giving off branches to the muscles of these parts, and are distributed to the skin of this region, branches passing forward to the scrotum in the male and labia majora in the female. It also sends a branch to the bulb of the penis.

The dorsal nerve of the penis pierces the posterior layer of the deep perineal fascia, and runs forward along the inner margin of the ramus of the os pubis between the two layers of deep fascia. Further forward it pierces the anterior layer of the fascia and passes through the suspensory ligament to the dorsum of the penis. In this position the nerves on each side lie to the outer side of the artery (Fig. 93). It

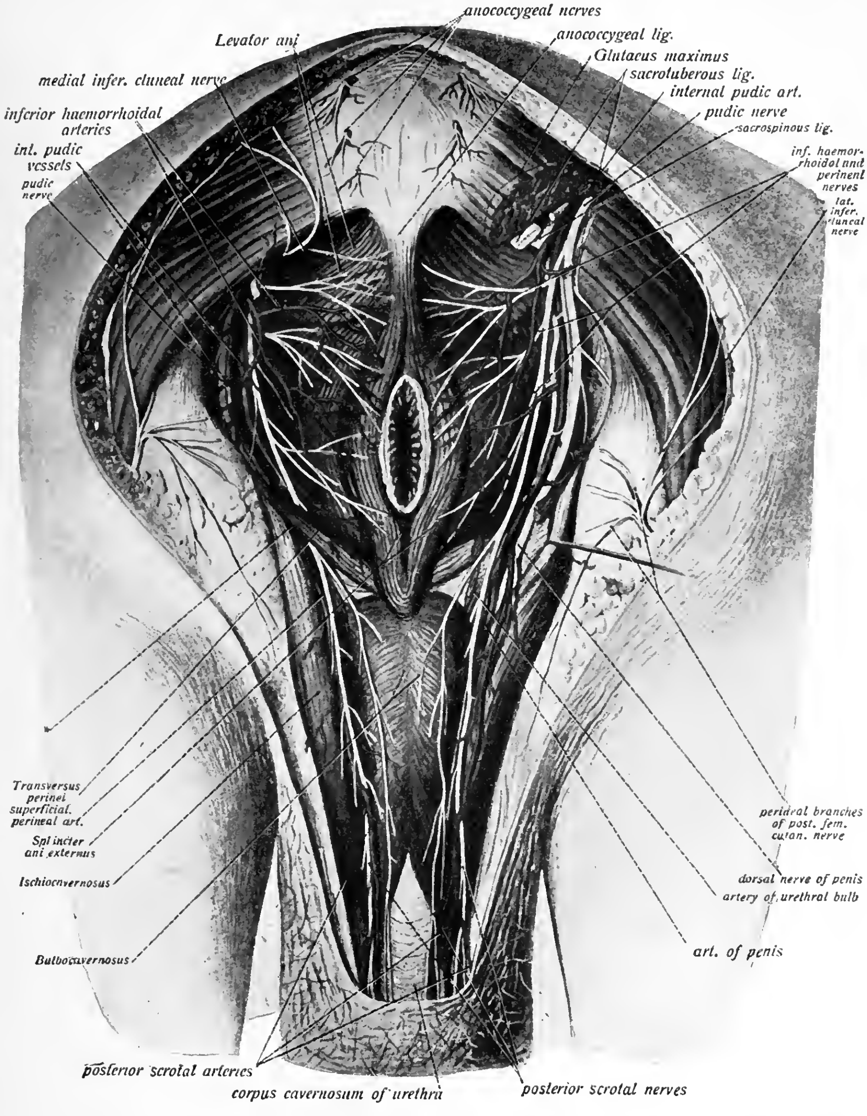


Fig. 92.—The nerves and vessels of the male perineum upon the left side, the superficial perineal musculature has been exposed and the ischiorectal fat removed; upon the right the transversus perinei superficialis has been divided, the urogenital diaphragm incised, and the ischiocavernosus drawn slightly to one side. * = Bifurcation of internal pudic artery into the perineal and penile arteries. (Sobotta and McMurrich.)

gives off a large branch to the corpora cavernosum, and along the side of the penis branches to this organ; its terminal filaments are distributed to the glans and prepuce.

Perineal branches of the small sciatic are distributed to the skin of the posterior and lateral parts of this region, one branch larger than the others; the inferior pudendal curves downward and inward around the tuberosity of the ischium, and passes forward and inward beneath

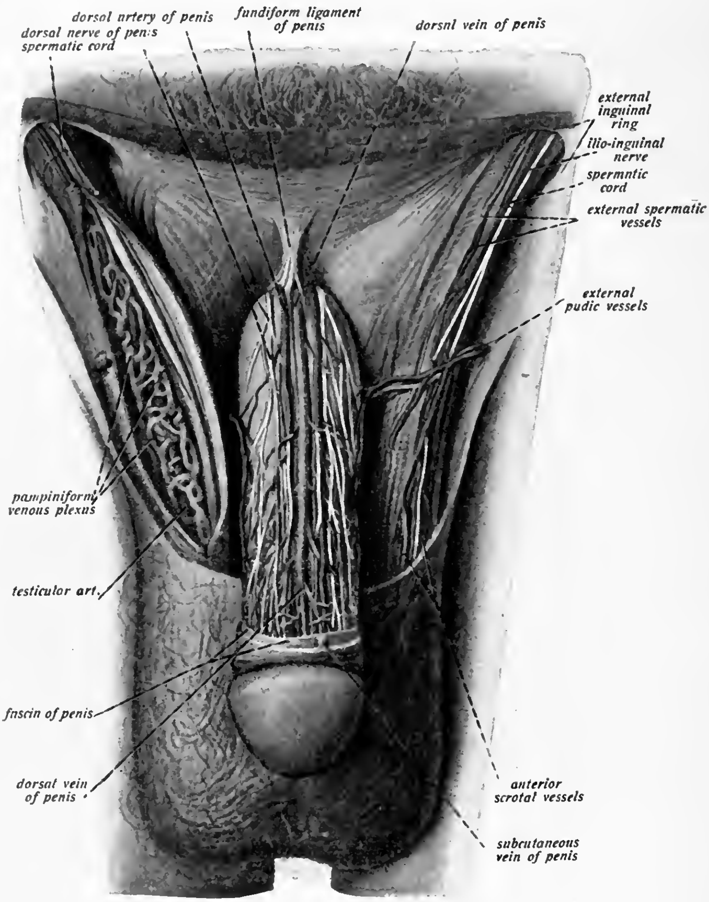


Fig. 93.—The vessels and nerves of the penis spermatic cord and scrotum as seen from in front. The skin and the greater portion of the fascia have been removed from the penis; the vessels of the right spermatic cord have been exposed by dividing its coverings. (Sobotta and McMurrich.)

the superficial fascia and is distributed to the skin of the perineum—scrotum in the male and the labia majorum in the female. The nerve in its passage around the tuberosity lies about $\frac{1}{4}$ inch to the outer side of the bone, between it and the great sciatic nerve.

The scrotum, in addition to its branches from the pudic and inferior pudendal, receives cutaneous branches from other sources, principally the ilio-inguinal, and probably, on its anterior part, a few branches from the iliohypogastric. Its nerve-supply is such that all operations done upon it must be through infiltration. The testicle, spermatic cord, and cremaster muscle are innervated by the genital branch of the genitocrural, but this nerve does not give any branches to the skin overlying these parts.

The bladder receives two nerves on each side from the third and fourth sacral, which enter the organ near its base.

Method of Blocking Pudic Nerve.—The tuberosity of the ischium is located as a landmark; the skin over a point about 1 inch internal and in front of the tuberosity is now anesthetized; a large syringe, containing a few drams of 0.50 per cent. novocain solution, with 2 or 3 drops of adrenalin, and fitted to a long needle, is now used. The needle is passed downward and outward toward the base of the tuberosity, varying in depth according to the stoutness of the individual, but usually about 1½ to 2 inches; at a point about ½ inch from the base of the tuberosity 2 or 3 drams of the solution are injected. The same procedure is repeated on the opposite side; or, if preferred, the long needle may be entered at a point 1½ or 2 inches back of the anus in the midline, after previously anesthetizing this point in the skin, and directing the needle obliquely outward and upward toward the base of the tuberosity of the ischium, guided by the finger within the rectum, when 2 or 3 drams of the solution are injected about ½ inch from this bone. The method of making this injection is shown in Fig. 103. The needle is then partially withdrawn and turned in the opposite direction, where the injection is repeated. These methods, however, are not often used, but when resorted to for operations on the rectum the perianal infiltration, as described later, should be made somewhat more liberal posteriorly between the anus and the coccyx and well into the subcutaneous tissue to reach the nerves that come into the field from this direction. The uncertainty of reaching this nerve at the point where it enters the pelvis with any degree of accuracy for a paraneural injection has led to efforts to reach it from without by an injection made through the gluteal region. This procedure has been recommended by Franke, and is done as follows: The skin of the gluteal region, at a point about over the spine of the ischium, is located by a finger passed within the rectum, and the long needle passed down from without through the anesthetized point and an injection made in contact with the spine. Neither of these methods have become very popular with others, and are rarely if ever used by the author. The methods preferred are those described in dealing with the different regions, as described later.

To *anesthetize the inferior pudendal nerve* an injection is made on the outer side of the tuberosity of the ischium, where this nerve passes close to the base of the process and between it and the great sciatic.

The needle is entered in the perineum to the inner side of the tuberosity and directed outward and upward, injecting as the needle is advanced to a point over the base of the bone; the injection is made after the needle is felt to pass the bone about $\frac{1}{4}$ inch, usually using about 2 drams of 0.50 per cent. novocain adrenalin solution. This, however, like the injection of the pudic, is uncertain.

THE PENIS

To anesthetize the entire organ a circumferential line of intradermal anesthesia is carried around the organ at its root, as seen in

Fig. 94.—Method of procedure for anesthesia of entire penis. (From Braun.)

Fig. 94. From this line two deep injections are made about $\frac{1}{4}$ inch on either side of the midline and carried down to the corpora cavernosa (Fig. 93), showing the nerve-supply and (Fig. 95) the point of injection, using here about 1 dram of 0.50 novocain adrenalin solution or a somewhat more liberal injection of solution No. 1.

If the contemplated procedure involves the urethra, a smaller quantity of the solution should be injected deep on either side of this structure in the sulcus, between it and the corpora cavernosa. Should a fine needle pierce the urethra in this injection no damage will result. A small stationer's elastic band, used as a constrictor, should now be placed around the base of the organ proximal to the injections, but not too tightly, for fear of injury. After a few minutes' delay anesthesia is produced. Gentle massage helps to diffuse the solution, when any operation involving these parts may be undertaken, from circumcision to amputation. Urethrotomy, internal or external, as well as plastic work, involving the urethra or the rest of the organ,

Fig. 95.—1, Shows line of anesthesia for suprapubic cystotomy; 2, points on each side of midline for paraneural injection of dorsal nerves of penis; 3, area of anesthesia for varicocele, hydrocele, or orchidectomy.

can now be painlessly done. The above is an excellent method for the cauterization of extensive or phagodenic chancroids of this region or for operations for paraphimosis.

The Oberst Method.—This is really a form of arterial anesthesia, and, while ingenious and effective, may at times be followed by hematoma, and for that reason is not very popular with the writer.

A constrictor is placed around the root of the organ. A syringe and fine needle filled with 1 per cent. cocain solution (which is the solution recommended by Oberst, though novocain could also be used) is now injected in the following manner:

The needle is thrust well into the corpora cavernosa, and from 5 to 7 min. of the solution is injected (Fig. 96). This is repeated on the opposite side. About 5 min. of the solution is injected into the subcutaneous tissues on each side of the organ, and about the same quantity on the undersurface around the urethra.

Anesthesia takes place in about fifteen minutes, and is usually very satisfactory and sufficient for any operation upon the organ. It has been especially recommended for circumcision as a substitute for the direct method of infiltration, on the ground that the edematiza-

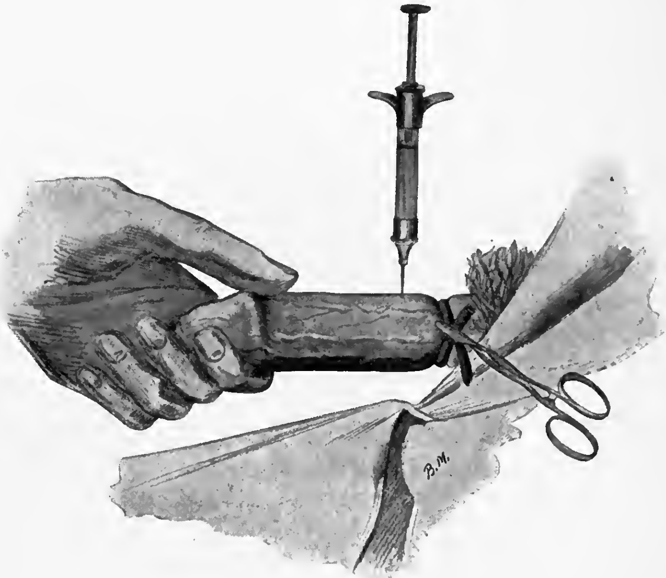


Fig. 96.—The Oberst method of cocain infiltration. A constrictor is first placed around the root of the organ and the injection made with a very fine needle, as described below. Oberst recommends a 1 per cent. solution of cocain, but the same strength of novocain could also be used. (Miller.)

tion of the tissues resulting from infiltration was an objection in this operation. The writer, however, has not found this to be the case.

Circumcision.—Solution No. 1, with an ordinary hypodermic with fine needle, is sufficient. The skin is pulled well over the glans and the point of incision determined. The injection is begun just proximal to this point and a circumferential injection is made into the skin and subcutaneous tissues around the organ. If the prepuce is well relaxed and can be freely retracted, a finger is passed up on its inner surface between it and the glans. The needle is now directed down through the already anesthetized parts on the surface toward this point, injecting as it is advanced, until it reaches a point on the inner surface of the prepuce just back of the cervix (neck of the glans). A station is produced here, the prepuce now retracted, and, beginning at this anesthetized point, a collar of anesthesia is created around the glans, carrying it well around into the frenum; or, instead of the above, the prepuce can be reflected and the anesthesia started from an injection made from the inner surface. Anesthesia will now be complete and the operation can be performed. A small stationer's elastic should first be applied as a constrictor around the organ near its base. In the event that the prepuce is very tight and cannot be retracted, it may be filled with a 1 per cent. solution and held for a few minutes, or the injection can be carried forward toward the constricted

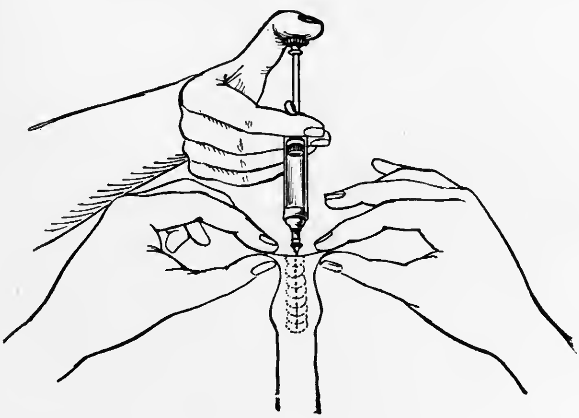


Fig. 97.—Anesthetizing dorsal surface of foreskin from periphery toward base. (From Braun.)

opening and this anesthetized and divided sufficiently to permit retraction, when its inner surface can be anesthetized; or the procedure as illustrated in Fig. 97 may be carried out.

The Urethra.—Two or 3 drams of 1 or 2 per cent. novocain solution and 1 or 2 drops of adrenalin held in the urethra for five or ten minutes will anesthetize the mucosa sufficiently to permit a painless internal urethrotomy or the gradual dilatation of a stricture, but will not permit divulsion (which, however, is now rarely practised), as it does not anesthetize the submucous and periurethral tissues. Stronger solutions than 1 or 2 per cent. are never necessary here. The same effects can be obtained with the weaker solutions if retained slightly longer. The urethra absorbs very actively, and many cases of poisoning, at times fatal, have been reported from the injudicious use of strong solutions; consequently, one should never be tempted by haste to exceed the safe limits.

The use of adrenalin solution when retained a few minutes in the urethra is often of great advantage, particularly in inflamed or congested conditions; the relaxation following the congestion will often permit the easy passage of an instrument which would seem impossible or very difficult without its use. Strictures which have been congested following alcoholic indulgence, causing acute retention of urine, can often be sufficiently relieved in this way to permit the passage of a

Fig. 98.—Line of infiltration for external urethrotomy.

small catheter when an external urethrotomy would otherwise have seemed indicated.

The Meatus.—To anesthetize the meatus a very satisfactory method is to dip the end of a moistened sterile probe into a bottle of cocain or novocain crystals, when a few of the crystals will adhere to the end and can be conveniently deposited in the meatus. In a few minutes this will have produced sufficient anesthesia to permit fairly considerable dilatation for the passage of a sound through a tight meatus, and will also permit a limited meatotomy. But it is better for the latter to infiltrate the meatus in the line of the proposed incision with a few drops of solution No. 1.

The **female urethra** is easily anesthetized by a few drops of 5 or 10 per cent. novocain on a film of cotton wrapped around an applicator, and passed into the urethra for a few minutes.

External urethrotomy in the ordinary case is quite easily performed under local anesthesia. In the presence of extensive urinary infiltration it may prove difficult and test the ability of any but an experienced operator under local measures, as the fibrous tissue encountered under these conditions is difficult of thorough infiltration.

If the strictured point is deeply situated the pudic and pudendal nerves had best be blocked, though it is possible to proceed entirely with infiltration, which is the method preferred.

The urethra is first anesthetized, a sound passed, and the strictured point located or a guide or filiform passed through it. Infiltration is commenced in the middle line (Fig. 98), just proximal to the stricture, and carried well down into the subcutaneous tissues. These are now divided, infiltrating further as we advance, until the urethra is reached, when a little solution injected periurethrally around the strictured point will permit its painless division or resection, if not too extensive, with subsequent approximation and suture of the divided ends of the urethra.

The following history of a patient operated on by the author illustrates a procedure which may sometimes prove useful:

Mr. A., aged forty-three, alcoholic, with chronic endocarditis and history of renal disease, presented himself, with a large infiltrated scrotum with urinary fistula on inner side through which urine and pus dribbled, only a few drops appearing at the meatus during efforts at urination. It was found impossible to pass a sound or filiform through the tortuous fibrous urethra. Through infiltration of the tissues at the base of the scrotum an incision was made down to about the position of the urethra, but it was found impossible to readily identify this structure. The wound was packed and suprapubic cystotomy done, liberating a large amount of foul urine. In the Trendelenburg position (to dilate the bladder with air) the internal urethral orifice was readily seen, and a small Poges silk-woven catheter passed forward along the urethra. This caused no discomfort. At a distance of about 3 inches the point of the catheter was arrested. While it was held in this position by an assistant we returned to the perineal wound. Some additional infiltration was found necessary here, as the parts had become sensitive. The urethra was now readily recognized in a mass of fibrous tissue by manipulation of the catheter and opened. The anterior portion of the urethra was easily followed and several strictures divided under infiltration.

The case made an uneventful recovery. The urinary fistula on the side of the scrotum closed without any special treatment. Subsequent examination of the urine showed albumin and granular casts.

This case would certainly have been a dangerous risk with general anesthesia. Spinal analgesia could, however, have been employed, but we resort to the latter only when local and regional methods are impracticable.

Epispadias and **hypospadias,** or other plastic operations, are usually quite easily performed under local anesthesia, but should not be done under infiltration. Instead, the regional method of blocking the nerves of the root of the organ as already mentioned should be employed; when extensive, always combining the operation with an external urethrotomy.

SCROTUM

All operations upon the scrotum can be performed under infiltration. Where resections are to be done, as in the case of superficial

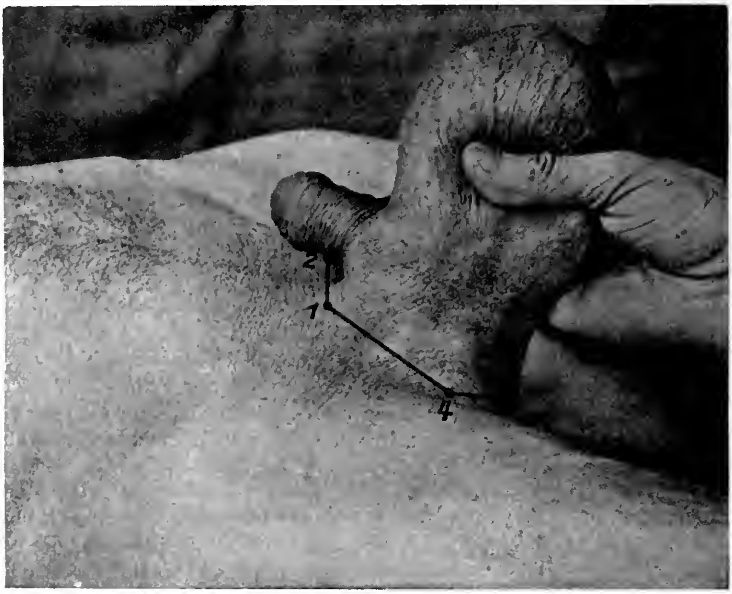


Fig. 99.—Method of surrounding penis and scrotum with zone of anesthesia for operations upon scrotum. (From Braun.)

growths or for elephantiasis, a zone of anesthesia should be created around the part to be excised. If it involves the entire organ, infiltration should be done around the base (Figs. 99 and 100). If the operation involves the contents of the scrotum, the cord should be exposed just below the spine of the pubis on one or both sides, as the case may require, and blocked there. The genitocrural nerve lies at the back of the cord, near the vas (Figs. 93 and 101). By infiltrating the cord freely in this position the nerve is reached; it is not necessary to directly expose it. In making an injection here care should be taken not to enter any of the large veins which may be found in this region. Make the injection only when advancing or withdrawing the needle, not when the needle is stationary, unless the parts are plainly in view.

The following case, operated on by Prof. Matas, illustrates the possibilities here:

"An adult negro laborer was admitted in my service in the Charity Hospital two years ago for the removal of an immense scrotal tumor, which extended from the pubes to the knee. After making a linear infiltration, 13 inches in length, in the vertical axis of the tumor, we reached a hernial sac which contained the cecum and a long appendix vermiformis. The hernial region was anesthetized. The appendix was removed, the sac

Fig. 100.—Method of injecting posterior surface of scrotum. (From Braun.)

excised, and the hernial canal closed by a Bassini operation. The dissection was then continued, and two enormous polycystic masses (originally hydroceles of the cord and tunica vaginalis), containing over 3 pints of fluid, were tapped and excised with the testis, which was incorporated in their walls. The patient never complained during this long and tedious procedure, and enjoyed a hearty meal shortly after returning to the ward. He made a perfectly uneventful recovery."

Operations Upon the Scrotal Contents.—*Varicocele, hydrocele, castration*, etc., can all be done following a uniform method of anesthesia. For typical operations this is as follows: The skin on the anterior surface is infiltrated longitudinally for about 3 or 4 inches (Fig. 95). If the operation is for varicocele or for an orchidectomy, the upper end of this line should begin at the spine of the pubis; if for hydrocele, it may be lower, and the lower end reach well over the surface of the tumor, but the upper end must reach sufficiently high to permit ready access to the cord above. The cord is now picked up through the scrotal wall with the finger, and the small needle passed through the anesthetized area at its upper end and an injection made on each side of the cord (Fig. 101) in close contact with it; some operators inject within the cord in this way, but I find it better not to do so, as a vein might be injured, and, while of no consequence, it might produce a hematoma or discolor the field with blood, and as the

Fig. 101.—Method of infiltrating around spermatic cord.

cord is to be later exposed nothing is gained. The incision is then made through the anesthetized skin and fascia down to the cremasteric fascia; this is divided and the cord freely exposed and drawn out of the wound; the deep injections previously made around the cord permit this manipulation without discomfort. With the cord now freely exposed out of the wound it can be thoroughly injected with the small syringe; the genitocrural nerve lies at the back of the cord near the vas, but all veins should also have a wall of anesthesia around them, as they are sensitive. These injections are all made high up at the proximal end of the field. Having completed this procedure, the entire scrotal contents are anesthetic, and any contemplated operation can be performed. The testicle can be drawn out of the scrotum and freely exposed to view, but traction should not be made upon the upper end of the cord, as this pulls upon the unanesthetized parts above and will produce pain.

If the condition is one of varicocele, the veins of the entire cord and about the epididymis can be resected.

If for hydrocele, the inversion operation or the removal of the parietal portion of the tunic, as in the Volkmann operation, can be performed with equal satisfaction.

In the event of inflammation creating adhesions within the scrotum, these may have to be infiltrated before the sac can be dissected away freely, particularly about the septum, for here nerve-filaments cross over from the other side.

In operations for hydrocele it has been suggested that the tunica vaginalis be filled for a few minutes with a 1 per cent. solution of novocain, after first drawing off its contents. This, however, is not necessary if the cord has been properly blocked, as the entire parts are anesthetized. This procedure may, however, be done through a cannula for the injection of irritating substances like iodin, but is hardly necessary for carbolic acid if the sac is first thoroughly emptied.

CHANCROIDS

The topical application of cocain or other agents except carbolic acid, even in very strong solutions, for the purpose of producing anesthesia to permit the painless cauterization of these lesions, is quite unsatisfactory, even for the use of nitric acid, the anesthetic effect of the agent not penetrating deep enough. A satisfactory method of treating these lesions is to first dry them thoroughly and then to apply pure carbolic acid. This rarely causes any complaint or, if so, too trifling to be of consequence. If a more thorough cauterization than that produced by carbolic acid is desired, nitric acid can now be added, when its action will be found painless. In using either of these agents this way care should be taken not to permit them to run over the skin of the surrounding parts. If the lesion is very superficial, this can be prevented by surrounding it with a smear of vaselin.

Cataphoresis can be made use of for carrying anesthetic drugs into the tissues in such lesions as chancroids. The objection to the method is the time necessary for the agent to penetrate to sufficient depth to produce satisfactory operative anesthesia. It is, however, nevertheless possible.

A pledget of cotton saturated with a 10 per cent. solution of the agent to be employed is placed over the lesion. The positive electrode is placed over this and the negative at some nearby part of the body. A mild galvanic current is used, when after about fifteen to twenty minutes, sometimes longer, it will be found that the anesthetic has penetrated to a sufficient depth to permit the painless use of the galvano- or thermocautery. The time consumed in this process renders it impracticable for the busy practitioner. A more satisfactory method is the following: When the lesion is situated upon any part of the foreskin the surrounding parts are well cleansed; a fine needle fitted to a syringeful of solution No. 1 is entered some little distance from the lesion, after first touching the skin at this point with tincture of iodin. As the needle is advanced the solution is injected until the surface beneath the lesion is reached, when the entire underlying subcutaneous tissue is infiltrated. This can be facilitated by sliding the skin toward the needle, if it is found that this will not reach far enough, rather than make several punctures with the needle, which may carry infection down with it. To replenish the syringe the needle is left in the tissues and the syringe unscrewed, refilled, and fitted on again. After thorough infiltration the actual cautery can be used. Where the lesion is too large, where there are several in different parts, or where they are situated upon the glans, the method of nerve-blocking, as previously described, had better be employed.

THE BLADDER

The fundus of the normal bladder is almost insensitive to pain. The base and neck are quite sensitive, but when inflamed even the fundus may become sensitive. According to Lennander, the pain caused by the overdistention of the normal bladder is due to the stretching of its peritoneal covering. Traction upon the bladder wall will cause pain. Any pain induced when operating upon the bladder, even at the fundus, is always referred to its neck, the urethra, and head of the penis. Certain manipulations may sometimes produce an urgent desire to urinate, although the bladder may be open and empty. In the uninflamed bladder such operations as lithotrity or suprapubic cystotomy for the removal of stones or pedunculated growths is quite easily carried out under local anesthesia. But in the acutely inflamed or old chronically inflamed and contracted bladder such operations may give some difficulty and will have to be handled gently under such methods as infiltration and topical applications, and had best be operated by regional methods. (See Parasacral, Epidural, and Spinal Anesthesia.)

Suprapubic cystotomy is always done by us under local anesthesia as a preliminary step to suprapubic prostatectomy in infected bladders, when, after a few days' free drainage and mild irrigations, allowing the cystitis to clear up, the organ is removed by a few minutes' narcosis under nitrous oxid or ether or may be removed under local anesthesia. By this plan, which stops the trying tenesmus and frequent efforts at urination so distressing to those patients, which prevents their rest and ability to properly nourish, they are now given a few nights' uninterrupted sleep, which greatly revives old and feeble patients, when the operation can be safely concluded, which would most likely result fatally if attempted at one sitting.

Antipyrin was formerly much used as a vesical anesthetic, due to its possessing styptic and mild antiseptic properties, but since the advent of adrenalin it is now rarely used.

In the normal bladder the power of absorption is very limited, but much more active in the urethra. In the acutely inflamed bladder this power is much increased, and is always more active at the base.

To anesthetize the bladder it is necessary to use only very mild solutions. Many cases of poisoning, often fatal, have resulted from the injudicious use of too strong solutions.

Solution of cocain (0.25 per cent.) or solution of novocain (0.50 per cent.) and a few drops of adrenalin is sufficient, using 2 or 3 oz. of this solution, either passed in by pressure through the urethra or by a catheter, after first well cleansing the organ to remove all mucus, pus, or blood-clots.

If the bladder is very irritable, and efforts at urination are excited with expulsion of the solution, only a few drams are passed in at once, when after a few minutes' delay, allowing time for some effect to be produced, a little more is added, until the desired quantity is introduced.

To anesthetize the neck of the bladder for the practice of cystoscopy, etc., it is more convenient to use small tablets of alypin or novocain containing from $\frac{1}{2}$ to 1 gr., which are deposited at the desired point by specially constructed depositors made for this purpose (Fig. 102). After using any anesthetic, either solution or tablet, it is necessary to wait from ten to fifteen minutes for the full effect to be felt.

Suprapubic Cystotomy.—When done for drainage, it is ordinarily unnecessary to anesthetize the interior of the bladder, unless it is very sensitive or inflamed, but it should be moderately distended with water to bring the fundus well up to the suprapubic space. When found irritable the anesthetic can be added to the solution. When the operation contemplates the use of retractors or other instruments within the bladder cavity, as for the removal of pedunculated growths, or thorough direct vesical inspection, then the bladder should first be anesthetized.

Operation.—The skin and subcutaneous tissues in the middle line just above the pubes (Fig. 95) are infiltrated and a few drams of solution directed down between the recti muscles. The tissues are then

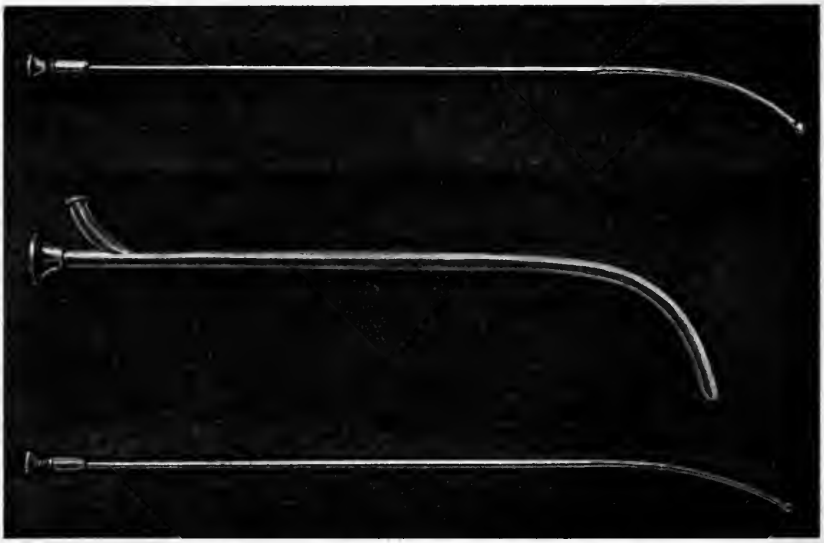


Fig. 102.—Bransford Lewis depositor (slightly reduced in size) for depositing anesthetic tablets at neck of bladder and in posterior urethra. The curved figure with the round end is the obturator; the other has a flat end and is intended to push the tablet home after obturator has been withdrawn and tablet dropped into lumen of cannula.

divided and the recti muscles retracted. More solution should now be injected into the perivesical space, and the fat and peritoneum pushed up out of harm's way when the fundus of the bladder is recognized by the large veins coursing over its surface. This is caught with tractors; if found sensitive a superficial injection is made into the walls with a fine needle. The mucous membrane at this point is usually not sensitive, or if so the injection made into the walls suffices to control it. The bladder may now be opened.

In operating upon the interior of the bladder the Trendelenburg position will be found highly useful. In this position, with long narrow retractors, one on each side, passed well down into the bladder, the upper wall of the bladder ascends under the pressure of the air which enters, thus freely opening the vesical cavity. A few sponges will remove the remaining fluid.

A very satisfactory method for the thorough direct visual examination of the bladder is to use a short proctoscope, with light on the end, passed into the cavity in the Trendelenburg position. This permits examination with far greater facility and accuracy than is possible with any cystoscope.

All of the above procedures are quite satisfactorily carried out under local anesthesia.

If a pedunculated or well-defined superficially situated growth is to be removed its base and surrounding mucosa is first infiltrated with solution No. 1, when we can proceed with the operation the same as with general anesthesia.

Sections of the fundus or posterior walls can be easily removed by infiltrating around the area to be excised, always leaving a catheter, preferably a Pezzer, in the bladder when finished.

After opening the bladder, if the base and walls are found sensitive, a few pledgets of cotton, soaked with 2 per cent. solution of novocain adrenalin, placed in contact with these parts for a few minutes, will usually suffice, or swabs may be used with stronger (10 to 20 per cent.) solutions in the same way as they are used in nose and throat work.

PROSTATECTOMY[1]

In the operative relief of hypertrophy of the prostate, we have in the great majority of cases to consider certain factors which are not, as a rule, involved in other surgical procedures, namely, that of age, as most of the cases requiring surgical relief for this condition have reached or passed middle age, and many of them are infirm or weakened by suffering and infection.

In the old and feeble prostatectomy is a formidable operation, though not attended by a greater mortality than that following any other major operation in the same class of patients. However, it may even show a more favorable comparison by observing certain methods in the handling of these cases.

Surgical technic has reached such a stage of perfection that in the more commonly performed operations it would seem difficult to suggest improvements in the recognized methods of procedure in typical cases. Improvements will come, but I believe that they will

[1] From a paper read by the author before Louisiana State Med. Soc., 1913.

be more in the preparatory treatment, general handling of the case, and refinement in details, rather than in the general principles involved in the operation.

One of the refinements of detail, recently introduced as a general surgical procedure, is the anoci-association of Crile; this, I believe, to be a factor of great consequence, particularly when applied in old and feeble patients, as it prevents shock-producing impressions from the field of operation from reaching the higher nerve-centers.

The two great factors in the production of shock are trauma and hemorrhage. Surgical trauma we cannot prevent, as we intentionally inflict it, but we lessen its shock-producing effect by blocking all nerve-endings in the field, by injecting the tissues with weak anesthetic solutions; this is done whether the patient is to have a general anesthetic or not, as Crile has shown that general anesthesia does not prevent shock from trauma. The method which I wish to present to-day is the result of a gradual evolution in handling cases of prostatectomy. While I had never noticed any marked shock following prostatectomy by former methods, in those cases in which I used the anoci-association of Crile, by resorting to a preliminary injection of the prostate with anesthetic solutions, there was an improvement, as these cases showed practically no change in their physical condition after operation.

The control of hemorrhage was accomplished by the logical addition of adrenalin to the injected solution; the absence of all bleeding in cases so treated was most striking, practically no blood being lost at all, just enough to moisten a few sponges, thus there was a decided gain for the patient—the two shock-producing factors eliminated.

The results of this technic were borne out by a more rapid convalescence of these patients, and this method, combined with a two-stage operation opening the bladder a few days before under local anesthesia, has enabled me to carry to a successful termination cases of badly infected bladders in feeble patients which I would have hesitated to operate by any other method.

The continued use of the above method and its gradual extension led to the elimination of general anesthesia, until now it is used only from choice and not from necessity, as these cases can be as successfully operated by local anesthesia as can hernia, rectal, and many other conditions.

The technic of the procedure is as follows:

One hour before operation a suppository, containing 10 gr. of anesthesia, is placed in the rectum to anesthetize this region and prevent any discomfort when the finger is introduced here in elevating the prostate.

About the same time, one hour before operation, a hypodermic of morphin, $\frac{1}{6}$ gr., and scopolamin, $\frac{1}{150}$ gr., is administered to lessen psychical disturbances. The operation is begun by opening the bladder under local anesthesia; its walls are then retracted by long, deep, narrow retractors, bringing into view the field of the prostate. De-

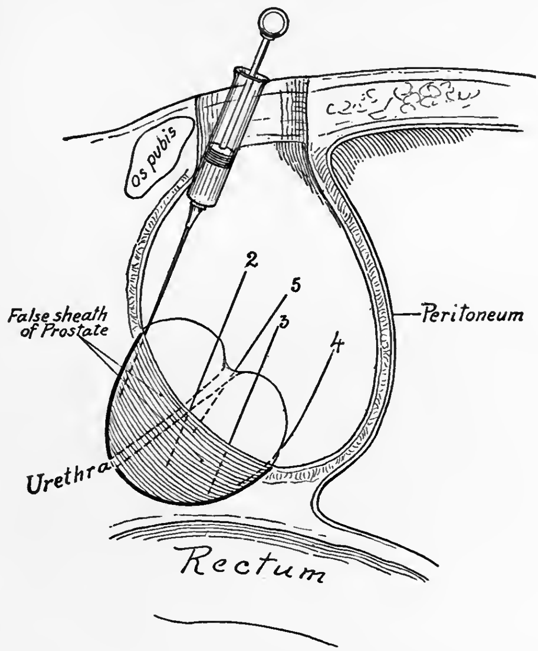


Fig. 103.—Author's method for injecting prostate: Lines 1–3 indicate points for injection above and on side of prostate; 4, beneath prostate, this may at times be more conveniently made by a curved needle; 5, enters urethral opening, penetrates urethra, and is made between lobes of gland. While the lines show the axis of the injections with the prostate lying normally in its bed when the injections are made, the prostate is lifted up by a finger in the rectum, so that the needle can be more readily entered in the proper position through the suprapubic opening.

pending upon the size and shape of the prostate, several points are selected for injection on the vesical surface, usually one below the opening of the urethra near the base of the gland and one on either side. The needle is passed through the mucosa with the idea of making the injection between the true and false sheath of the prostate, as it is in this plane that the solution must diffuse around the gland, and it is in this plane that its enucleation is effected; it is here where the large venous plexuses are situated and where the nerve filaments are more easily reached as they pass through to the prostate.

Two or 3 drams of a 0.50 per cent. novocain solution, containing 15 min. of adrenalin to the ounce, are injected at each of the above points. The needle is then passed into the urethral opening, and the lateral wall pierced first on one side and then on the other, and similar injections made at these points (Fig. 103).

If the gland is very large, or there is much of a projection above the urethral opening, an additional injection can be made here, otherwise the above will prove sufficient. It is well now to wait two or three minutes for the solution to diffuse and through anesthesia to be established before beginning the enucleation. While waiting for the solution to diffuse the action of the adrenalin is observed in the prostate, which becomes quite pale and bloodless.

In making the injections, should they be made into the substance of the gland itself, no harm will be done, only they are not quite as effective as when injected peripherally between the true and false sheath; any excess of the solution thrown into the gland in this way is removed during its enucleation and not absorbed.

This method may not appeal to all of my audience, as it requires a certain familiarity with local anesthesia before one cares to undertake major operations by its use alone.

I will, nevertheless, urge that even under general anesthesia you resort to the preliminary injection of the field with a local anesthetic, combined with adrenalin, as a most potent agent in the elimination of those two most active factors in the production of shock—trauma and hemorrhage.

Dr. Tinker ("Jour. Amer. Med. Assoc.," Feb. 11, 1905) reports a perineal prostatectomy by first blocking the pudic nerves and using infiltration on the skin and deep parts.

Prostatic abscesses, when pointing toward the perineum, can be opened under infiltration. With the finger in the rectum as a guide, the infiltration and dissection is advanced until the abscess is reached. It is hardly necessary to block the pudic nerves, unless the abscess is very deeply situated.

A particularly favorable method of operating upon these parts is by parasacral anesthesia, as described under that heading.

ANORECTAL REGION

Any of the many affections involving the easily accessible parts of this region may be quite satisfactorily operated upon by local anesthesia, provided the procedure is not too complicated; where this is the case, as in extirpation of the rectum, parasacral anesthesia should be resorted to.

The region of distribution of the pubic nerve may, in many respects, be compared to that of the fifth nerve, the two most sensitive areas in the body. The disturbances arising from disease of these parts are often considerable and out of all proportion to the size of the lesion if situated elsewhere; their reflexes are numerous and varied, and often involve remote parts of the body.

In the rectum the sensitive area is practically limited to the terminal 2 inches of the bowel or anal canal. Above this point there is very little sensation. It is in this terminal 2 inches that disease is most frequently encountered—in fact, more often than in all the rest of the alimentary canal. When we consider the nature of these affections, we are forced to the conclusion that the great majority of them may be claimed by the domain of local anesthesia, reserving a few of the more serious operations, such as extensive resections, for general narcosis; these, however, are a small percentage of the operations performed in this region. Persons affected with anorectal disease are, as a rule, more nervous and apprehensive, and for this reason the preliminary hypodermic of morphin, $\frac{1}{6}$ gr., scopolamin, $\frac{1}{150}$ gr., recommended elsewhere for all major operations, should not be omitted here.

All operations under local anesthesia in this highly sensitive region have to be performed with great care, and the technic of any method of anesthesia employed carried out with exactness and thoroughness to insure success; the solutions need not be of any greater strength than those used elsewhere (0.25 per cent. novocain for infiltration and 0.50 per cent. for nerve blocking, with the addition of the usual amount of adrenalin), though stronger solutions may sometimes be necessary.

Reclus, in 1889, was the first to satisfactorily anesthetize this region to permit the painless dilatation of the anus. He used 1 to 2 per cent. solutions of cocain. He was followed by Scleich in 1894, and the methods of infiltration used in this region to-day are largely the same as those advocated by these two pioneers in the field of local anesthesia.

The **nerves** of this region are practically the same as those described for the genito-urinary organs, and, when preferred, the pudic nerve can be blocked in the same way near the spine of the ischium (Fig. 104), and if the operative field extends some distance behind and to the

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side of the rectum, as in fistula, the inferior pudendal will also have to be blocked on the outer side of the ischium; both procedures are discussed under the above heading. When used, this method should be combined with a thorough perianal infiltration in the same way as described later.

This procedure, while used by some operators, is not very popular, as it often fails to produce a satisfactory surgical anesthesia, due to the uncertainty of accurately reaching the nerve at the point of injection.

Fig. 104.—Method of making paraneural injection around pudic nerve. The long needle is entered at an anesthetized point about $1\frac{1}{2}$ inches back of rectum. The finger in the rectum locates the spine of the ischium and guides the advancing needle. The injection is slowly made as the needle is advanced to about $\frac{1}{2}$ inch to the inner side and slightly in front of the base of the tuberosity of the ischium.

The following method is much to be preferred, being simpler, quickly executed, and absolutely reliable in producing a perfect surgical anesthesia.

This technic is so simple and quickly executed that the writer almost invariably uses it for all operations in this region (hemorrhoids, fissure, prolapse, etc.) in preference to a general anesthesia.

The tissues are first infiltrated subcutaneously around the anus at the mucocutaneous junction, as seen in Fig. 105. It is better to start the injection an inch or more away in the less sensitive skin, and advance toward this region, when the injection is then carried out circumferentially, rather than to make the first puncture in this area, which is highly sensitive, and will always excite some complaint, and in nervous patients cause them to become uneasy and lose confidence in the promise of a painless operation. The author always uses an ethyl chlorid spray on the skin at the point of puncture, first thoroughly protecting the anus against any contact with the spray by holding a gauze sponge well against it.

Fig. 105.—Points of injection for surrounding anal canal with zone of anesthesia. (From Braun.)

The circumferential injection is made subcutaneously, as the skin and mucous membrane at their point of junction are very thin, and an intradermal injection difficult and not at all essential.

By drawing out the skin of this region with one hand the tissues are put upon the stretch, and all folds and creases obliterated (Fig. 106), making it less likely to transfix a fold causing pain; the solution is injected as the needle is advanced; for each re-insertion of the needle starting just back of the point where the needle last stopped; having completed the circumferential injection, a finger is now passed within the rectum as a guide, and the large syringe and long needle used; the

Fig. 106.—Method of making subcutaneous injection around anus. Patient in Sims' position.

Fig. 107.—Method of making deep perirectal injections.

needle is passed through the anesthetized area of skin and directed up the bowel, just outside of the sphincters, injecting, as the needle is advanced, to a depth of about 2½ or 3 inches (Fig. 107); four points are injected: one on each side, injecting in each of these about 10 c.c., and one in front and behind the bowel, injecting in each of these about 5 c.c.

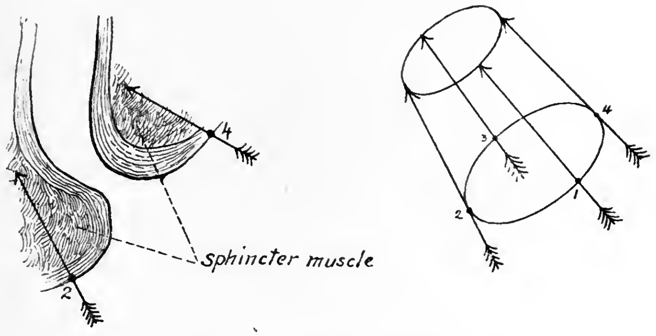

Fig. 108.—Schematic representation of method of producing anesthesia of anal canal —taken from Braun, slightly modified.

Anesthesia results almost immediately, at most after a delay of a few minutes, when dilatation may be begun and can be as thoroughly carried out as under a general anesthetic.

Fig. 109.—Method of dilating rectum with hand in cone shape.

A graphic illustration of the method of making these injections is shown in Fig. 108. The author always prefers to use the hand as a dilating medium, which is less likely to tear or lacerate the parts, using soap as the lubricating medium; first one finger is passed, then two and three, and, finally, the whole hand in a cone-shape is rotated around in a screw-like fashion (Fig. 109) until dilatation is complete. This is the method always used by Prof. Matas for dilatation and is superior to any other.

In operations for fistula, in addition to the above method of anesthesia, which anesthetizes the anal canal and permits dilatation, the fistulous tract must also be anesthetized by injections made on each side and beneath it, so as to thoroughly embrace it within a wall of anesthesia. The method of making these injections is illustrated in

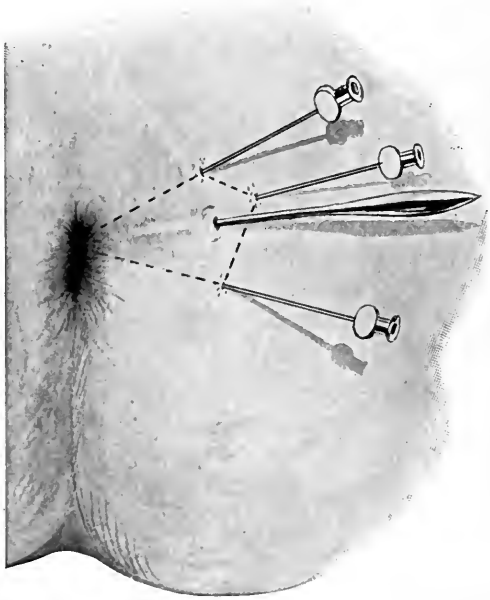

Fig. 110.—Method of anesthetizing fistulous tract. (From Braun.)

Fig. 110. The fistulous tract can then be slit up, excised, or curetted as preferred.

For methods of infiltration it is well to precede the injections in badly inflamed or sensitive cases by placing a pledget of cotton saturated with 5 or 10 per cent. novocain solution within the anal canal, and allow it to remain while injecting elsewhere; in this way the canal will permit the painless introduction of the finger to guide the needle in the deep infiltration.

In the original method, first advocated by Reclus and Schleich, the infiltration was made directly into the substance of the sphincters, but this is not necessary, and it would seem advisable to infiltrate the loose cellular tissue surrounding the bowel rather than the muscle itself. When the above technic has been well carried out it is not necessary to infiltrate the mucosa; this is then, consequently, a paraneural regional anesthesia. By the above technic any of the ordinary operative procedures for hemorrhoids, fistula, polypi, ulcers, fissure, or resection of the rectal mucosa for prolapse may be quite satisfactorily and painlessly performed. In many operations upon this region it is not necessary to dilate the sphincter. While this is desirable in all operations of any magnitude to paralyze the muscles and permit free inspection and access to the anal canal, there are many cases of sentinel piles and other superficially situated lesions, as fissures, where this practice may be dispensed with and the lesions dealt with by simple infiltration. This is particularly suited to office practice, where many of the minor affections of these parts may be operated upon.

In operations for fissure, while it is always desirable to stretch the sphincter, this procedure alone often sufficing for a cure in superficial lesions, it is not absolutely necessary. With the proper care and delicacy in manipulation these cases can often be operated in the office or at the patient's home with satisfactory results. The needle is entered in healthy tissue, just below the lesion, and infiltration gently carried out, advancing the needle under the fissure in the substance of the sphincter, infiltrating gently as it is advanced, until the entire underlying area is well infiltrated; the finger will then be quite easily tolerated in the rectum, and the extent of the lesion well explored.

A blunt-pointed bistoury is now advanced on the flat against the finger until the upper part of the area is reached, then turned edge down, and the fibers of the sphincter at the base of the fissure incised to a depth of about $\frac{1}{4}$ inch. This may be done at one point in the middle or on each side, and effectually puts the muscle-fiber at rest and permits the ulcer to heal; it is then dressed with ichthyol and anesthesin ointment, 15 or 20 per cent. of each.

In performing the operation this way, care should be exercised not to incise too far up the bowel or too deeply for fear of opening some small artery, which may give rise to an unpleasant hemorrhage; it is only in that portion of the canal surrounded by the external sphincter that the incision should be made; more extensive ulcerations, extending up the bowel, should not be treated this way. Malignant disease of these parts unless quite limited, superficially situated, and of easy access should be reserved for parasacral, spinal, or general anesthesia. Perirectal and ischiorectal abscess if superficial may be easily opened by infiltration. In the case of the former, where it is desirable to dilate or divide the sphincter, one of the above-mentioned methods should be used to secure anesthesia.

The use of sterile water as an anesthetic agent when injected into the tissues has long been known, and its application to surgery of these parts has frequently been tested; Dr. S. G. Gant, of New York, is particularly enthusiastic in its use, and has done much to popularize it here. For hemorrhoids or fistula operations of limited extent the anesthesia is quite satisfactory, but it is not suited for extensive operations where the deep parts are involved. The objection to its use is the burning pain produced by the infiltration; this, while greater in some cases than others, is often quite severe, and is not a negligible factor in considering this form of anesthesia. The pain in making these injections is much lessened if the injection is very slowly made, so as not to distend the tissues too rapidly; by the addition of a small quantity of cocain or novocain, $\frac{1}{10}$ per cent., this infiltration pain is entirely relieved; this, however, is no longer pure-water anesthesia. For a further consideration of water anesthesia (anesthesia dolorosa), see chapter on this subject.

The use of ethyl chlorid about the anus is rather unsatisfactory, as it often produces considerable burning, but for superficial incisions in areas removed from the anal margin, or where this can be protected, it is often quite satisfactory.

Before dismissing this subject reference should be made to the use of quinin and urea, which are applicable for the surgical treatment of a limited number of rectal affections, and the reader is referred to the chapter on this subject.

The topical application of the various analgesic and anesthetic preparations is often of great value here for the palliative relief of the inflammatory affections of these parts, such as hemorrhoids, fissures, ulcers, etc. Anesthesin has largely replaced the use of antipyrin and orthoform, as it is a more active agent, and, in view of its slow solubility, maintains this action for a long time; it is also practically non-toxic, even in concentrated solutions (10 to 15 gr. can be safely administered internally at a time). It is best used in ointment form in 10 and 20 per cent. strengths. Combined with other astringent and sedative drugs (adrenalin, hemamelis, belladonna, etc.), in this form its application externally or to the anal canal with a pile-pipe or by suppository often affords gratifying relief in many painful affections. Cocain, novocain, alypin, etc., when used in a similar way, have to be frequently repeated, and may prove dangerous from their rapid solubility if used in concentration or, if long continued, may encourage a habit, and for these reasons are rarely employed in this way.

Operative procedure under the topical application of pure carbolic acid, while practical for limited procedures involving nothing more than a superficial incision, is rather unsurgical, and is not to be recommended for more than an incision such as would be needed for turning out the clot in a thrombotic hemorrhoid or opening a superficial abscess; it can also be made use of for anesthetizing a small point to permit the painless introduction of the hypodermic needle. When used for anesthesia the surface upon which it is applied should be perfectly dry, and after allowing it to remain a few minutes the excess is wiped off.

As a postoperative application the topical use of one or more of the various sedative and analgesic preparations is often of great value in allaying the after-pain and burning common to most operations upon these parts, particularly hemorrhoids, where the cautery has been used. Dr. James P. Tuttle claims for sodium bicarbonate a sedative action superior to anything else; he says for this purpose it is incomparable; it has no analgesic action under other conditions. Following other operations the immediate free use as a primary dressing of a 10 or 15 per cent. ointment of anesthesin or orthoform will be found to greatly lessen the postoperative discomfort as the anesthesia passes off.

For the non-operative or palliative treatment of chronic tuberculous, syphilitic, or cancerous ulcers, anesthesin, orthoform, or carbolic acid in ointment form prove effective analgesic applications. A quite satisfactory treatment for fissures, one of the most painful of rectal conditions, is by tampons soaked in ichthyol and freely sprinkled with anesthesin, such applications giving relief often for many hours; the same may be said of quinin and urea used in ointment form.

Much of the after-pain from rectal operations is due to spasm of the sphincters, and when opiates are used for this purpose it may take unsafe doses to control it; better agents are chloral and bromids (per orem), which are often more effective and safer, used in conjunction with an anesthesin ointment. For the chronic aching or neuralgic pain of this region a satisfactory combination is antipyrin, acetanilid, and codein administered internally.

GYNECOLOGIC OPERATIONS

The surgery of the female generative organs forms a large part of the operative work of the present time. Much of this work on the external and readily accessible parts may be quite easily and satisfactorily performed under local methods of anesthesia, and even some of the more complicated procedures on the deeper parts may, with skill and gentleness, be painlessly, or almost painlessly, accomplished in suitable subjects.

Women, as a rule, are more apprehensive and fearful than men, and often so extremely nervous, particularly when having suffered long

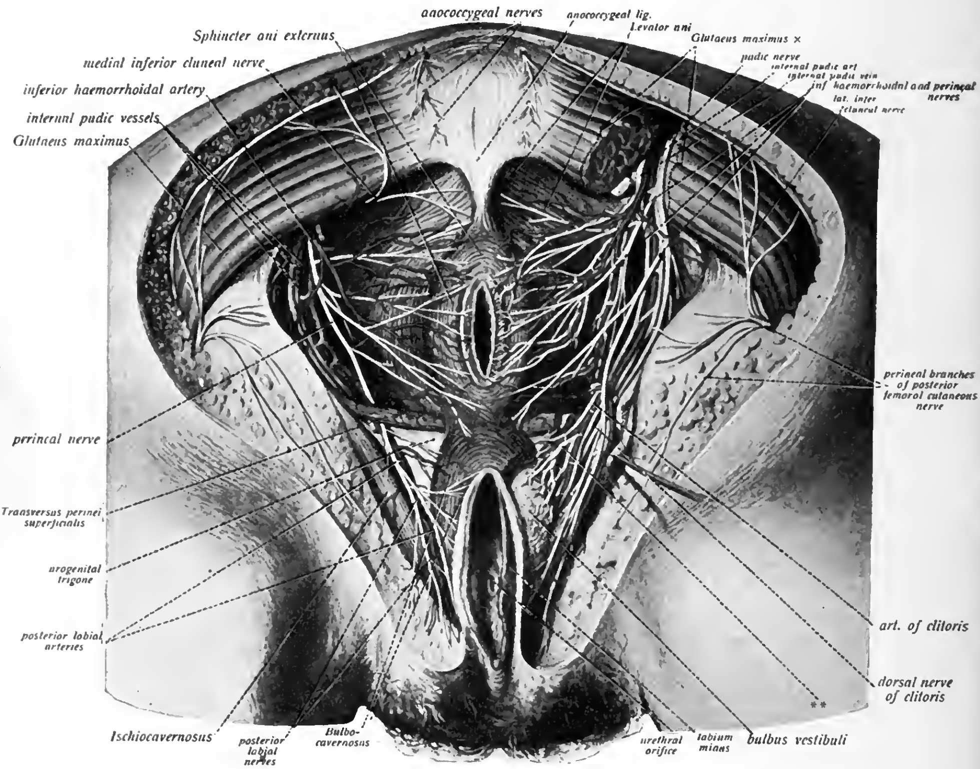

Fig. 111.—The nerves and vessels of the female perineum. Upon the right side the bulbocavernosus has been partly removed and the vestibular bulb exposed, the transversus perinei superficialis divided, and the urogenital diaphragm incised. ** = The origin of the internal pudic vein from the vestibular bulb (vena bulbi vestibuli). (Sobotta and McMurrich.)

from their various affections, that they make poor subjects for any form of local anesthesia. Many prefer to take a general anesthetic, and be treated as if they were really not there at all. It is, accordingly, advisable with the timorous and fearful not to attempt any but the simpler operations on the exposed parts by local anesthesia, reserving all complicated procedures for parasacral, spinal, or general narcosis. However, in the presence of contra-indications to general anesthesia, and with positive indications for operative interventions, many of the more complicated procedures may be safely and satisfactorily performed by the skilful use of local measures alone, or in combination with light superficial anesthesia for the more painful and deeper parts. (See chapter on Combined Methods of Anesthesia.)

In nervous and sensitive patients care should be taken to always administer one hour before operation a preliminary or preparatory hypodermic of morphin, $\frac{1}{8}$ to $\frac{1}{4}$ gr., with scopolamin, $\frac{1}{100}$ gr., as recommended in the preceding part of this volume. It is also well to have a sympathetic nurse stand by the patient and hold her hand or encourage her if she is uneasy. For a consideration of the nerve-supply of this region see Fig. 111, and for description and methods of blocking same see section on Genito-urinary Organs.

In all the external parts and lower 2 or 3 inches of the vaginal tract sensation is very acute, but the vault and upper parts of the vagina have very little sensation. The cervix and uterus are not very sensitive to incisions—volsellum, forceps, or needle punctures—but are quite sensitive to stretching, as in dilatation of the cervix. Also, the mucosa of the cervix and uterine cavity has very little sensation, but will not stand a thorough curettage without anesthesia. The same may be said of the peritoneal investment of the uterus, which should not be operated upon without some infiltration.

Solution No. 2, $\frac{1}{2}$ per cent. novocain, is used in all operations upon the external parts, which are highly sensitive. Solution No. 1, 0.25 per cent., is ample for the deeper infiltrations, but if preferred No. 2 can be used throughout.

To each solution add from 5 to 10 drops of adrenalin, 1:1000 to 3 or 4 ounces, if the field is extensive and much solution will likely be injected, using the smaller quantity of adrenalin.

The Perineum and Postvaginal Wall.—A point on the perineum midway between the anus and vaginal outlet is anesthetic intradermally; establishing here a station through which the long needle is entered, in the event of an extensive laceration up to or including the sphincter ani, this point can be made just within the vaginal outlet.

The long needle is entered here and passed up in the middle line, injecting as it is advanced as far as the contemplated field of operation, using often as much as 5 or 10 c.c.; a finger can be used either in the vagina or rectum as a guide. If the plane of tissue is quite thick it is best to pass the needle well below the vaginal mucosa in the deeper planes, as the solution can better diffuse in these deeper layers, but when dealing with an extensive laceration with rectocele, where the rectum and vaginal mucosa are in close contact, the needle had best be passed just beneath the vaginal mucosa, and here the finger is kept in the bowel as a guide. By injecting the solution as the needle is advanced, the solution separates the plane of tissues and there is less danger of the needle puncturing the rectum.

Fig. 112.—For anesthesia of vaginal outlet, including labia majora. (From Braun.)

Having made the midline injection, the needle is partially withdrawn and directed slightly laterally and upward on first one side and then the other, using in each an additional 5 or 10 c.c., depending upon the extent of the field. Similarly, a third or fourth injection can be made just lateral to the preceding, until practically the entire vaginal canal except the roof has been infiltrated. A crescentic-like injection, made subcutaneously with the long needle around the vaginal outlet and carried up on each side the full extent of the field, completes the anesthetizing process.

If a perineorrhaphy is to be done, and the tear involves the sphincter, the anal canal must then be anesthetized, as described in that section. The above method of injection gives a perfect anesthesia and is very quickly done after a little practice, and the latter steps of the operation, if for perineorrhaphy, much facilitated through the separation of the different planes of tissues by the injected solution.

To Anesthetize the Entire Vaginal Outlet.—This is done by a circumferential injection, as illustrated in Fig. 112, the lower portion as described above. Another crescent-like injection is made from above, which meets the lower field, starting preferably over the external

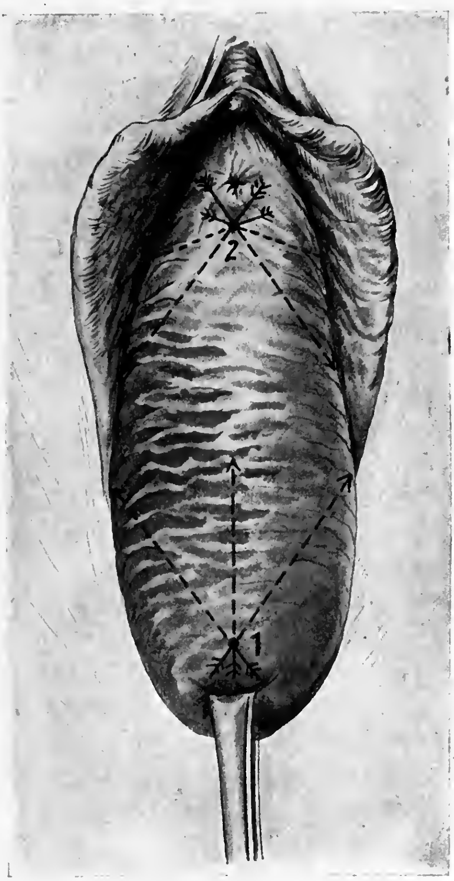

Fig. 113.—Area of infiltration for anterior colporrhaphy. (From Braun.)

ring of the inguinal canal on each side, making the injection fairly deep and liberal here to thoroughly block all fibers of the ilio-inguinal and genitocrural nerves, as they emerge from this opening to be distributed to the tissues of the labia majora.

Anterior colporrhaphy is done by pulling down the cervix with a volsellum; at this point on the cervix a little infiltration can first be done before applying the instrument. With the cervix well down and on the stretch the submucous tissues between the cervix and urethral opening are well infiltrated (Fig. 113), carrying the infiltration well out laterally to permit free exposure of the deep fascia in the subsequent dissections.

The **cervix** is anesthetized by drawing it down with a volsellum and making a free submucous infiltration around its neck, at its junction with the vaginal vault. In making this injection in front care should be exercised not to injure the bladder; the point of the descent of this organ and its proximity to the vaginal vault had best be located beforehand by a sound passed within the bladder. A long fine needle with large syringe is now used, the needle directed up in the long axis of the cervix on each side, just within the cervical tissues, to a depth of from 1 to 2 inches, and about ½ ounce of 0.50 per cent. novocain injected on each side, injecting as the needle is advanced.

After a few minutes this will permit a fair degree of dilatation, when trachelorrhaphy can be done, combined with a curettage of the cervical canal. Curettage of the body of the uterus is not often very satisfactory under local anesthesia when thoroughly done, but a limited amount is often well tolerated after the above injections, or a few whiffs of ether can be given just at this point in the operation.

Ruge describes the method of anesthesia for a vaginal hysterectomy as follows:

"A long needle is introduced to one side of the cervix to a depth of 4 to 5 cm., being directed in a somewhat lateral direction, in order to strike the nerve-trunks before they have undergone their ultimate division. If the needle is introduced slowly, most vessels and any coils of intestines with which it may come in contact will be pushed aside and not injured. When the needle has been satisfactorily introduced, the 10 c.c. syringe is attached and the solution injected as the needle is withdrawn.

"The process is repeated on the opposite side, then at two points on the anterior and two on the posterior vaginal vault injections of 3 to 5 c.c. are made. In the anterior vaginal vault it is necessary to introduce the needle 2 to 3 cm. deep, but in the posterior just through the mucosa.

"Vesical symptoms are controlled by using instillations to prevent pulling on the viscus from being unpleasant."

This operation has never been performed under local anesthesia by the author, and it would seem somewhat questionable to pass a needle in any direction in which it might perforate the bowel. If the needle is fine and the solution injected as it is advanced the danger of injuring the ureter or vessels at these points is very slight, and if punctured with a fine needle no damage is likely to result, but we cannot feel the same about the intestines. It would seem safer to the author in doing this operation to first free the bladder from the uterus and open the peritoneum above, as was done in the case described later, then with a finger in the cavity the broad ligaments or their internal attachments can be infiltrated under the guidance of the eye and finger.

Thaler, in describing the technic for the **Dührssen-Bumm operation** of anterior hysterotomy, as done in Schauta's clinic for cases of placenta prævia, eclampsia, etc., where rapid delivery is indicated, states that the injection is made high up on the anterior lip of the cervix and to the right and left of the midline, well down into submucous tissue, about 1 cm.; the cervix is slit up to this point, when further injections are made into the anterior uterine wall as the procedure progresses. The use of adrenalin in the solution prevents hemorrhage.

The *female bladder* can be quite easily opened through the vagina by infiltrating above and in front of the cervix in the middle line, carrying the infiltration well down to the submucous tissue of the bladder. A sound is passed into the bladder and turned point down to present the bladder at this point; unless the bladder is inflamed or hypersensitive it is not necessary to anesthetize it; when necessary it is done in the same way recommended for the male bladder. The infiltration of the submucous tissues over the point of incision is sufficient to anesthetize the mucosa here, and its incision causes no discomfort.

Operations for vesicovaginal fistula, if easily accessible, can be performed in this same way by infiltrating around the opening, the infiltration facilitating the separation of the bladder from the vaginal wall.

The **female urethra** is easily anesthetized by a film of cotton placed around the end of a probe, and saturated with a 5 or 10 per cent. solution of novocain passed into the urethra and allowed to remain for a few minutes.

Caruncles are easily extirpated by infiltrating around and beneath them; a swab with 10 per cent. solution can be used on the surface for a few minutes at the point at which the needle is entered.

The removal of Bartholin's glands or benign growths is quite easily performed by infiltration; also epitheliomata when superficial and of limited extent; malignant diseases of the cervix, uterus, or deeper parts should not be undertaken by these measures, but reserved for parasacral, spinal, or general anesthesia.

In operating upon the cervix and uterus, pulling down these parts to the vaginal outlet is attended with some discomfort, and should not be attempted where they are bound down by adhesions or fixed in the abdominal cavity, but in cases where these parts are well relaxed and freely movable operation can be quite satisfactorily undertaken.

Polypi can also be removed in this way, or even without anesthesia, as they have no sensation and the division of their pedicle is without pain. Where the parts can be well brought down, as in prolapse, the peritoneal cavity can be easily opened in front of the uterus, its fundus brought down, and any of the various fixation operations performed.

The following history illustrates an extensive operation upon these parts on a favorable subject:

Mrs. H., aged sixty-three, a stout lady with flabby and relaxed tissues, had been suffering with a complete prolapse of the uterus with marked rectocele and cystocele for the past fifteen years, the result of extensive lacerations during the child-bearing period. The bladder and rectum hung down from the vagina like two distended pouches, the uterus protruding from between them, making it necessary for her to replace it before she could sit down. She suffered the usual disturbances with the bladder and rectum as well as the other symptoms common to this condition; her dread of an anesthetic had forced her to tolerate these discomforts for many years. When I assured her, much to her surprise, that she could be easily and painlessly operated on under local anesthesia she embraced the opportunity readily.

The Operation.—The anterior vaginal wall in the midline, between the cervix and meatus, was first infiltrated and then incised down to the bladder wall; the infiltration and dissection was carried well out to the sides to freely separate the bladder from the surrounding parts; the same was done with its attachment to the uterus. The peritoneal cavity between the bladder and uterus was then opened, and, with one finger holding up the bladder, a long needle was used to inject a small area on the anterior surface of the uterus to prevent any pain which might be caused by catching the organ at this point with tenaculum forceps; the uterus was then secured and anteverted, so as to bring its fundus forward into the wound in the vagina; it was held here while the bladder was pushed up well into the cavity and behind it, and the fundus secured to the deep fascia behind the pubis; thus firmly anchored in this position it prevented the descent of the bladder and was itself prevented from retroverting, the first step necessary for its descent; the superficial parts were then closed. The perineum was now dealt with by commencing at the vaginal outlet and making a rather free submucous infiltration, extending well back in the middle line and well out on each side. The mucous membrane was then incised from side to side at the vaginal outlet and dissected up freely, this step being markedly facilitated by the infiltration which separated the rectum from the vaginal mucosa and greatly lessened the danger of opening the rectum so likely to happen in bad cases of this kind. The muscles in the vaginal walls were next sought for, and their atropic remnants approximated in the middle line, restoring a fairly satisfactory perineum and normal vaginal outlet. After trimming away the excess of vaginal mucosa the wound was closed. This entire procedure was without pain and the convalescence without incident.

It is now six years since the operation was performed, During this interval I have heard from the patient repeatedly, and she has remained entirely well. The infiltration method was used for the above case instead of the regional injection of the pudic nerves, as the infiltration greatly facilitates the separation of the different planes of tissues in cases of this kind, and the work is more quickly and easily done than under a general anesthesia without the aid of infiltration.

Operations upon the **round ligaments** in the inguinal canal for purposes of shortening them by the Alexander method or any of its modifications is quite easily done under infiltration, and should be governed by the same indications as when operating under general anesthesia, that is, the free movability of the uterus and other internal parts.

Infiltration is first done over the external ring and along the course of the inguinal canal; the superficial parts are incised, and the external ring and aponeurosis of the external oblique exposed; an injection is then made through the fibers of the external oblique into the inguinal canal, the canal then opened, and round ligaments located and freed. As it is being drawn through the internal ring, the tissues around this point down to the peritoneum are infiltrated with a fine needle, bearing in mind the position of the deep epigastric artery. By proceeding in this way the drawing of the ligament through the internal ring and stripping back of the peritoneum causes no pain.

Suprapubic cystotomy is performed the same in the female as in the male, but it is easier to perform cystotomy by the vaginal route, as has already been described, and if to be left open for drainage it is more convenient, as the patient can wear a urinal and not be continually soiled as with a suprapubic opening.

In operating within the abdominal cavity only a limited number of operations are feasible, and only then under favorable conditions, with free movability of the parts. In the presence of adhesions or inflammation about the tubes or ovaries the case should be operated by other methods. The abdomen is opened in the middle line after infiltration, first of the skin and subcutaneous tissues, then passing the needle down to the interval between the recti muscles; after these have been opened the subperitoneal tissue, which is quite relaxed at this point, is now infiltrated, this infiltration anesthetizing the peritoneum. (See chapter on Abdominal Operations.) After a few minutes this is opened. Retractors should be gently used, as any undue traction on the abdominal wall will cause pain. The uterus should be raised into the wound with the hand, not with volsellum or other toothed instruments, unless the point at which they are applied has first been infiltrated. A variety of operations are now possible—

salpingo-oöphorectomy, when these parts are free, by lightly infiltrating the broad ligaments, pelvic and uterine attachments, of these parts along the proposed line of incision on their anterior and posterior surfaces (Fig. 114); pedunculated ovarian cysts, when not adherent, are quite easily removed in the same way; subperitoneal fibroids removed, or resection of the body of the uterus performed by first lightly infiltrating the proposed line of incision; this can often be omitted, as the uterus has very little sensation; ventrosuspension, or fixation, is quite easily done, and usually without any discomfort; if any is experienced, light infiltration can be resorted to on the fundus, where the sutures are to be placed.

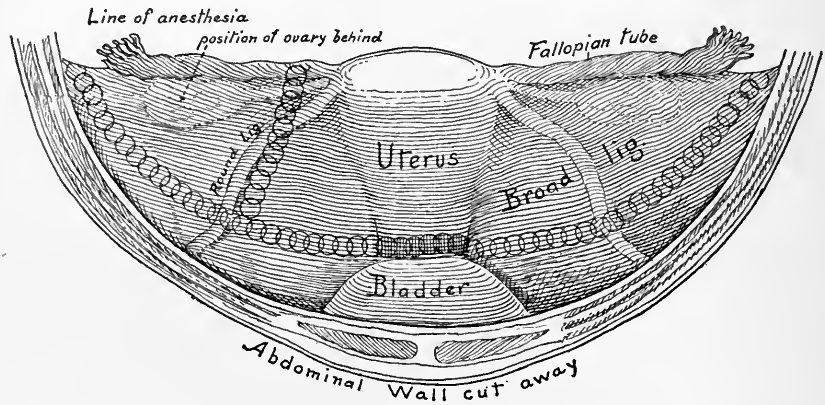

Fig. 114.—Shows uterus, broad ligament, and attachments. Series of circles shows line of infiltration beneath anterior peritoneal fold of broad ligament. Where this line crosses uterus, in shaded portion, infiltration is more liberal. On left is seen small line joining longer one at about right angles, and shows area infiltrated when limited to one side as in the case of removal of tube and ovary only. Similar infiltrations are made posteriorly, as described in text.

Intra-abdominal operations for purposes of shortening the round ligaments may be done under local anesthesia, but it would be preferable to do an external Alexander, unless the cavity has already been opened. The ligaments may be doubled on themselves and sutured, using light infiltration at these points if necessary or fixed behind the uterus. The various operations of drawing the ligaments through the abdominal wall, at or near the internal ring, may also be done by first raising the abdominal wall gently and infiltrating the peritoneum and subperitoneal tissue around these points, as well as the tract through which the forceps will be passed through the abdominal wall in grasping the ligaments, remembering the location in this neighborhood of the deep epigastric artery and vein and making the injection only when advancing or withdrawing the needle.

Cesarean section can be performed under local methods when other forms of anesthesia are contra-indicated.

The following is from a paper by Drs. R. K. Smith and Jacob Schwarz, of San Francisco, read at the San Francisco Medical Society, May, 1910, and amply describes the procedure. In both cases there was a contracted pelvis with contra-indications to general anesthesia; in both cases mother and child survived:

"The solution used was novocain (0.50 per cent.), to each 10 c.c. of which was added 1 drop of adrenalin solution (1:1000). This solution was freshly made and boiled for five minutes before using. Two points, one 9 cm. above the umbilicus and the other a like distance below it in the median line, were infiltrated with a drop of the solution, and from these, as points of departure, the solution was injected about a diamond-shaped area subcutaneously and then subfascially. The line of the incision was not infiltrated in either of these cases. The amount of solution used was about 75 c.c. in Case 1 and 60 c.c. in Case 2, and it is my belief that a smaller amount might be sufficient.

"The operation was carried out as follows: Incision through the abdominal wall, 15 cm. long, with its center opposite the umbilicus, peritoneal cavity packed off with gauze, uterus incised with knife down to the placenta for about 1 inch, and the incision rapidly enlarged with scissors to about 15 cm.; the placenta pushed aside, the membranes ruptured, the child grasped by its feet and extracted, and the placenta removed from the uterus while it was *in situ;* the uterus lifted out of the abdominal cavity and surrounded by pads dipped in hot saline solution. In Case 1 the hand was introduced through the incision into the cavity of the uterus and one finger passed through the cervix, this was followed by a Goodell dilator, which was carried through the cervix and stretched open. This was not necessary in Case 2, operated upon on April 4, 1910, as the cervix was completely dilated before beginning the operation. The uterine incision was closed with deep and superficial interrupted sutures of chromic catgut, and these buried with a continuous Lembert suture of the peritoneum, the peritoneal cavity wiped out, and the wound closed."

CHAPTER XX

SPINAL ANALGESIA AND EPIDURAL INJECTIONS

SPINAL analgesia[1] had its beginning in the experiments of Dr. J. Leonard Corning, which were published in the "New York Medical Journal," October 31, 1885.

Corning first experimented on a dog, injecting a 2 per cent. cocain solution in the lower dorsal region, and obtained paralysis of motion and sensation in about five minutes, followed by complete recovery, without noticeable ill effects. He next injected a man suffering from sexual disturbances, using 30 min. of a 3 per cent. cocain solution, between the eleventh and twelfth dorsal vertebræ. There was no result in eight minutes, and the injection was repeated, producing anesthesia and incoördination of the lower extremities. The anesthesia was complete, as proved by various tests; urethral sounds were passed and other manipulations used about the genitalia. This was done in the office. In an hour the patient was able to leave with sensation still impaired, but otherwise no worse for his experience.

Corning, in concluding, states:

"Whether the method will ever find an application as a substitute for etherization in genito-urinary or other branches of surgery further experiences alone can show. Be the destiny of the observation what it may, it has seemed to me, on the whole, worth recording."

Corning was not a surgeon, and did not have the opportunities of applying this method further, and, as it did not attract favorable

[1] To Prof. R. Matas is probably due the credit of having performed the first operation under spinal analgesia in America. An operation for hemorrhoids was performed upon a young colored male in the Charity Hospital Clinic on December 18, 1899, Profs. F. A. Larue and H. B. Gessner assisting, with the author, then an intern in his service. The spinal canal was reached between the fourth and fifth lumbar vertebræ, with escape of spinal fluid; two injections were made five minutes apart, each about 1 c.c. of 1 per cent. cocain in normal salt solution; anesthesia immediately followed, and was complete from the waist-line down, with a gradually lessening degree of anesthesia reaching as far up as the neck. Some reaction followed the operation (chill, nausea, vomiting, and temperature), which shortly subsided, the patient making a good recovery.

An unsuccessful attempt had previously been made on November 10th with beta-eucain, but the resulting anesthesia was unsatisfactory. (Jour. Amer. Med. Assoc., December 30, 1899, p. 1659.)

attention at the time on the part of his American confrères, it was accordingly dropped until revived some years later by Continental surgeons.

In these experiments Corning had aimed to inject the fluid between the spinous processes, and permit it to be carried by the veins to the cord. Corning deals with the subject again in 1888, and in 1894 appeared his book on "Pain in its Neuropathological, Diagnostic, Medicolegal, and Neurotherapeutic Relations."

Corning's intention was to make the injection into the neighborhood of the cord; he did not aim to puncture the membranes; whether this occurred or not, he must at least have gotten within the canal, else it is hard to understand how anesthesia resulted, as it could not take place from diffusion, as the cord is well isolated from its perivertebral surroundings, and it is not at all likely that it could be carried to the cord by the surrounding circulation in any effective quantity. This, then, was the first attempt at a paravertebral injection, but was, no doubt, intraspinal if not intrameningeal.

Real interest in the method was aroused in 1891 by the lumbar puncture of Quincke, which was developed largely by the activity of Continental surgeons, notably by Bier and Tuffier.

Bier, with admirable courage, first tried the method upon himself, to more accurately observe its effects. The anesthesia was satisfactory. It was followed by a slight headache.

The method was soon in general use on the Continent and in America, but did not so early gain followers in England, probably due to conservatism, as well as to the fact that here general anesthesia had reached a high plane of development, being regarded as a specialty and given largely by professional anesthetists.

The wave of enthusiasm which followed the general introduction of the method has been followed by a reaction, and we find, upon the study of the large number of statistics which are now available, that the method cannot compare in safety at the present stage of its development with general anesthesia. If it is to compete with general anesthesia it must be by the introduction of some other agents or methods than those now in use.

It has, however, a decided field of usefulness in selected cases and under certain conditions.

A thorough understanding of spinal anesthesia is not possible without the consideration of certain anatomic, mechanical, and physiologic facts.

ANATOMY

The spinal cord ends opposite the lower border of the first lumbar vertebra (in the child, opposite the third lumbar), in the filum terminalis, which is given off from the conus terminalis (Fig. 115).

The spinal cord and cauda equina are surrounded by the same membranes as the brain—viz., dura, arachnoid, and pia.

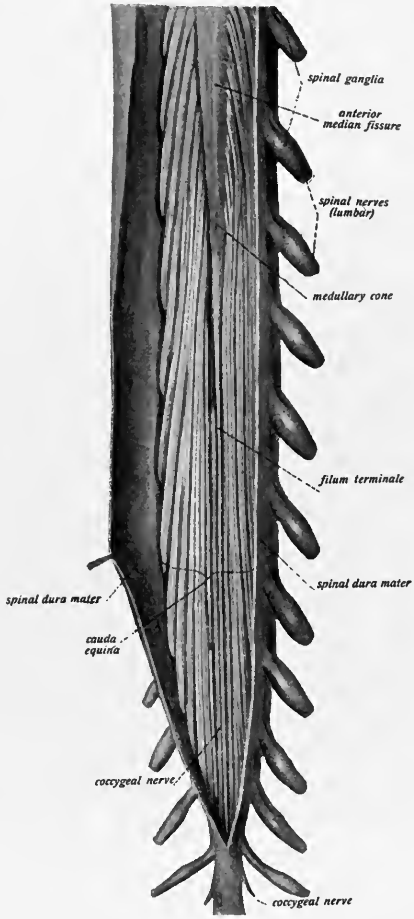

Fig. 115.—An anterior view of the lower portion of the spinal cord. The dura mater has been divided longitudinally. (Sobotta and McMurrich.)

The dura, continuous with that which invests the brain, is a loose sheath, not attached to the bony framework of the spinal canal, but separated from it by loose areolar tissue containing a plexus of veins which are most numerous in front and on the sides, less so posteriorly. The dural sac terminates at the third sacral segment. It is attached by fibrous slips to the posterior common ligament, and is largest in the cervical and lumbar regions. At the beginning of the cauda equina the nerves lie in bundles on each side, with an appreciable interval between, through which runs the filum terminale. They approach each other lower in the lumbar region and surround the filum, which continues to the termination of the dural sac and blends with its attachment to the periosteum of the coccyx.

On the side of the cord and in the cauda equina the motor nerves lie in front, the sensory behind, on the side of the cord, separated by the ligamentum denticulatum in the cauda equina, still separated by an irregular cribriform membrane. This accounts for the motor nerves not being more regularly reached and affected by the anesthetic fluid in spinal puncture.

The arachnoid is separated from the dura by a slight interval, the subdural space.

Within the arachnoid membrane, the subarachnoid space, is the cerebrospinal fluid. This space is of considerable size and is largest at the lower part of the spinal canal. Within this space is the cauda equina. This space communicates above, through the foramen of Magendie, with the subarachnoid and general ventricular cavity of the brain. The space is partially divided by a longitudinal cribriform membrane, connecting the dura with the pia membrane.

It will be seen from the above description, as well as by consulting Fig. 115, that the most favorable site for the spinal puncture is the midlumbar region, for here the cauda equina lies in two bundles on each side of the middle line, and is less likely to be injured by a needle introduced at this point, which has been termed the "cisterna terminalis" by Donitz.

PHYSICAL AND PHYSIOLOGIC FACTORS INFLUENCING THE MOVEMENTS OF THE CEREBROSPINAL FLUID

It is generally believed that the cerebrospinal fluid moves freely in and out of the spinal canal with changes in the position of the body, that is, from the erect to the recumbent or inverted positions. The tension within the membranes must certainly be influenced by such changes, but I doubt that there is as free movement to and from the cranial cavity as we have been led to believe, for the following reasons:

The spinal canal is surrounded by an unyielding bony framework, and is uninfluenced by pressure upon it from the outside. The space within the canal must always be filled, a vacuum cannot exist.

If the body is inverted and the fluid runs into the cranial cavity, what is to take its place? The position is certainly not favorable for an engorgement of the venous plexuses around the canal; besides, the inverted position readily congests the large venous cavities within the skull and must increase the pressure here, making less room for the entrance of the spinal fluid. That such change of position does influence the pressure within the canal we must readily admit, but that there is any extensive to-and-fro movement is no doubt an error, but probably takes place to only a limited extent.

Investigations made upon the open canal of animals is of no value, for here the atmospheric pressure which enters through the opening permits the fluid to be displaced. The results of experiments upon animals cannot be applied to man. The dog has only about 6 c.c. of cerebrospinal fluid throughout the entire subarachnoid space, while in the monkey it is still less, and the cord and meninges fill the canal closely.

Further evidence upon this subject has been furnished by the very thorough investigations of A. E. Barker, from which I will later quote rather freely. (See Isotonic Qualities and Specific Gravity of Anesthetic Solutions and Movements of Cerebrospinal Fluid.)

ANESTHETIC AGENTS

Nearly all agents that have been used for local anesthesia have at some time or other been used for spinal analgesia. That none of these have proved thoroughly satisfactory accounts for the change from one to the other.

The advent of spinal anesthesia was before the introduction of some of the more recently discovered anesthetics.

Cocain was the first used, and was soon found to be too dangerous to justify its continuance by the majority of operators, but is still used by some few; 6 to 10 min. of a 2 to 4 per cent. solution is the strength usually employed.

Beta-eucain was employed, but was found unsatisfactory.

Stovain next claimed attention. It was introduced by Fourneau in 1904, and was first used by Chaput and Tuffier, and for a time became the agent most in use. It possessed some noteworthy properties. Its solutions were able to stand boiling without decomposition, and it possessed mild antiseptic properties. It is freely soluble in water and is of a feeble acid reaction. It has a more marked effect upon motor nerves than has cocain, paralyzing all the sphincters—anal, uterine and vesical—as well as producing general muscular relaxation when it comes in contact with the motor roots. This is of decided advantage in operating upon the abdomen and perineum; in laparotomy it permits wide retraction of the abdominal muscles, which greatly facilitates the work. This paralyzing action on the motor nerves may reach high enough to effect the respiratory nerves or even the centers in the medulla, and thus add a grave danger to its action. It is somewhat irritating to the tissues as well as to the nerve-fibers.

Alypin has been used, but has been discarded as being unsuited for use in the spinal canal.

Novocain, the least toxic (six times less than cocain) and least irritating of all the local anesthetics, has been applied to spinal anesthesia, but has not proved generally satisfactory, and is, accordingly, less used at the present time. Its action on motor nerves is much less marked than that of stovain, and there is, accordingly, less danger of respiratory paralysis. The usual dose is about 1 gr.

Tropococain is the agent most popular at the present time, and is being generally adopted by most operators. Less unfavorable results have been reported from its use. From ½ to 1 gr. is the dose usually employed. The smaller dose for peripheral operations, the larger dose for abdominal operations and those upon the trunk.

The *method of preparing the various agents* differs largely in the hands of different operators.

Most operators prefer to use 5 or 10 per cent. strengths in sterile solutions of the various agents, using a sufficient number of minims to give the desired strength of the drug. The solution used may contain a definite quantity of sodium chlorid to make it isotonic with the cerebrospinal fluid. This may be injected directly into the spinal cord, or, as practiced by Bier, and Tuffier, at present, the required quantity of the solution is placed in the syringe and an equal quantity of cerebrospinal fluid drawn into the syringe before injecting into the canal. Similarly, the dry sterile salt may be placed in the barrel of the syringe and dissolved in the aspirated fluid before injection. This last method is becoming more popular.

Tablets of the various drugs used in the usual strength employed, with or without adrenalin, but usually containing a small amount of sodium chlorid, are placed on the market by various manufacturers.

The tablets are sterilized and in sterile containers, and when mixed with a definite quantity of sterile water produce a solution isotonic with the cerebrospinal fluid.

The keeping qualities of the tablets for any length of time is somewhat in question, particularly if they contain adrenalin preparations; also the power of rendering and keeping them sterile.

Sterile ampules, similar to those used for serums, each containing the recognized dose of the agent in use, are put up by the various manufacturers in this country and abroad. It is a convenient and safe method, provided the contents of the ampule can be thoroughly depended upon. When about to be used they are first immersed in a strong antiseptic solution—bichlorid, carbolic acid, or alcohol—before being opened by the operator, who opens them just before he is ready to withdraw their contents.

ISOTONIC QUALITIES AND SPECIFIC GRAVITY OF ANESTHETIC SOLUTIONS AND THEIR MOVEMENTS WITHIN THE CANAL

It is absolutely necessary that the injected fluid be as nearly isotonic with the cerebrospinal fluid and as free from irritating qualities as possible. This, as determined by the usual physical tests to which the liquid is subjected, is not reliable, as proved by the investigations of Dr. A. E. Barker. As the subject is so thoroughly handled by him, I will give it in his own words:

"To secure isotonicity might appear an easy matter at first sight, but from my observations is not so. A 5 per cent. solution of stovain in distilled water freezes at about 0.58° C., almost the same point as that of blood-serum. If this were the only test applied it ought to be isotonic with the blood. But if a drop of blood be added to a little 4 or 5 per cent. solution of stovain under the microscope, in five minutes the red corpuscles swell and become pale, in ten minutes are almost invisible, and in twenty minutes are all gone. The same is seen if a drop of blood is added to 5 c.c. of these solutions in a test-tube; but here the changes are apparently slower, as at the end of an hour a few swollen, pale cells can still be seen, but in an hour and a half they are all invisible.

"In a really isotonic fluid, such as normal saline (0.91 per cent. sodium chlorid) or normal glucose solution (5 per cent. of glucose), the cells are seen in twenty-four or forty-eight hours unchanged.

"The hemolytic action of stovain, which I have tested in every way I could think of, appears hitherto to have escaped notice. It has been supposed too readily that if its 5 per cent. solution has the same freezing-point as the blood it would be isotonic with it, but, as we have seen, the blood-cells are destroyed by it. Even the solution prepared for Bier, in the belief that it was isotonic (stovain, 4 per cent.; sodium chlorid, 0.11 per cent.; epirenin borate, .01 per cent.), I find to be markedly hemolytic, tested as above on the microscopic slide and in a test-tube. But further than this I have found that if to an isotonic solution of sodium chlorid or glucose, in which blood-cells are seen to be unaltered at the end of twenty-four hours, 5 per cent. of stovain be now added, the cells rapidly swell, grow pale, and disappear, no trace of them being found in one and one-half hours. No combination of sodium chlorid or glucose with stovain which I have made hitherto has prevented this hemolytic action of the drug.

"Furthermore, it may be added that I have added a 5 per cent. solution of stovain with a freezing-point of —0.58° C. to an equal part of cerebrospinal fluid, and found in this compound destruction of all blood-cells in about one hour. Nothing is seen then under the microscope but débris and oily globules. This is as much as to say that a 5 per cent. solution of stovain injected into the spinal cord would be hemolytic too.

"Leaving the point of osmotic tension for the present, and admitting that we have no evidence to show that the small amount of the drug injected has produced any injurious effect as the result of its hemolytic action, there are other physical qualities which an injected compound may possess which also appear to have attracted little or no attention.

"There are three ways in which an analgesic fluid injected in the second lumbar interspace can make its direct effects felt in the mid-dorsal region, or even higher, as is sometimes the case in this procedure. These are either:

"(1) By slow diffusion; (2) by shifting of the whole column of cerebrospinal fluid, in which it is suspended upward; or (3) by gravitation, if the injected compound be distinctly heavier than the liquor spinalis.

"(1) Diffusion alone of one fluid in another is a slow process, and, as we shall see, is unlikely to be the mode of spread of the injected fluid in this procedure.

"(2) Bier and his followers have aimed at shifting the injected compound upward or downward, with the whole mass of the cerebrospinal fluid, by raising or depressing the pelvis. That the cerebrospinal fluid does recede somewhat toward the head on elevation of the pelvis is undoubted, but it is hard to imagine its doing so to such an extent as to carry with it a cloud of fluid lighter than itself from the second lumbar to the fifth dorsal vertebræ. I venture to think that with such a fluid as he has used, whose specific gravity is 1.0058, suspended in the liquor spinalis, whose specific gravity is 1.0079, that what he has achieved by elevation of the pelvis has rather been a more rapid diffusion of the injected drug, due to the consequent oscillation of the spinal fluid, aided perhaps by vascular pulsation.

"(3) There remains, then, the third possibility, namely, that an injected compound heavier than the liquor spinalis may be affected by gravity, and sink through the latter in a way quite different to the behavior of a fluid of less specific gravity such as that just referred to. It is easy to observe the behavior of one fluid injected slowly into another through a needle if the fluid be colored with anilin blue. Provided that each be of the same temperature and specific gravity, the injected liquid forms at first a distinct blue cloud, which slowly diffuses itself through the whole mass, into which it enters if the latter be in a state of rest. On the other hand, if the injected fluid be of the same temperature, but of much greater specific gravity, it sinks rapidly from the point of the needle in a definite stream to the bottom of the second fluid, and remains there as a distinct stratum, without diffusion for a time, proportionate to its density and viscidity.

"The densities of the only three compounds used in our series compared with that of the cerebrospinal fluid are as follows at 15° to 17° C.:

"Liquor spinalis (from three patients, mixed fresh)	=	1.0070
1. Chaput's Compound:		
Stovain, 10 per cent.; NaCl, 10 per cent., distilled water, 80 per cent.	=	1.0831
2. Writer's Compound:		
Stovain, 10 per cent.; glucose, 5 per cent.; distilled water, 85 per cent.	=	1.0300
3. Bier's Compound:		
Stovain, 4 per cent.; NaCl, 0.11 per cent.; eperenin borate, 0.01	=	1.0058

"All these are, as we have seen, more or less hemolytic, tested by immersion in them of blood-cells, the first much the most so (three minutes), the two last about the same in this respect (one to one and one-half hours). The first, a very heavy fluid, in which the common salt is present at the point of saturation at ordinary temperature, has long been used by Chaput and Tuffier with good results, but apparently for other reasons than its density. Their grounds for employing such a high percentage of common salt, as stated by the former, were that M. Billon (Paris), who prepared the compound for them, hoped thereby to prevent the splitting up of the stovain by the alkalinity of the spinal fluid. That it does not do so is evident to any one who adds some of their compound to the cerebrospinal fluid drawn off. It will then be seen that the latter becomes almost at once milky. If a little of the fluid in this state be examined under the microscope it will be seen that this turbidity is due to the presence of small globules of an oily nature, which, in the course of time, run together into larger and larger globules.

"A solution of 5 per cent. pure glucose in distilled water freezes at about 0.56° C., and is really isotonic, producing no effect on the blood or tissue cells in twenty-four hours. Five per cent. stovain in normal solution gives a specific gravity of 1.0126. The hemolytic action of stovain cannot be avoided.

"Alypin,	5 per cent.;	distilled water, 95 per cent.;	sp. gr., 1.0036;	freezing-point, 0.53
Novocain,	5 per cent.;	distilled water, 95 per cent.;	sp. gr., 1.0090;	freezing-point, 0.555
Tropococain,	5 per cent.;	distilled water, 95 per cent.;	sp. gr., 1.0160;	freezing-point, 0.545
Stovain,	5 per cent.;	distilled water, 95 per cent.;	sp. gr., 1.0064;	freezing-point, 0.585
Cerebrospinal fluid,			sp. gr., 1.0070;	freezing-point, 0.56
Blood-serum,				freezing-point, 0.56

"Drawing conclusions from the above, these fluids should behave differently.

"Tropacocain, with its high specific gravity, should sink. The uniformly good results obtained by many with this agent may be due

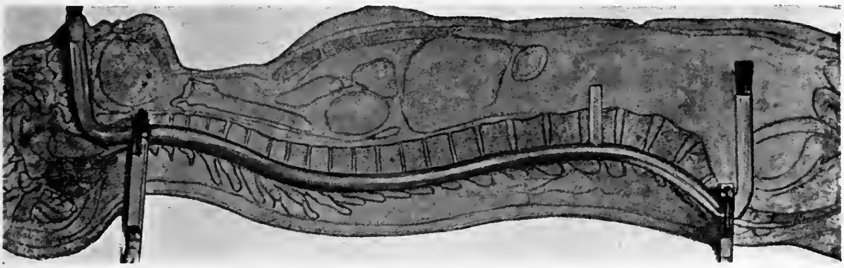

Fig. 116.—A photograph of a tracing from Braune's well-known plate of a frozen mesial section of the female cadaver lying level. Details omitted for the sake of clearness. Over the spinal canal, and following its curves accurately, is a glass tube filled with saline solution of the same specific gravity as that of the cerebrospinal fluid = 1.0070. Through the middle vertical arm over the second lumbar interspace the hollow needle has been introduced into the curved tube, and 1 c.c. of Chaput's solution (specific gravity 1.0831) colored with methyl-violet has been slowly injected. This has run down rapidly into the dorsal curve, and at the end of two minutes is seen as a dark stratum opposite the fifth and sixth dorsal vertebræ. The dark area in the cervical portion of the tube is a shadow on the glass. (Barker, in "Brit. Med. Jour.")

partly to its physical properties, perhaps more so than to any specific action on nervous structures. Allowance should be made for the behavior of any fluid after injection and during operation on the patient.

"By glass tubes bent to conform to the spinal canal, filled with salt solution (specific gravity 1.0070), and having an opening to conform with the position of the second lumbar space, the action of different solutions *in vitro* has been studied. Of course, it is conceded that certain vital phenomena would modify the conditions somewhat, but, in the main, what occurs here furnishes us with fairly correct evidence on most of the scientific physical points connected with these injections in the living patient (Figs. 116–122).

"Each of the compounds to be colored with the same quantity of methyl-violet, and used at the ordinary temperature of the air and fluid filling the tube. It has been gently passed into the latter, as

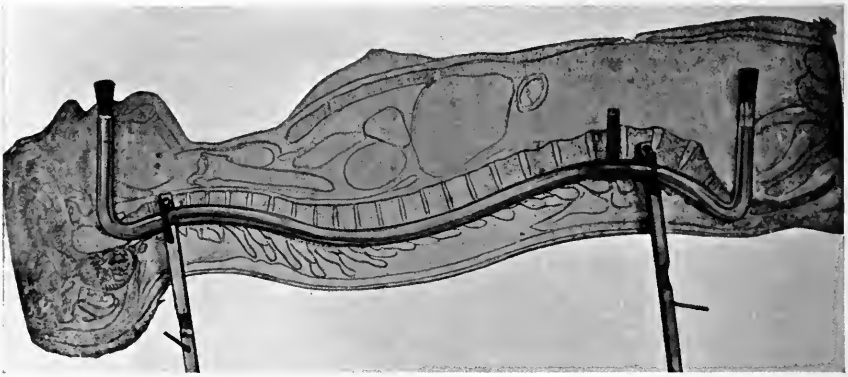

Fig. 117.—Same as Fig. 116, but with the pelvis raised 3 inches from the level. In this case 1 c.c. of Bier's solution has been similarly injected colored. This, having a specific gravity of only 1.0058, has not altered its position, except that, being lighter than cerebrospinal fluid (1.0070), it has risen in the vertical arm. In this position it remains for a long time undiffused. (Barker, in "Brit. Med. Jour.")

on the living patient, with the usual needle through the vertical arm over the second lumbar interspace. From frozen sections of the cadaver, lying on its back, it may be seen that the highest point of the canal from the level is in the cervical region. Next to this a point between the third and fourth lumbar—that is, the point at which the puncture for spinal analgesia is made. From this last point the dural canal slopes downward in both directions. The caudal incline ends for the dura opposite the third sacral vertebra. The cephalic incline slopes from the point of puncture downward as far as the fifth or sixth dorsal vertebra, when it begins to run up again to reach its highest point at the third cervical vertebra. With the head thrown downward on a pillow, as the writer believes it should always be during intradural injections with heavy fluids, the foramen magnum would be the highest point in the spinal canal. These curves vary considerably in individuals and at different ages, but the above may be taken as generally correct. Now, if it were possible to punc-

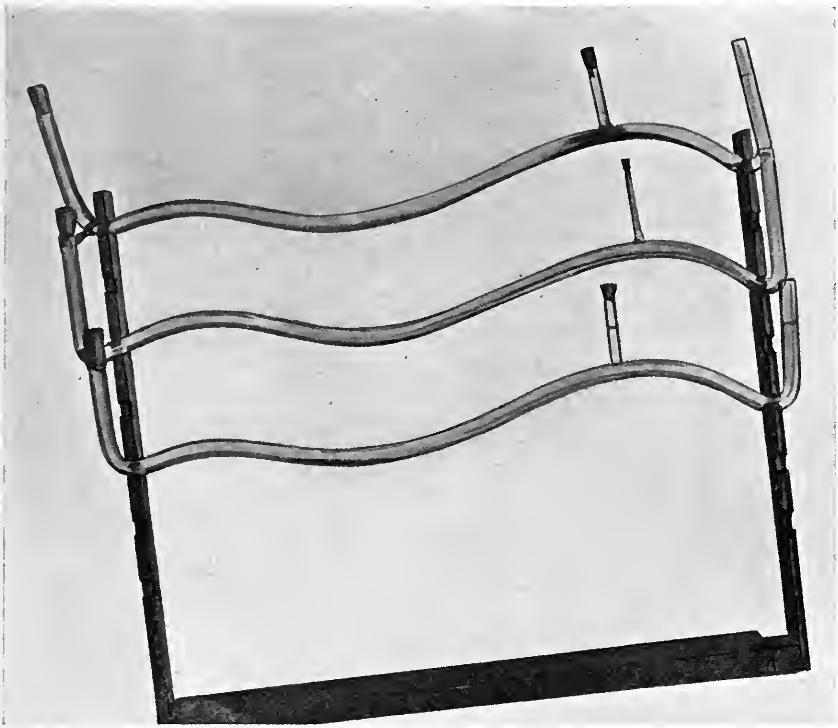

Fig. 118.—Three tubes, as in Figs. 116 and 117, but without the tracing behind. Into the top one Bier's light solution has been injected, into the middle tube glucose stovain (author's solution, specific gravity 1.0300), and into the lower tube Chaput's. The pelvis has been raised 3 inches as before. In the top tube Bier's compound, being lighter than the fluid in the canal, has remained stationary; the glucose-stovain (1.0300) is still running down. Chaput's, the heaviest compound, has already reached the dorsal curve and is at rest. Photographed two minutes after infection. (Barker, in "Brit. Med. Jour.")

ture the lumbar sac from behind, at the classical point, with the patient lying on the back perfectly horizontal, a liquid heavier than the spinal fluid would always flow for the greater part from the injection needle toward the dorsal curve and settle in a layer about the fifth dorsal spine, while some of it would gravitate toward the caudal end. This is actually what happens when the experiment is made with the glass tube bent accurately to the curves of the spinal canal. But in the living body there are practical difficulties in penetrating from behind with the patient supine. However, if the injection be made while the patient lies on the side (or face), as I have occasionally done, and he then turns over on the back with the head thrown forward, a heavy fluid should take the same course. That it does so is almost proved by the regularity with which the analgesia produced

Fig. 119.—Sitting position for puncture when analgesia of the perineum is required. The line from iliac crest to crest crosses the fourth lumbar spinous process, above which the needle is entered. The patient is then gently laid on his back with the head and neck well raised, all unnecessary movement being avoided. From a photograph by Dr. E. Worrall. (Barker, in "Brit. Med. Jour.")

by the Chaput heavy saline stovain-sodium-chlorid compound or the writer's stovain-glucose one, though not quite so heavy (see above), rises to about the episternal notch or a little higher—that is, the region supplied by the sixth and seventh dorsal nerves. This varies a little, according as the head and neck are raised, and so the dorsal curve increases. This was so frequently observed in the second 50 cases, where the glucose-stovain compound was alone used, as to be remarkable. Of course this may be modified somewhat by raising the pelvis a little, as has usually been done, to hasten the flow of the

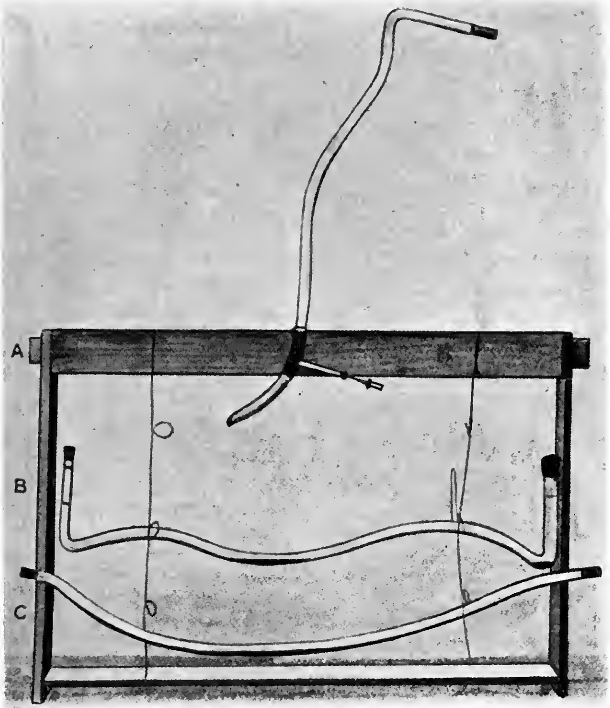

Fig. 120.—Glass tubes accurately bent to curves of spine, and filled with solution of sodium chlorid of the same specific gravity (1.0070) as that of the cerebrospinal fluid. A, Sitting position. Tube curved to the line of the dural sac from occiput to caudal termination (frozen section, Braun). This has been injected with 1 c.c. of our heavy analgesic compound (specific gravity 1.0230) of the same temperature as the solution in the tube. The injection was previously colored with 1 per cent. methyl-violet. In the photograph taken two to three minutes later it is seen to have run down to the sacral sac and to remain unmixed there. In the living subject subsequently laid on the back it would again flow a very little with the cerebrospinal fluid toward the head. B, The same, quite horizontal. Shows the injection pooled in the dorsal curve two minutes after introduction in the second lumbar space. A little has run down into the sacral sac. Of course, the patient can never be injected actually on the back for practical reasons. C, Tube bent to a tracing of the lateral curve with head and pelvis raised before injection, as in Fig. 121. The injection is seen collected in a pool about the sixth and seventh dorsal vertebræ two minutes after introduction through the second lumbar interspace. This curve is greater than usual, but represents what increase may be produced in it by inclining the back a little toward the operator when the patient lies on the side, as in Fig. 121. From a photograph by Dr. E. Worrall. (Barker, in "Brit. Med. Jour.")

injected fluid toward the dorsal curve before it becomes diluted by diffusion. It must not be forgotten, however, that in raising the pelvis, while the head and neck are supported forward on a pillow, the lumbar curve is diminished, while that of the dorsum is increased. The pelvis would have to be raised very high indeed to bring the level of the dorsal curve at the fifth or sixth spine above that of the foramen magnum, with the head and neck bent forward, as described. There is, therefore, but little likelihood of the heavy compound reaching the medulla, or even into the cervical region at all. In some cases in Germany inversion has been carried to a very extreme degree, the head being unsupported, with the idea of displacing the whole mass of the cerebrospinal fluid toward the cranial cavity. But we must remem-

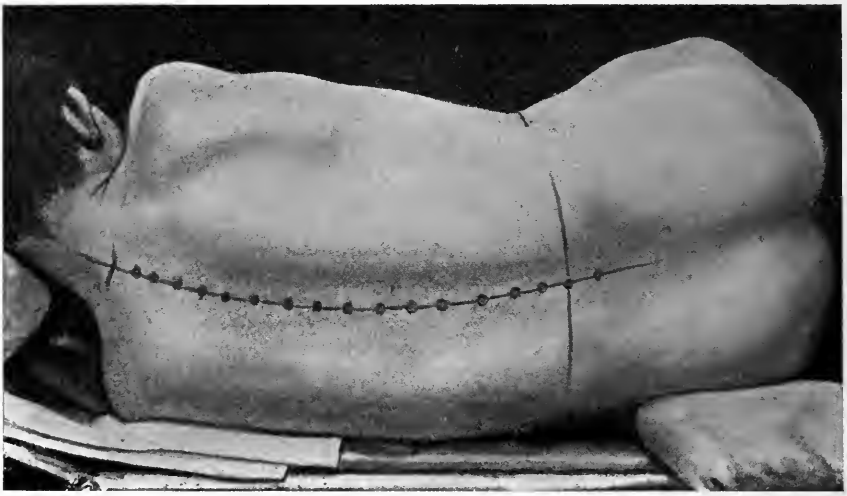

Fig. 121.—Photograph of patient ln typical position on side, with head and neck raised and a 1-inch padded board under the trochanter and iliac crest. The line of the iliac crests is given crossing the fourth lumbar spine. The level of the first cervical spine is seen to be well above that at which the injection compound "pools," and will be relatively higher when patient rolls on the back, as in Fig. 122. From a photograph by Dr. E. Worrall. (Barker, in "Brit. Med. Jour.")

ber that in these cases the compounds have usually been of low specific gravity, and in the case of Bier's (see above) actually lighter than the spinal fluid, so that it would not be likely to move as far as the neck by any oscillation of the column of the spinal fluid. There have been a few cases, however, both in France and Germany, in which the analgesia has extended over the whole head, as well as the rest of the body, without injury, but the details as to injection and pelvic elevation are not given. They were probably instances of diffusion helped by oscillation. Personally, I have never aimed at getting a higher analgesia than to the transverse nipple line. At the caudal curve the effects of a heavy compound can be limited in the same way by position. If the patient be seated on the edge of the operating-table, with his feet on a low chair and his back rounded, the heavy fluid injected at the second lumbar interspace at once tends to run into the sacral dura, as we see also in our tube experiments. Here it accumulates at the end of the dural sac, where it quickly affects the roots of the nerves supplying the parts about the anus and the perineum. This is seen so constantly, even where analgesia is less satisfactory in other parts, that it suggests that when the injection is made in the sitting position most of it makes its way caudally, and it requires much and immediate elevation of the pelvis and oscillation of the cerebrospinal fluid to dislodge it from the sacral

Fig. 122.—Photograph of the same patient gently rolled over on the back with the same relations of head, neck, and pelvis. The line across the fourth lumbar spine is seen, and also that the dorsal curve is deeper than the previous lateral curve. From a photograph by Dr. E. Worrall. (Barker, in "Brit. Med. Jour.")

sac. That is why I have thought it well in some cases to puncture with the patient lying face downward, with a hard pillow crosswise under the umbilicus, so as to decrease the lumbar curve. In this position a heavy fluid runs toward the head, and if after half a minute the patient roll over on the back and have a pillow placed under the head and neck pretty high, the injected fluid collects in the lower dorsal curve. This prone position, otherwise desirable, has the defect that the flow of cerebrospinal fluid is not so good unless the patient is told to raise his head and to bear down, but I think this can be overcome. But so great is the tendency for the injection fluid to be in part locked up in the sacral sac when the injection is done in the sitting position, that if I want the analgesia to reach to the border of the ribs for an abdominal operation, the patient is placed on the side with the knees drawn up as high as possible for puncture, and thus all the compound flows at once upward and all of it collects in the dorsal curve as the patient rolls over on the back. In such cases, where the patient remains for any time on the side after the puncture, we have noticed that the analgesia reaches higher up at the end of the operation on the side on which he has been lying. This seems to indicate clearly that the bulk of the compound has run along the roots on that side, but that it ultimately becomes segmental, affecting both sides, though still unequally."

Dr. Babcock, of Philadelphia, who has had extensive experience with spinal analgesia and has carried out some original investigations in this field, reverses the procedure of Barker and uses solutions of lighter specific gravity than the cerebrospinal fluid, using alcohol as the means of accomplishing this purpose. Stovain is the agent usually employed, and is put up in sterile ampules containing 10 per cent. alcohol.

The high lumbar puncture is usually employed, and the patient then placed in the inverted or Trendelenburg position, with the idea that the injected fluid being lighter will float upward in this position toward the caudal end of the dural sac.

The position undoubtedly has its advantages in any operation under spinal puncture. Should syncope occur it is best combated in this position, and should it be necessary to resort to artificial means of respiration the position is also favorable. However, certain objections may be found to the supposed movements of the injected fluid within the canal. The anesthetic fluid, if undisturbed by physical influences, should float upward and remain in that position, but the attraction of alcohol for water is so great that its influence must soon be exhausted, when the injected solution may then gravitate downward, thus producing first an ascent and then a descent of the injected fluid.

The action of glucose solutions, as suggested by Barker, is quite different, as the glucose is but slowly affected by the surrounding cerebrospinal fluid, and its anesthetic content quite thoroughly exhausted before the specific gravity is appreciably altered.

The influence of alcohol upon the injected fluid can be tested in the following way: Take two sections of glass tubing connected by a short joint of rubber tubing, stop one end and fill with a clear solution of known specific gravity, color a little solution of lighter specific gravity with methylene-blue, and add 10 per cent. alcohol; by injecting some of this second solution with a hypodermic syringe into the first, passing the needle through the rubber connection, its movements within the tube can be observed (Fig. 123); it will be seen to slightly ascend, when, after a few moments, some of it begins to gravitate downward, finally distributing itself over a wide area.

Fig. 123.—Author's simple device for testing movements of solutions of different specific gravity when injected one within the other, the injected solution being colored. Consists of two sections of glass tubing connected by a short section of rubber tubing.

Letting alone experimental tests of this kind, which cannot accurately represent conditions within the body, the proof must come from clinical experience. This has been satisfactory in Dr. Babcock's hands, although the method does not seem to have been extensively adopted.

INDICATIONS AND CONTRA-INDICATIONS

In its present stage of development all operative procedures, except in very exceptional cases, should be restricted to the perineum, external genitals, and lower extremities. While the lower abdominal walls are easily reached by the analgesic influence, the most likely operation here is for hernia, and, as this is so easily and safely done under local anesthesia, spinal puncture for that purpose should never be performed. While it has often been used for abdominal operations, particularly those of the lower abdomen, unless the analgesia is very high, complete analgesia is not secured, as the parietal peritoneum receives many nerve-fibers from the lower dorsal nerves, and the analgesia would have to be carried beyond the recognized safe limits to reach these nerves. Certain observers have claimed that the intestines become contracted under anesthesia with stovain and tropacocain; it, therefore, may have some claim in operations for ileus. Gray also states that the intestines become anemic. Its power also of relaxing the abdominal walls may be of aid here.

In all operations, from Poupart's ligament down, in which general anesthesia is contra-indicated, and which cannot be performed under local, regional, or vein anesthesia, then spinal analgesia should be considered. Such cases will be found in patients suffering from advanced pulmonary, cardiac, or renal disease. Particularly, in tuberculosis and cardiac disease should great care be exercised not to let the analgesic fluid reach the higher centers.

Spinal puncture has been demonstrated to be irritating to the kidneys, but less so than general anesthesia, consequently should have the preference here.

In diabetes Braun has observed coma to follow spinal puncture.

It is also indicated in pronounced alcoholics, and may be indicated in cases suffering from pelvic neuroses—visceral, uterine, and rectal; here it may act beneficially, in a way similar to the epidural injections of Cathelin.

It is contra-indicated in nervous and hysteric patients, in children and in extreme old age, in all suppurative processes (here it may create a "locus minoris resistentia" for suppurative processes in the cord by the organisms already in the blood); in recent syphilis, locomotor ataxia, and other diseases of the spinal cord or central nervous system, advanced arteriosclerosis, high temperature, and all acute infectious diseases. If after puncture the spinal fluid is found to be turbid, no injection should be made.

General anesthesia acts on the highest centers first and progresses downward; spinal anesthesia acts on the lowest centers first and progresses upward. In dealing with a certain class of cases, notably, extensive crushing injuries of the lower extremities with shock, spinal anesthesia would seem, on theoretic grounds, to be highly indicated, provided its action can be limited to the lower centers, as further depression of the heart and vasomotor centers would precipitate death. The value of nerve-blocking in such cases has been clearly demonstrated, but a sufficient number of observations on the action of spinal puncture in such cases, from which conclusions can be drawn, is not yet available.

J. Blumfeld, in writing on the subject, states the following: "The effects of spinal anesthesia in minimizing shock, by cutting off peripheral impulses, will probably prove its great claim to utility in the future. There is no reason why this valuable effect should not be employed in conjunction with general anesthesia. The extremely small amount of general anesthesia that need be administered to a patient who has been subjected to stovain reduces any risk of the general anesthesia to a minimum; only enough need be given to insure absence of all consciousness."

Jonathan M. Wainwright, of Scranton, Pa., in his Address on Surgery before the Medical Society of the State of Pennsylvania ("Pennyslvania Med. Jour.," November, 1905), makes a careful study of spinal analgesia and other anesthetics, especially in their relation to shock. He concludes, from experimental evidence, that in conditions where (1) shock exists ether very markedly increases the shock; (2) if the spinal canal be injected with cocain or stovain, traumatism, amputations, etc., which would otherwise cause marked shock, do not have any effect; (3) the amounts of cocain or stovain needed for spinal analgesia do not have any systemic effect when absorbed into the general circulation; (4) the fall of the temperature, noted in some cases after spinal injection, is a mechanical effect, and is not due to the drug. The following general conclusions are also offered: Ether and chloroform are much more dangerous than has formerly been supposed. In many cases of shock, ether or chloroform will cause death, even without an operation. They should not be given where local or regional anesthetics are at all practicable.

TECHNIC

About one hour before the administration of spinal puncture it is advisable to give a hypodermic of a small dose of morphin ($\frac{1}{8}$ or $\frac{1}{6}$ gr.). Many observers prefer the combination of morphin and scopolamin, as recommended by the writer, before major operations under local anesthesia. By this method the bad after-effects are much lessened and the analgesic effect much intensified and prolonged. The dose should never be large enough to produce somnolence, but just sufficient to allay the fears and anxiety of the patient by inducing drowsiness and indifference. Morphin, gr. $\frac{1}{8}$ or $\frac{1}{4}$, with scopolamin, gr. $\frac{1}{150}$, is the dose recommended by the writer. Under this influence the fear and psychic influences which may contribute to shock are greatly lessened or entirely eliminated. This is particularly useful in nervous patients and in all patients for amphitheater work. Coming before

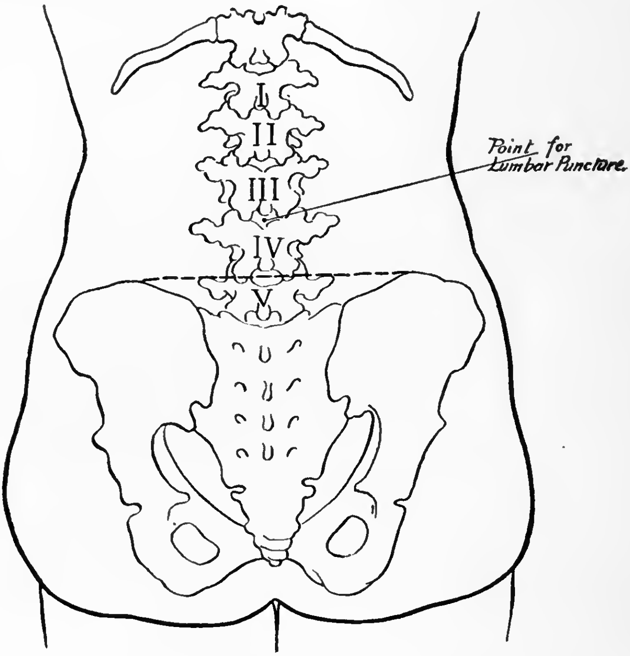

Fig. 124.—The point for lumbar puncture. ("Keen's Surgery.")

large crowds, and being operated in the conscious state, is bound to have some disturbing effect even upon the most stoical.

Dr. Fowler has recommended $\frac{1}{10}$ gr. of strychnin a quarter of an hour before the puncture, stating that it lessens shock, respiratory, and circulatory disturbances. While this method is theoretically good, it does not seem to have found much favor, and it would seem better to use the morphin and scopolamin as above suggested. Their action in allaying nervousness and excitement in the patient, and thus arresting psychic influences, operate more toward lessening shock than stimulation of the centers with strychnin.

This technic should vary according to whether you are using an anesthetic liquid heavier than the cerebrospinal fluid or not. The heavier liquids, as used by Barker, have much to recommend them, for you can more easily determine and control its movements within the subarachnoid space. The point of puncture should also vary according as to whether the operation is to be above or below Poupart's ligament.

As the spinal cord ends at the second lumbar vertebra, no injection should be made above this point. The method of Jonnesco, which we regard as dangerous, will be discussed in a subsequent section. Jonnesco's method is not necessary, however, to obtain high analgesia. By using solutions of high specific gravity, and changing the position of the patient, we can control the movements of the solution within the canal and secure high analgesia if desired.

There are three points for puncture, as ordinarily practiced—the intervals between the second and third, third and fourth, and fourth and fifth lumbar vertebræ (Fig. 124).

The interval between the third and fourth vertebræ is commonly known as Quincke's point; between the fourth and fifth, as Tuffier's.

Also to determine whether the injection is to be made with the patient:

(1) Lying on the side and remaining subsequently in the horizontal position;

(2) Sitting during puncture, with subsequent horizontal position; or,

(3) In either of the above, with subsequent inverted (Trendelenburg) position.

The larger the quantity of anesthetic solution used, the higher the anesthesia.

The value of the use of solutions of high specific gravity, and controlling their action within the canal, is amply stated by Dr. Barker.

The positions in which the patient is placed after having received the injection have the most important influence upon the extension upward of the anesthesia. A comparison of these may be made, taking only three varieties for the sake of brevity:

(1) Injection, with the patient lying down on the side and remaining horizontal;

(2) Injection in the sitting posture, the patient subsequently lying on the back;

(3) Injection in the sitting posture, followed by elevation of the pelvis.

With the first of these we find the lowest, with the second a higher, and with the third the highest extension upward of anesthesia.

The cause of the difference is very simple.

If the horizontal position is changed into the sitting, the liquid cerebralis runs out of the cranial cavity into the spinal cord. If the patient again lies down, the fluid runs back once more into the skull. When the Trendelenburg position is produced a still larger amount of the cerebrospinal fluid flows toward the head. Seeing that the analgesic compound injected is carried with the spinal fluid, the extension of the analgesia upward or downward is determined by the movement.

"This all means simply that the heavy fluid containing the drug flows from the highest point of the lumbar curve (point of puncture) to the lowest, in the lateral or dorsal depression, by virtue of the specific gravity (1.0230), the liquor spinalis (specific gravity 1.0070) being in a state of rest.

"But if any other proof were needed of the behavior of our heavy analgesic fluid in the canal, it is furnished by those cases in which we have kept the patient on the side from before the injection to the end of the operation, without any change of position at all. One or 2 cases out of many will suffice: It was necessary to amputate a young man's left leg below the knee. He was laid on the left side, with the head well raised on pillows, the left shoulder resting on the table. In this position, which was not altered in the least until he left the table, the injection was done in the second lumbar interspace. In the course of five or six minutes paralysis of sensation was absolute in the dependent left leg. In the right leg sensation was never lost at all. The patient was quite comfortable throughout the amputation.

"In another case of operation for varicose veins of the left thigh and leg the same was done with like results. Dr. Henry Head, who was present and was kind enough to test the phenomena of sensation and motion most minutely, stated that the right (upper) thigh and leg remained entirely unaffected, both as to sensation and motion. This can only be explained by the flow of our heavy analgesic compound along the roots of the lumbar nerves of the left side without any diffusion. It certainly was not augmented by diffusion, as the functions of the other limb remained unaffected throughout. It would be incorrect, then, to call this medullary anesthesia, as is sometimes done" (Barker).

In operations upon the perineum Barker uses the sitting position; in all others, the injection is made in the recumbent position.

Only in high abdominal operations is it necessary to slightly elevate the pelvis, so that the fluid will more readily gravitate toward the dorsal curve.

Several operators, notably Bier, Braun, and Donitz, have spoken of the use of a band, which is placed around the neck sufficiently tight to produce venous congestion of the head. This raises the intracranial tension and forces the cerebrospinal fluid downward. After its removal the fluid flows back again. They have at times resorted to this procedure, but it would seem superfluous, and not at all necessary, as an adjunct to our technic.

If the injection is to be made in the sitting position the patient sits on the side of the table, a stool being provided for his feet. The elbows are placed upon the knees, with the head and shoulders bent

Fig. 125.—Spinal puncture needle (1) compared with ordinary needle (2). Note short, sharply beveled point on spinal needle; this is the same type of needle as is used for reaching the branches of the fifth nerve at base of skull.

far forward—the scorcher position—so as to arch backward the lumbar regions and increase the interval between the lumbar spines.

The kind of needle used in making the puncture is of much importance. It should have a sharp but short point; if the point is made too long only a part of it may enter the membranes, permitting the escape of the cerebrospinal fluid, causing you to think you are well within the sac, but may slip out, or, when the injection is made, only a part of it may enter the subarachnoid space, the remainder escaping extradurally and lead to a failure in anesthesia (Figs. 125 and 131).

A long sharp point may also produce damage to the cauda. It is preferable, therefore, that the needle have a short, sharply-beveled point, and be from 3½ to 4 inches long, and of as small a caliber as possible consistent with strength, and permitting a lumen of sufficient size so as not to be readily choked.

Some use a cannula for making the injection, which is passed down the lumen of the needle after the puncture is made, thus insuring the entrance to the subarachnoid space; this, however, does not seem necessary and increases the size of the needle (Figs. 126, 127).

With skill and care, in a normal subject, no great difficulty is experienced in entering the sac. Any good all-glass syringe will answer for making the injection. A metal syringe should never be used, as you should always be able to see the condition and watch the movements of the fluid within the syringe.

A syringe of 2 c.c. capacity is ordinarily sufficient; but if you decide to use the cerebrospinal fluid as the solvent medium for the

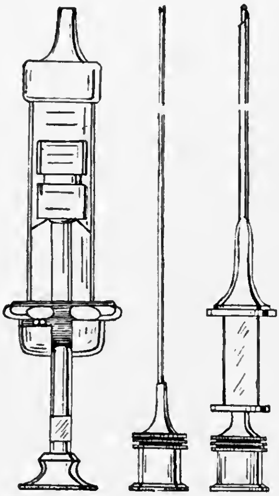

Fig. 126.—Syringe and cannulas for subarachnoid anesthesia. (According to Barker.) ("Keen's Surgery.")

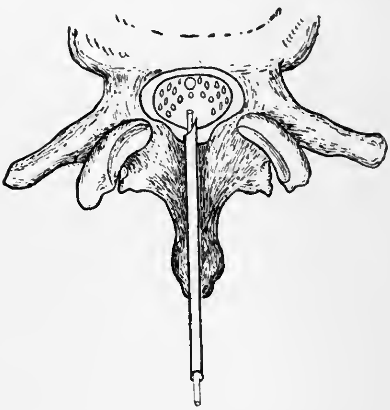

Fig. 127.—Demonstrating the use of the inner cannula for injection into the subarachnoid space. (According to Barker.) ("Keen's Surgery.")

dry sterile powder previously deposited in the barrel of the syringe, then a large one, up to 5 c.c., is to be preferred; or, if it is preferred to mix the anesthetic fluid within the syringe with an equal quantity of cerebrospinal fluid before final injection, as practiced by Bier and Tuffier, the larger syringe should be selected.

The syringe, needles, etc., used for spinal puncture should never be used for any other purpose, and should be sterilized by boiling in plain water. No alkalis or antiseptics should be used. Alkalis destroy the anesthetic agents, and a small dose of antiseptic may prove irritating to the cord.

The site of puncture should be prepared by cleansing with soap and water only, or, if antiseptics are used, they should be carefully washed away before making the puncture. Tincture of iodin may be as satisfactorily used here as elsewhere for sterilizing purposes.

Before beginning everything should be tested to make sure that it is in perfect working order. Sterile water should be injected through the needle to determine if the lumen is freely open, as well as to clear out any possible small particles of metal loosened from its lumen during the process of sterilization.

In making the puncture the needle may be used alone or fitted to an extra syringe, which will serve as a handle. The objective site

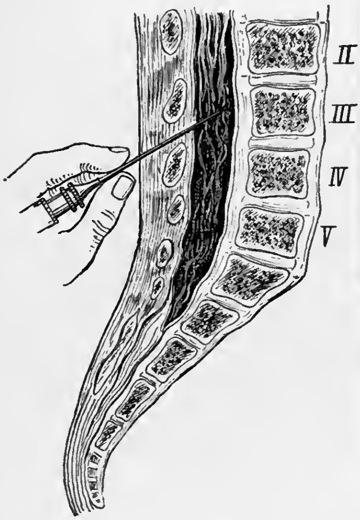

Fig. 128.—Side view of lumbar puncture between the third and fourth lumbar vertebræ. ("Keen's Surgery.")

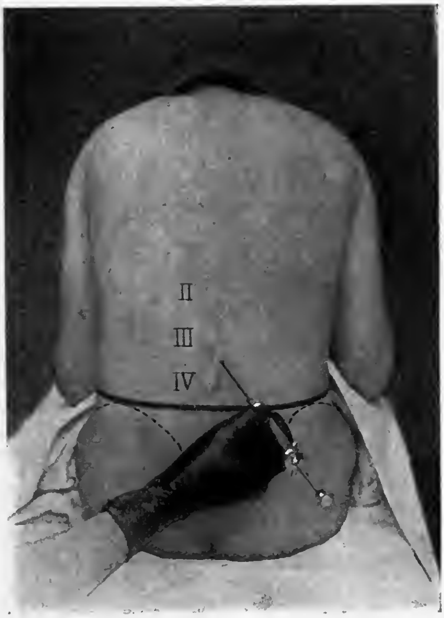

Fig. 129.—Showing flexed posture of patient and point for making lumbar puncture, 1 cm. to the side of the median line, and between the third and fourth lumbar spines. ("Keen's Surgery.")

for the injection is the midline of the subarachnoid space, between the two divisions of the cauda equina. If the needle enters on either side, its point may enter the bundle of nerves and the discharged solution be more or less retained among them, leading to one-sided or unsatisfactory anesthesia. Some operators make the puncture directly in the middle line, between the spines of the vertebra. In this position it is more difficult to avoid the bony prominences with which the needle may come in contact.

An easier and equally reliable method is to enter slightly from the side (Figs. 128–130).

The point of puncture having been decided upon, we will say the interval between the third and fourth lumbar vertebræ (the spine of the fourth vertebra lies on a level with a line drawn between the highest points of the iliac crests), the finger of the left hand is placed on the spine of the fourth vertebra, and the needle entered about $\frac{1}{4}$ inch to the right and just below the highest point of the spine,

Fig. 130.—Section through vertebral column. Needle in position between spines of fourth and fifth lumbar vertebræ.

directing the needle slightly upward and inward at such an angle that after penetrating $2\frac{1}{2}$ or 3 inches it will reach the dura in the midline. The distance from the surface to the dura varies within certain limits, according to the stoutness or size of the individual, but it is usually about $2\frac{1}{2}$ or 3 inches. Before making the puncture, it is, of course, desirable to render the skin anesthetic, either with ethyl chlorid or with a syringeful of weak novocain or Schleich solution.

After the skin is passed very little sensation is felt by the patient.

Just before entering the canal the needle is felt to encounter the dense fibrous ligaments of the spine. When this is pierced, no further resistance is felt and we feel we are in the spinal canal. The only proof of entering the subarachnoid space is the escape of cerebrospinal fluid. If this does not escape we cannot feel that we are properly within the membranes. If this does not occur we may advance the needle a little further, but we should be careful not to advance too far, or we may completely pass through the subarachnoid space into the parts on the anterior surface of the canal. The failure to secure a proper entrance within the membranes may be due to their flaccid condition and their being pushed forward in front of the needle. If such is the case, and the patient is asked to hold his breath and bear down, the membranes become tense and the needle will enter more readily.

If now the fluid does not escape, and we feel sure we are within the membranes, the failure of the flow may be due to the needle having become plugged during its passage through the tissues. Gentle aspiration can be made by fitting the empty syringe to the needle. If nothing comes, the needle had better be withdrawn and re-inserted, either in the same interspace or in another. Should only blood appear and no cerebrospinal fluid, the needle had better be withdrawn and re-inserted, care being taken to first free its lumen of any clots. Occasionally the flow of fluid is preceded by a drop of blood, which is of no moment.

The plexus of veins surrounding the membranes are more numerous in front and on the sides, less so behind; the escape of blood with the anesthetic fluid into the sac is one of the causes of failure in anesthesia as well as a possible cause of after-trouble.

After the subarachnoid space has been reached, it is generally advisable to allow a quantity of cerebrospinal fluid to escape equal to the volume of anesthetic fluid to be injected. Some allow the escape of much more, as much as 5 to 10 c.c., or even 15 c.c., claiming to have less unpleasant after-effects when this is resorted to, but it is thought best not to allow too much to escape.

Dr. S. P. Delaup, of New Orleans, states, "It has been a common observation that patients with a high spinal pressure, as evidenced by a strong, continuous flow of the cerebrospinal fluid, are more powerfully influenced by the analgesic solution than those in whom the spinal fluid escapes by drops. It is possible that the diffusion occurred too rapidly in such cases."

The syringe containing the anesthetic solution is now fitted to the needle and very slowly injected. The injection should never be made rapidly, but always slowly, for we must remember that the cerebrospinal fluid is really a water cushion on which rest the brain and cord, and any shock transmitted to it will traverse throughout its entire extent. The point of puncture is sealed with sterile adhesive plaster or cotton and collodion.

After the puncture and injection have been successfully made anesthesia sometimes fails to set in. In this event we may have resort to one of two procedures—either we may repeat the injection, provided the two injections will not exceed the safe maximum dose of the agent employed, or we may resort to general anesthesia if the case is suitable.

It is usually advisable to allow the patient a light meal before making the puncture, the same as before any other major procedure with local anesthesia. They stand the puncture and subsequent operation better, and are less liable to be disturbed by nausea and fainting while on the table. The objection to this is that, in the event of failure to secure the needed anesthesia, it may prevent the administration of a general anesthetic. During the progress of the operation, after successful puncture, it is a good practice to allow the patient some stimulating drink—toddy, coffee, or milk-punch.

Adrenalin.—Whether or not adrenalin should be used in the spinal canal is a question much in doubt. At one time it was most favorably thought of by most of the leading operators—Bier, Tuffier, Braun, and Donitz—but later there has been a reaction against its use. Braun has explained its favorable action by stating that it contracts the vessels in and around the cord, thus creating a larger space in the dural sac and producing a flow of cerebrospinal fluid in this direction, thus lessening the tendency of the anesthetic solution to ascend and produce disturbing symptoms. These views, however, have radically changed. That adrenalin does prolong and intensify the action of some anesthetics when injected into the spinal canal with others, notably tropacocain, it is contra-indicated, as the anesthetic agent opposes the action of adrenalin. We cannot draw a conclusion here by a comparison of the action of adrenalin when used in the tissues with a local anesthetic, where it is of decided value.

In the spinal canal we are dealing with an open lymph-sac. The adrenalin here must expend its influence upon the vessels of the cauda, and cannot aid directly in retaining the anesthetic *in situ.*

The congestion and ecchymosis sometimes seen to follow its action in the tissues may here, in the loosely supported vessels of the cord and meninges, have a more pronounced effect, which may lead to unpleasant sequelæ.

FAILURES

They average about 9 per cent., but differ greatly with different operators.

This includes cases of complete failure, partial, incomplete, or unilateral anesthesia, and short or delayed anesthesias.

Failures may occur even when every detail of the technic is carefully carried out and the injection is apparently successful. Many of these cases have been attributed to idiosyncrasy on the part of the patient, but this is hardly likely to be the case, except in a very limited number of cases, for if such frequent idiosyncrasies existed we would have more failures from local anesthesia. It is more than likely due to some technical error made possible by anatomic abnormalities, an

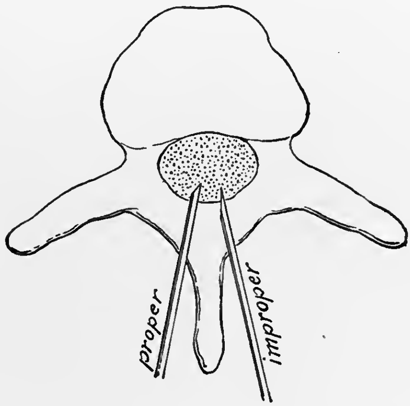

Fig. 131.—Schematic representation of proper and improper kind of needle puncturing membranes of cord show how use of improper needle may withdraw cerebrospinal fluid by point partially entering membranes, but permits escape of most of injected fluid outside of membrane.

imperfect puncture of the membranes, the lumen of the needle only partially entering them, permitting an escape of cerebrospinal fluid, but when the injection is made most of the solution escapes extradurally (Fig. 131), or may have become entangled in the bundles of the cauda equina, producing only partial or unilateral anesthesia, due to the puncture being made too laterally.

The agent used may have become inert through oversterilization or age.

The delayed appearance of anesthesia cannot be satisfactorily accounted for. In some few cases the delay has been as long as half an hour. Hollander reports a case in which, after three-quarters of an hour's delay, anesthesia set in.

Schleich and other observers have shown that the admixture of the various anesthetic agents with blood renders them inert. This has been attributed to the strong alkalinity of the blood, but, as the cerebrospinal fluid is also alkaline, it must be due to other factors, too. But it may be that the wounding of a vein, permitting an escape of blood into the subarachnoid space, may account for some of the failures.

IN OBSTETRICS AND GYNECOLOGY

Various results have been recorded from the use of spinal analgesia in obstetric work, some reporting fairly satisfactory results, while others report indifferent results with numerous failures. It has been stated by those whose experience qualifies them to speak, that when once labor has well started the spinal puncture does not interfere with the uterine contractions, but may, if it ascends high enough in the canal, lessen the power of the abdominal muscles, and thus remove a valuable aid to the expulsive power of the uterus. When used it should be the aim to limit its action to the pelvic canal and perineum, consequently low puncture, between the fourth and fifth lumbar, should be used, with elevated shoulders following. The great objection is that the analgesia is not of sufficient duration and often passes off before the completion of labor, but when successful aids greatly in the relaxation of the pelvic outlet, permitting the painless application of forceps and later repair of the perineum when necessary. It is, however, not a method for routine use in obstetrics, but may be advisable in exceptional cases. Abdominal cesarean sections have been successfully performed under its action, but here it is simply abdominal surgery, and meets with the same success and is governed by the same conditions influencing other abdominal work with this method.

The same may also be said of abdominal gynecologic operations. Regarding vaginal operations, we have shown that the perineum and external genitals are particularly favorable for spinal analgesia; their nerves come from the lowermost portion of the dural sac. Operating with solutions of high specific gravity, with the head and shoulders elevated, there should be little danger from toxic effects upon the higher centers. These regions are the first to feel the anesthetic effect and the last to return to normal sensation.

If spinal analgesia were the method of choice this would be a favorite field for work; but we must accept the weight of the evidence of statistics, and admit that the mortality is greater even under the most favorable conditions. If general anesthesia is positively contra-indicated, a large number of vaginal operations can be safely and easily performed under local anesthesia, leaving a much reduced number, which, if necessary, may then be performed under spinal analgesia.

MILITARY SURGERY

Here it may find a field of usefulness, but as yet no opportunities have arisen where it could be put to practical tests. Military surgeons have taken different views on the subject. The great danger would be that the absolutely necessary details of asepsis may be neglected. This is most likely to be the case on the field.

Dr. Thomson, in the "Journal of the Association of Military Surgeons," writes as follows:

"Tropacocain spinal analgesia has its place in military surgery, especially field work in time of war, because it offers the following advantages: (1) It obviates the necessity for the storage and transportation of the bulk of general anesthetics. (2) Is much more economical than general anesthesia. (3) The immense saving of time and attention in its administration. (4) The saving in operative personnel, dispensing with the necessity of anesthetizers. (5) The saving in the number of attendants for individual patients—after operation under spinal anesthesia the patient does not require such attention as under general anesthesia. (6) The saving of a number of bearers—under spinal anesthesia, patients are much more able to assist themselves. (7) Its employment on the field of battle, at dressing stations, ambulance stations, etc., must be the means of relieving much suffering, as well as the prevention of shock from pain, and, at the same time, render the wounded man better able to assist himself to reach the field hospital."

PHENOMENA OF ANALGESIA: COURSE AND DURATION

In the great majority of cases the onset of analgesia is without any noticeable disturbing effect upon the patient, and generally begins to make itself felt in from three to five minutes, sometimes longer, being ushered in by a sense of numbness or tingling in the lower extremities. Analgesia appears first in the external genitals, perineum, and inner side of thighs, then progresses down the limbs and up toward Poupart's ligament or higher, depending upon the point of puncture, position of patient, volume and strength of the agent used. It extends always to a higher level posteriorly than anteriorly on the trunk, owing to the general direction of the spinal nerves.

The return of sensation is in inverse order to its development, disappearing first in the parts last affected and last in the perineum and external genitals.

The duration is from about three-quarters of an hour to an hour and a half; tropacocain slightly shorter than cocain or stovain.

As anesthesia develops the reflexes begin to disappear. Some muscular incoördination is usually seen, and usually more or less paresis of the lower extremities—sometimes complete paralysis. The motor disturbances are always more marked with stovain, hence its danger in high analgesias, where it may paralyze respiration.

Tactility is usually not affected, except by large doses, which paralyze all sensation.

The symptoms vary much with the size of the dose as well as in different individuals. By using only the smallest efficient dose many of the unpleasant symptoms will be avoided.

Occasionally analgesia is ushered in by muscular twitchings of the lower extremities, more or less violent; slight weakness, nausea or vomiting may occur, or sweating may be noticed. As a rule, there is not much difference in the pulse in low anesthesia. In a few cases the above symptoms are most marked associated with symptoms of collapse. The respiration may at first be rapid, labored, or sighing, becoming more shallow later; the pulse becomes rapid and feeble. The patient may be seized with a feeling of terror or be so collapsed as to be indifferent. Respiration may cease entirely and death be imminent.

The muscular relaxation of the anesthetized parts will depend upon whether the anesthetic fluid has reached the anterior roots of the spinal cord and varies with the different solutions used—always more marked with stovain.

DANGEROUS EFFECTS

As a rule, the bad effects increase in number and severity the higher the analgesia and the larger the dose used. Our aim should be to find an anesthetic agent, combination, or technic which will leave the heart's action, vascular pressure, and respiration uninfluenced.

Zur Verth, writing from Bier's clinic, has the following to say:

"Until this ideal is realized it is wiser to keep the blood-pressure at its normal figure, with drugs to act on the heart, when high spinal anesthesia is attempted. Bier has been having the blood-pressure studied during the last six years, and Zur Verth gives his experience with 44 patients anesthetized by the spinal technic with or without epinephrin. A drop in blood-pressure of more than 25 per cent. was observed in 18 cases, but the operation had been high in the rectum or on the kidney or bladder in all of these, and thus above the level of the absolutely 'safe' region. The addition of the suprarenal preparation did not seem to have any influence in preventing the drop in blood-pressure, while it reduced the extent of the analgesia, but seemed to prolong it. A few whiffs of ether augment the force of the heart without acting on the vessels. Epinephrin, on the other hand, acts on the tonus of the vessels; this raises the blood-pressure if the heart is working as usual, but the epinephrin acts also on the heart, reducing its energy. As the blood-vessels are contracted at the same time, the result is naturally more in the line of a collapse of the whole cardiovascular system than in the line of stimulation. That the collapse does not occur, as a rule, is due to the special counteracting influence of some component of these suprarenal preparations acting directly on the heart function."

There are definite limitations placed upon our means of combating dangerous symptoms. An excessive dose, whether absolute or relative, as in the case of idiosyncrasy, is more immediately and hopelessly fatal than is the case after ether or chloroform, because it cannot be antagonized by mechanical eliminative means. In the treatment of emergencies one runs the danger of fatal syncope if we sit the patient up; if we invert him, we increase the toxic action on the higher centers and he may succumb.

McCardie gives the following statistics, gathered from the large clinics:

"In 23,955 cases of spinal analgesia, collected from forty observers, there were 29 deaths, or one in every 826. Strauss collected, 30,000 cases, with 1 death to 1800 cases. At another time he said that tropacocain had a record of 7059 cases, with 5 deaths, or 1 in 1411. Hochmeier and König, when speaking of the present position of spinal anesthesia, collected from many hospitals and clinics 2400 cases, with 12 deaths, or 1 in 200. Hochmeier concludes that spinal analgesia should only be used when *ether-rausch* and local anesthesia will not suffice, and there is marked contra-indication to general anesthesia."

AFTER-EFFECTS

About one-third of the cases have slight headache and nausea, coming on within an hour or two after the injection and passing off within a few hours. Slight elevation of temperature (about 100° F.) is usual, but subsides in a few hours.

In a small percentage of cases, 2 or 3 per cent., the headache is quite severe, and in some may become quite unbearable and last for five or six days or longer. Occasoinally the temperature rises quite high, sometimes reaching 104° F., and may require a day or two to subside. The pulse may become rapid and weak and profuse sweating occur. Collapse may come on immediately or is sometimes delayed for from a few hours to several days after the puncture. More marked symptoms of meningeal irritation (meningismus) may appear, with headache, stiffening of the muscles of the back and neck, which may persist for several days, associated often with disturbances of motion and sensation in the lower extremities. These cases may clear up in a few days or go on to the development of purulent meningitis.

Vertigo, more or less persistent, is occasionally observed. The writer had a case in which the vertigo lasted for six weeks. The patient was almost unable to walk during this time.

The character of after-symptoms may vary greatly, and are by no means regular as to kind or time of onset.

Reynier reported a case of syncopal collapse in a patient the evening after an operation under spinal anesthesia. She revived under prompt artificial respiration. In another case unbearable pains in the leg, commencing a week after the operation, persisted for a week. In another case a fracture of the malleolus had been reduced under spinal anesthesia without mishap. A month later the man was affected with complete paralysis of the arms, legs, and back of the neck. He could not hold his head erect or turn it; the head dropped back whenever it was passively lifted. He was like a jumping-jack whose strings have all been cut. As there were no sensory disturbances, hysteria was out of the question. The paralysis gradually subsided, and he left the hospital in apparently normal condition at the end of two weeks. Reynier has also heard complaints from patients that they could not walk so well as before their operation under spinal anesthesia. Guinard was one of the first and most enthusiastic adherents of spinal anesthesia, but he stated that he had completely abandoned it since his experience in 3 cases. In the first a woman of fifty passed successfully through a vaginal hysterectomy. Three months later she developed paresis of the legs, with incontinence of urine and feces, and died with symptoms of softening of the brain within the year; this result also occurred in a second case. In a third case the patient died suddenly three weeks after a simple suture of a perineal laceration under spinal anesthesia.

Incontinence of urine and paralysis of the anal sphincter have frequently been observed, more frequently the former. They usually require no special treatment other than providing for the discomfort, as they usually clear up in a few days.

That some of the late after-effects may be due to causes other than the puncture and injection is, of course, possible, but the reports of these cases are too numerous to leave any doubt that the great majority are the direct results of the spinal analgesia.

Gangrene has frequently been reported as occurring in various parts of the lower extremities and buttocks.

The after-effects are of two kinds: the immediate, due to the toxic action of the injected drug on the nerve-centers, and the late, the irritating results of the injection. That the immediate effects are not due to the systemic action of the drug, but to its extension upward and direct action on the higher centers, is amply illustrated by the following experiments of Dr. Ryall:

"Two possibilities at once strike us when we come to consider the causation of respiratory paralysis: (1) Are they the results of reabsorption of the drug into the general circulation? or (2) are they caused by the ascension of the analgesia solution in the dural sac and the direct contact with the vital centers in the cerebral nervous system? We know that the rapidity of the reabsorption of drugs dissolved in the cerebrospinal fluid of dogs, on account of the activity of the reabsorption surfaces, is generally much more rapid than that of the subcutaneous cellular tissues. The same amount of poison has a much more toxic action in subdural than it has in subcutaneous injections.

"That the extension of the drug in the dural sac is the essential cause, and that the reabsorption into the circulation is quite, or for the greater part, irrelevant, is proved by the following experiments:

"(1) When novocain, in the same dose (0.03 gm. per kilogram body-weight) and same concentration is injected into rabbits, we find (*a*) in intradural injections there is always at once intense and persistent fall of the blood-pressure and frequently death within a few minutes; (*b*) in intravenous injections there is an immediate fall of the blood-pressure, but it is of very short duration, and death only supervenes if the injection has been made with great rapidity; (*c*) in intramuscular injections there is no action on the blood-pressure which can be recognized. From this comparison one must draw the conclusion that in subdural injections the reabsorption of the poison cannot possibly be the only cause, and never the chief cause, of the poisoning. For no matter how rapidly it may be sucked up out of the dural sac and reabsorbed from the subcutaneous cellular tissue and muscular system, the intensity of the action must still remain far behind, as compared with the immediate flushing of the circulation with the poison, such as takes place in intravenous injections, and yet we see much more severe and prolonged poisoning which, moreover, runs an entirely different course in intradural injections. This fact can only be explained thus: that the course of the poisoning in intradural injections is characteristically not caused through the rapidity of the reabsorption, but through the direct action of the poison on the substance of the central nervous system. It is only after contact with the central organs that the course of the poisoning becomes impressed with the characteristic stamp.

"(2) In a second series of experiments the dural sac was closed before the injection was given by means of a ligature encircling the membranes and cord at the height of the upper thoracic portion of the spine. When 0.03 gm. of novocain per kilogram body-weight was injected subdurally below the ligature (which under normal circumstances would, without exception, cause a violent fall of the blood-pressure, and which frequently resulted in the death of the animal) the blood-pressure did not alter at all. Injections of the same dose above the ligature generally killed the animal at once." Similar experiments were undertaken and like conclusions drawn by Heneicke and Laiven.

We know, through the experiments of Aducco and Mosso, that a drop of concentrated solution of cocain deposited on the floor of the fourth ventricle will cause the immediate death of the animal.

Guinard's observations upon patients who had been operated upon under spinal puncture showed that in those suffering from bad after-effects there was a marked rise in the pressure of the cerebrospinal fluid, as demonstrated by a second puncture, and the symptoms were relieved by allowing the escape of 10 to 20 c.c. of fluid.

Patients who showed no after-symptoms were found to have no change in the pressure of the cerebrospinal fluid.

Ravaut and Aubourg found in disturbed cases a great number of leukocytes in the spinal fluid, but no bacteria. In cases that were not disturbed the appearance of the fluid and its tension were not changed.

This aseptic puriform condition of the cerebrospinal fluid is met with in other conditions. It has been reported occurring with otitis media, syphilis, and many suppurative conditions. When encountered in the course of spinal puncture, it should be a contra-indication to further procedure and the injection should not be made.

The possibility of hemorrhage within the dural sac, the result of the puncture wounding some small vessel, must also be considered as a cause for the after-effects in some cases. When it is remembered how often the puncturing needle withdraws blood, it is not unlikely that complications from this cause occur oftener than is suspected.

EXPERIMENTAL WORK

The introduction of spinal analgesia has stimulated experimental work within the spinal canal, and investigators have tested the effects of various substances introduced into the canal. The introduction of sterile water has been found to produce disturbances of motion, but affecting sensation very little. Sicard has injected dogs weighing about 20 or 30 pounds with 200 c.c. of 5 per cent. salt solution and produced marked disturbances in motility, but it disturbed sensation only slightly.

Oelsner and Kroner report the experiences at Sonnenburg's clinic and the results of considerable experimental research. They experimented with injections of salt solution cooled to freezing-point, after withdrawal of a corresponding amount of cerebrospinal fluid. The ice-cold fluid does not injure the tissues, while the anesthetic effect justifies, they say, further trials of this method; especially, they add in conclusion, as none of the methods of spinal anesthesia in vogue to date are entirely free from possible evil effects, and never can be free from them, as they are based on the introduction of a foreign chemical substance which must inevitably do more or less injury.

Klapp's experiments on dogs showed that the addition of oil to the solution of cocain entirely abolished all symptoms of intoxication. When the cocain was in an oily vehicle, total anesthesia could be induced in the dog without the slightest symptoms of intoxication. The capillaries and lymphatics are probably unable to take up the emulsion as rapidly as in an aqueous solution, and hence the cocain remains longer at the point of injection and is very slowly absorbed. Glycerin also retards absorption.

We know that in the use of oily solutions of anesthetics locally the anesthetic effect is greatly prolonged, owing to the inability of the lymphatics to take up the oil, and the danger of toxemia thus greatly lessened, but the method has other disadvantages and has never found favor.

When used in the spinal canal, if the solution was permitted to come in contact with the higher centers, the danger would be just as great as with watery solutions, or probably more so, as it would take longer for the oily solution to be removed by absorption, and oily solutions, being ordinarily lighter than the cerebrospinal fluid, would be expected to float upward.

The danger in spinal analgesia, as has been shown, is not that of general toxemia through absorption, for the dose is always within safe limits, but for its local action on the vital nerve-centers.

The addition of small quantities of gum arabic to the analgesic solution has been experimented with by some, who claim for it that it does not interfere with its anesthetic action, but minimizes the dangers by preventing absorption by the higher centers; this, however, is unlikely. It no doubt owes any advantage it possesses to its greater specific gravity, thus keeping the solution away from the higher centers.

But if anything of its kind is to be used, it is far better to use glucose, which is normally a constituent of certain parts of the body, as advocated by Barker, and referred to at length elsewhere.

Of considerable interest was the discovery by Meltzer of the anesthetic effects of magnesium salts when injected into the spinal canal. Meltzer first experimented on monkeys, and found it to be a motor and sensory paralysant. In one animal he injected what would have been a lethal dose. In twenty-five minutes respiration had ceased. Tracheotomy was done and artificial respiration was instituted. The heart, which had nearly stopped through asphyxia, now regained its force and rate. Artificial respiration was continued for seven hours, but, as there was no effort on the part of the animal to resume its own respiration, it was continued for seven hours longer, the heart during this time acting perfectly. At the end of this time spontaneous respiration was resumed. The animal recovered completely and was apparently in good condition.

This experiment seemed to prove conclusively that death is due to paralysis of respiration alone, the heart apparently not being affected.

Meltzer found that 0.06 gm. per kilogram was not dangerous in monkeys. He suggested one-third this amount to be used on man, giving 1 c.c. of a 25 per cent. solution of magnesium sulphate to each 25 pounds body-weight. Following these suggestions, operations were performed under its use, and it was used for a time extensively in tetanus, both by spinal injection and by hypodermoclysis; but, while it controlled the convulsions often for twenty-four hours at a time, the high temperature characteristic of this disease continued and the patients succumbed from exhaustion, without there being any gain in the reduction of the mortality. The method was, accordingly, discontinued as offering no advantage.

Canestro experimented with it on dogs, using adrenalin in addition, and confirmed Meltzer's observations. He stated that it was free from irritating effects on the tissues, and could find no histologic changes in the nervous system or kidneys.

COMPLICATIONS AND SEQUELÆ

The simple tapping of the spinal canal for purposes of examination has at times been followed by after-effects similar in kind, though usually less severe, than those we are accustomed to see following spinal analgesia. The experiments of Guinard and Kozlowski, and later confirmed by Stolz and Schwarz, show that the intraspinal injection of sterile water, or even normal salt solution, is followed by after-disturbances. Any change in the tonicity of the cerebrospinal fluid will cause a change in the cerebrospinal pressure, lowering or raising it accordingly as hypo- or hypertonic solutions are used.

Clinically, we are well familiar with the symptoms of increased cranial pressure the result of other causes.

Certainly the most serious complication is paralysis of respiration. When this occurs, artificial respiration should be instituted at once, either by using the arms, as in the Sylvester method, or, if the apparatus is at hand, the use of the Matas-Smyth pump, with a Meltzer intratracheal tube attached, or attached to a simple bellows, as used for anesthesia. Either of these methods, if vigorously persisted in, even in bad cases, runs a fair chance of success, as the heart usually continues to beat for quite a while after respiration ceases. Tracheotomy, with the passage of a tube down the trachea, may, of course, be resorted to, but is no more effective than the other methods and consumes valuable time.

URINARY CHANGES

Numerous observations made on the urine show that spinal analgesia is irritating to the kidneys. Albumin and casts have frequently been noted, but of short duration. The changes may appear in a few hours or be delayed several days, disappearing a few days later. No permanent changes or no fatal results from renal effects have been recorded.

All the agents used may show this effect; stovain slightly more so.

As compared with the renal changes following anesthesia, Tomaschewski gives 60 per cent. for spinal analgesia compared to 72 per cent.

for general anesthesia. He also states that 66 per cent. of major operations under local anesthesia show slight traces of albumin.

Csermak, in a study of 60 cases with stovain, gives 39 in which the urine remained normal. Albumin appeared in 12; albumin and a few white blood-cells in 6; albumin and granular casts in 2; albumin, granular casts, and white blood-cells in 1.

Hartleib, in making similar observations, found stovain to produce albumin in 78 per cent. of cases; in 20 cases with tropacocain only 1 showed albumin. These observations have been amply confirmed by others.

EFFECTS ON THE NERVOUS SYSTEM

Many observations and experiments have been made to show the effect of spinal analgesia upon the spinal cord and nerves within the canal. Nearly all of these investigations were with stovain. We know that stovain affects both motor and sensory nerves, also that it is irritating. Necrosis has at times been noted following its use locally. Prolonged paralysis, at times ending in death, has been recorded following its use. It was consequently to be expected that nerve changes should occur. They are, however, in the great majority of cases, transient. These findings emphasize the great danger of using spinal analgesia in patients suffering from diseases of the nervous system.

Spielmeyer has examined the central nervous system in 13 cases dying after spinal analgesia. In 1 case death was the result of the puncture, the patient dying forty hours after, the other 12 cases dying of other causes following operation. In all cases stovain was used.

The changes, for the most part, consisted in degeneration of the motor ganglion cells of the anterior horn, and were seen low down and high up in the cord. In some the changes were so pronounced that they would seem to be irreparable, but that none of these changes were discovered in cases where the dose did not exceed 0.9 gr. In the case dying as a result of the puncture, 1.7 gr. had been used. Here paralysis of respiration had been the first sign of trouble. His experiments on dogs gave the same results; when small doses were used, no change could be detected.

Klost and Vogt's experiments agree with Spielmeyer. They found chromolysis in some of the anterior motor cells. Direct injections of the anesthetics into the substance of the cord further confirmed their toxic action. When normal salt solution was used instead of the anesthetic solution no changes were observed, showing that they were not of mechanical origin.

Wossidlo and Lier's investigations were equally as interesting, and agree in the main with the experiments of others. Wossidlo concludes that tropacocain was less dangerous than stovain or novocain, but that their effects were not serious enough to prevent the use of the drugs in this method.

Particularly interesting and thorough were the investigations of Spiller and Leopold, which I quote as follows:

"The technic of our experiments consisted in performing lumbar puncture on five dogs, with careful avoidance of infection. The stovain solution used on dogs D and E was boiled. The dose of each stovain injection varied from 0.05 to 2 gm., and, except in dogs A and B, in each of which only one injection was given, the injections were usually at intervals of two or three days.

"The symptoms may be divided into the temporary and the permanent. The temporary consisted of flaccid paralysis and complete or partial sensory loss. The hind limb showed flaccid paralysis, while the entire body frequently showed the loss of sensation, implicating even the ear. Bladder and rectal control was lost, and the tendon reflexes where either diminished or absent. These symptoms occurred immediately or several minutes after the injection was given, and persisted from one to several hours.

"The permanent symptoms consisted of ataxia, decreased sensation, and, in dog E, loss of patellar reflex. The symptoms became permanent after the third injection, remaining until the end of the experiment. The ataxia was recognized by the irregular gait, and the tendency to stand with the hind legs well apart and the peripheral part of the hind limbs well on the ground.

"Axis-cylinders in the periphery of the anterolateral and posterior columns were found here and there considerably swollen; some were of large size; swollen axis-cylinders were seen in the root entrance of the posterior columns, but otherwise not in the posterior columns except near the periphery. A moderate degree of cellular reaction to the stovain was detected in the pia and roots of the cord in the form of round-cell infiltration, but never as cells of polynuclear type. This is not a surprising finding, and resembles what is seen in tabes. One would expect some cellular reaction to a poison affecting the nervous system as does stovain. A very slight perivascular round-cell infiltration was seen here and there in the cord; it was so slight as to be of no importance, and its existence was disputable. "The swelling of the axis-cylinders in the anterior and posterior roots was very distinct, and the swelling affected most of these axis-cylinders. One forms the impression that the axis-cylinders were more swollen in the anterior than in the posterior roots.

"The posterior columns in the lumbar region were degenerated, as shown by the Marchi method, throughout a transverse section, but much less so in the ventral zones. The reflex collaterals were also much degenerated, and the degenerated fibers could be traced forward into the anterior horns. Small black dots were found along some of the anterior roots within the spinal cord, and this finding indicates a moderate amount of degeneration here. A slight degeneration was found by the Marchi method along the periphery in the anterolateral columns; it was far less intense than in the posterior columns. In the thoracic region the degeneration of the posterior columns was confined to the columns of Goll; the columns of Burdach seemed to be intact. The degeneration of the anterolateral columns in the thoracic region was insignificant. The lumbar sections were taken fully 1½ to 2 inches above the point of injection.

"Anterior and posterior roots, taken between the dural cavity and the posterior ganglia, were teased in the fresh state and stained with a 1 per cent. aqueous solution of osmic acid. They presented considerable degeneration, chiefly in the form of minute black granules within the neurilemma sheaths, and the degeneration was more advanced in the anterior roots. One could not conclude from this finding that stovain affects the anterior roots more than the posterior; rather, the finding would seem to imply that the roots, having been affected by the stovain within the dural sac, secondary degeneration would be found in the portion of the anterior roots examined, and retrograde degeneration in the portion of the posterior roots examined. Nerve-roots taken from within the interior of the dural canal, unfortunately, were not examined by this method.

"The nerve-fibers in one of the lower spinal ganglia, placed in the fresh state in 1 per cent. osmic acid solution, showed intense degeneration of the fine granular variety. The cells of the ganglion presented little degeneration.

"A nerve taken from the hind leg appeared intensely degenerated when placed in the fresh state in osmic acid.

"It seems clearly demonstrated that stovain affects especially the anterior and posterior roots; the degeneration of posterior root-fibers in our sections was intense. What is worthy of note, the degeneration of the intramedullary portion of the lumbar and sacral posterior root-fibers in the thoracic region was still intense. The posterior thoracic roots were unaffected. Stovain evidently also causes slight degeneration in the periphery of the anterolateral columns, but has less effect here than on the nerve-roots.

"These lesions obtained by us could not have been produced by the trauma of the needle, as the sections of the lumbar region examined were $1\frac{1}{2}$ to 2 inches above the point of injection, and yet the posterior and anterior roots were greatly degenerated.

"It would be unwarranted to apply these findings too strictly to man, as no grave changes have been found as yet in the human spinal cord. At most, our findings would show that repeated injections of stovain might be injurious, and would make one cautious in employing several injections within a short time in the same subject. We do not know whether stovain has more effect on the nervous system of the dog than on that of man."

The investigation shows further that the paralysis produced by stovain is of the motor type, as the anterior roots were greatly degenerated.

OCULAR PALSIES

Associated with the nervous lesions following analgesia are those of the ocular muscles. These lesions are usually transient, appearing five to ten days after puncture and disappearing in four to six weeks. Occasionally the lesions are more persistent and, in rare instances, have been permanent. They occur much more frequently in high analgesia. Their frequency has been stated to be 1 to 400 or 500 cases. Our colleague, Dr. Delaup, who employs almost exclusively the low puncture, has had 1500 cases and his associates about 500 more. They have not met with a single case of ocular paralysis. In the writers' experience, and that of their associates, no cases have been observed.

The pathogenesis of these palsies is not at all clear. They have occurred most frequently following the use of stovain, but also happen with the other agents. The irritating qualities of stovain and its action on motor nerves is well recognized, but many of the other agents are supposed to be free from such action. One theory is that it is due to changes in the pressure of the cerebrospinal fluid, permitting pressure or traction on the nerves as they course along the undersurface of the brain. This, however, is very unlikely, as it would occur just as frequently with low puncture, and also with operations upon the spinal cord, when frequently large quantities of cerebrospinal fluid escape. The fact that occasionally palsies have followed cerebral operations has no analogous bearing here, for in such cases the disturbance was most likely due to edema or congestion following the procedure.

OCULAR PALSIES. (Copied from Reber.)

Reporter.	Reference.	Age.	Sex.	Alkaloid used.	Dose. Cgm.	Muscles affected.	Time after operation palsy appeared (days).	Duration of palsy.	Result.
Loeser	Med. Klin., 1906, No. 10	45	M.	Novocain	?	L. sup. oblique	5	6 mos	Recovery.
Loeser	Med. Klin., 1906, No. 10	25	F.	Stovain	?	L. ext. rect.	8	8 mos	Recovery.
Schoeler	Soc. d'Opht. de Berlin, 1906	?	?	Stovain	?	R. ext. rect.	8	?	?
Feilchenfeld	Centralb. f. prakt. Augenh., 1906	?	?	Stovain	?	L. ext. rect.	12	?	?
Feilchenfeld	Centralb. f. prakt. Augenh., 1906	?	?	Stovain	?	L. ext. rect.	?	?	?
C. Adam	München. Med. Wchnschr., 1906	33	M.	Stovain	?	L. ext. rect.	20	3 mos	Still palsied at time of report.
Mühsam	Deutsch Med. Wchnschr., 1906	26	M.	Stovain	15	R. ext. rect.	10	21 days	Recovery.
Mühsam	Deutsch Med. Wchnschr., 1906	27	F.	Novocain	8	R. ext. rect.	4	22 days	Recovery.
Lang	Deutsch Med. Wchnschr., 1906	61	M.	Novocain	15	Both ext. rect.	R. 11 L. 30	?	Persisted at time of report.
Lang	Deutsch Med. Wchnschr., 1906	41	M.	Novocain	?	L. ext. rect.	11	5 days	Recovery.
Vossius	Med. Gesellsch. Giesen, 1906	60	F.	?	?	L. ext. rect.	6	?	Persisted after six months.
Blanluet and Caron	Soc. d'Opht. de Paris, 1906	51	M.	Stovain	5	L. ext. rect.	9	?	Persisted after six months.
Hermes	Med. Klin., 1906	?	?	?	?	One ext. rect.	?	?	?
Deetz	München. Med. Wchnschr., 1906, No. 28	?	?	Stovain	?	One ext. rect.	12	?	?
Rausscher	München. Med. Wchnschr., 1906	?	?	Stovain	?	One ext. rect.	8	?	Recovery.
Rausscher	München. Med. Wchnschr., 1906	?	?	Stovain	?	One ext. rect.	13	?	Recovery.
Loeser	Med. Klin., 1906, No. 10	25	F.	Stovain	?	L. ext. rect.	12	12 days	Recovery.
Schmidt-Rimpler	Klin. Monatsbl. f. Augenh., July, 1907	?	?	?	?	One ext, rect.	?	?	Recovery.
Schmidt-Rimpler	Klin. Monatsbl. f. Augenh., July, 1907	?	?	?	?	One ext. rect.	?	?	Palsy persisted.
Adam	Deutsch. Med. Wchnschr., 1906	26	M.	Stovain	?	One ext. rect.	?	?	Recovery.
Adam	Deutsch. Med. Wchnschr., 1906	26	F.	Novocain	?	One ext. rect.	?	?	Recovery.
Scheppens	Clin. Opht., Nov. 25, 1908	?	?	Cocain	?	L. ext. rect.	?	?	?
Baisch	München. Med. Wchnschr., 1905	?	?	Alypin	?	Both ext. rect.	?	5 days	Recovery.
Goetermann	Berl. Klin. Wchnschr., 1908, No. 28	?	?	Tropacocain	?	Both ext. rect.	8	?	?
Landow	München. Med. Wchnschr., 1905	?	?	Novocain	?	Both ext. rect.	7	?	Recovery.
Mingazini	Rev. Neurol., March 15, 1906	16	M.	Stovain	?	Almost complete ophthalmoplegia externa.	13	?	?
Becker	München. Med. Wchnschr., 1906	?	?	Stovain	6	Third nerve and sixth nerve.	11	?	?
Ach	München. Med. Wchnschr., 1907	?	?	Stovain	?	One ext. rect.	8	21 days	Recovery.
Ach	München. Med. Wchnschr., 1907	?	?	Stovain	?	One ext. rect.	4	43 days	Recovery.
Ach	München. Med. Wchnschr., 1907	?	?	Stovain	?	One ext. rect.	11	6 days	Recovery.
Ach	München. Med. Wchnschr., 1907	?	?	Tropacocain	?	One ext. rect.	7	8 days	Recovery.
Reber	Present report	40	M.	Stovain	6½	Both ext. rect.	12	?	Persisted at the time he left hospital.
Reber	Present report	16	F.	Stovain	6½	Both ext. rect.	8 weeks.	6 mos.	Palsy persisted.
Reber	Present report	24	M.	Stovain	6½	L. ext. rect.	7	7 days	Recovery.
Reber	Present report	35	M.	Tropacocain	6½	One ext. rect.	10	14 days	Recovery.
Reber	Present report	19	F.	Stovain	6½	L. ext. rect.	7	?	Under observation only three days at time of report.

The possibility of hemorrhage being the cause has been advanced, but has not met with much support. It was suggested that the change in the cerebrospinal pressure acting upon diseased vessels induced minute ruptures, but, if such were the case, we would most likely have associated disturbances elsewhere with greater frequency than they occur.

The fact that these disturbances occur most often in high punctures would suggest the direct action of the agents or toxic properties induced by this preparation acting directly upon the nerves, or their origin in the floor of the fourth ventricle; to act on the nerve-trunks themselves would necessitate a much higher ascent of the drug and most probably produce other disturbances. A special affinity or susceptibility of these nerves or their centers must also be presumed. This last view is concurred in by Dr. Babcock in a letter to Dr. Reber, extracts from which I give below.

"There have now been given by Dr. Steele, Dr. Martin (and his assistants), Dr. Applegate, and myself about 2000 injections for the production of spinal analgesia. Personally, I have given about 1400 injections, having used stovain, tropacocain, eucain, cocain lactate, novocain, and alypin. Most of the injections have been given with stovain or tropacocain. These analgesics have been given dissolved in water, with or without the addition of sodium chlorid, adrenalin, 10 per cent. alcohol, or strychnin. I have had great difficulty in securing uniform solutions, although ampules of the solution have been prepared for us by German, French, and several American chemists, and we have also prepared the solutions extemporaneously. All these local anesthetics seem to share with cocain, though perhaps to a lesser degree, instability in the presence of heat, so that boiling may set free certain undesirable and even toxic substances. I have noticed the clinical evidence of this with cocain in decreased anesthetic action and severe pain after the injections of boiled solutions of this alkaloid for purposes of ordinary local anesthesia. I have seen local necrosis follow the injection of stovain in strong solution in the prepuce. When used for spinal analgesia, boiled stovain solutions give more frequent and more severe secondary headaches (and, at times, even stiffness and rigidity of the muscles of the back of the neck) than solutions which have not been exposed to high degrees of heat. Moreover, the solutions which show the greatest untoward after-effects seem to show a deficiency in analgesic power. Similar observations have been made in reference to tropacocain.

"The interesting fact is that all of the 4 cases in which ocular palsies have been noticed have occurred after injections for analgesia of the lower abdominal segments.

"At the present time I would draw the following conclusions:

"1. We have no positive final proof that pure stovain or tropacocain when used for spinal analgesia will be followed by paralysis of the ocular muscles.

"2. The use of solutions of both stovain and tropacocain may be followed by such palsies and by other symptoms suggesting the presence of associated by-products.

"3. The palsy may occur irrespective of the use of adrenalin, alcohol, glucose, or other admixture, although it is possible that some of these substances may accentuate or favor the undesirable effect.

"4. The antiseptic properties of stovain and tropacocain, and the fact that in quite a number of instances I have withdrawn cerebrospinal fluid from one to many days after the spinal analgesia, and have never found the slightest turbidity of cellular exudate or other indication of inflammatory action, inclines me to the belief that sepsis or a bacterial irritation is not responsible for the ocular palsy.

"5. An incidence of ocular palsy in 1 to 400 or 500 spinal analgesias and the occurrence of frequent headaches should make surgeons very careful to avoid heated or decomposed solutions for spinal analgesias.

"6. Spinal analgesia should not be discredited by the untoward effects resulting from decomposition or contaminating by-products. Unfortunately, no Squibb has yet arisen to do for spinal analgesics what has been done for ether and chloroform."

THE METHOD OF JONNESCO

Dr. Jonnesco first brought forward his method before the International Society of Surgery in Brussels, Sept., 1908, when he reported 14 cases. Since then he has repeatedly been in print, either alone or with Dr. A. Jiano, writing on the same subject. For the most part, his later articles have been in defense of his method or in reply to criticisms.

The essentials of his injection consist of high punctures over the spinal cord proper, and in the addition of strychnin sulphate, which he claims combats the bad effects. He writes as follows:

"There are two essential points of novelty in this method: (1) The puncture is made at a line of the spinal column appropriate to the region to be operated upon. (2) An anesthetic solution is used which, thanks to the addition of strychnin, is tolerated by the high nervous centers."

He at first advocated four points of puncture—a mediocervical, upper dorsal, mediodorsal, and dorsolumbar—but later has dropped two, using only the upper dorsal, between the first and second dorsal vertebræ, and dorsolumbar, between the twelfth dorsal and first lumbar.

The drug used has been principally stovain. The size of the dose, as well as the dose of strychnin used, varies with the point of puncture and the age of the patient, using less in high punctures and in young subjects. The dose of strychnin varies between .5 to 1. mg. If it were advisable to add strychnin it could be given beforehand, as is scopolamin and morphin. Dr. Fowler has recommended this, giving $\frac{1}{10}$ gr. strychnin hypodermically a quarter of an hour before the puncture, but the procedure has not been generally adopted. In administering such drugs as strychnin, in direct contact with the nervous system, their action is much more active than when administered subcutaneously; but, as in the case of such drugs as strychnin, it would seem unnecessary to inject them into the canal. In spinal puncture our aim should be to simplify, as much as possible, the anesthetic solution, and to add nothing to it not absolutely necessary. Reports from surgeons who have witnessed Dr. Jonnesco's injections in this country and abroad are, on the whole, condemnatory of the method. In some the injections worked well, in others they were complete or partial failures. Many were made quite ill, and some barely escaped with their lives after heroic efforts at resuscitation. The method, while possible, is fraught with too much danger, and, from the humane standpoint, unjustifiable.

The necessity of practicing artificial respiration on conscious but terrified patients, with paralyzed respiration, must be an experience they can never forget.

In surgery of the upper parts of the body, when general anesthesia is inadvisable, local or regional anesthesia can be used in a large number of cases, and this number is steadily increasing with our improvement in technic. Where high spinal anesthesia seems advisable the method, as suggested by Barker, would seem preferable, but it seems doubtful, even with this method, that analgesia will be safe higher than the clavicles.

TREATMENT OF AFTER-EFFECTS

Slight headache, nausea, or temperature usually require no treatment, passing off in a few hours to a day or two at most. The headache may be very severe, often unbearable, and may persist for a week or longer. The usual headache remedies—ice-bag, aspirin, antipyrin, phenacetin, codein, etc.—may be used and sometimes do good. Nitroglycerin and amyl nitrate have been recommended and claimed to benefit some cases, though it would seem, on theoretic grounds, that if the headache is due to reactionary increase in intracranial tension or irritation they would be contra-indicated. Small doses of atropin hypodermically have also been said to yield good results. Several observers have reported benefit following tapping of the subarachnoid space, allowing the escape of 5, 10, or 15 c.c. of cerebrospinal fluid, which in these cases is said to be under much greater tension, as evidenced by the way the fluid will flow from the needle, and is often turbid. When this practice has been followed, the headache has been much benefited or entirely disappears; some cases, where the fluid has been turbid, have required tapping several times. The practice should be tried in severe cases that do not yield to other means.

Temperature, if sufficiently high or continuous, should be combated by the usual means—sponging, wet back, or ice-water enemas.

Nausea or vomiting is not much benefited by remedies by the mouth, as the trouble is central, but these may be tried, and sometimes seem to do good; washing the stomach may also be tried.

Keeping the patient perfectly quiet in bed, free from surrounding disturbances and noises, is often of much benefit to the headache and nausea; any movement on his part is often followed by an increase in the headache or an attack of nausea.

Weak pulse or collapse, coming on after operation, is best met by the usual remedies—caffein, oil of camphor, adrenalin solution, or digitalin by needle.

The after-vertigo seems to yield to full doses of strychnin kept up for some time, but it is often persistent and may last for several weeks.

The numerous lesions and trophic disturbances should be treated the same as those arising from other causes.

In the event of spinal meningitis developing as the result of a lumbar puncture, it has been suggested to irrigate the subarachnoid space by two punctures, one above the other below the area involved.

It is, however, not very likely that such a practice will do any material good in a septic inflammation of the meninges. The irrigation would no doubt have to be of limited duration and practiced only at intervals. However, it is worth bearing the procedure in mind, as it may prove of some value occasionally.

EPIDURAL INJECTIONS

In connection with spinal analgesia should be considered the epidural injections of Cathelin.

The dural sac ends opposite the third sacral segment. The remaining space in the sacral canal is filled with cellular tissue, and contains nerve trunks which form the sciatic and pelvic nerves, running from the dural sac to the sacral foramina. Cathelin conceived the idea of medicating the nerves in this position for various pelvic neuroses, especially neuralgias of the lower half of the trunk and incontinence of urine. The method has lately been used during labor to anesthetize the pelvic outlet; it has also been suggested for sexual neuroses.

The technic is as follows: With the patient lying on his abdomen or side, the opening of the sacral canal is sought for with the finger. This is located just below the last sacral spine, just above the articulation with the coccyx. The skin over this point is anesthetized with a weak novocain solution, and a long needle is inserted into the opening in the long axis of the bone and pushed up $1\frac{1}{2}$ or 2 inches until it is well within the sacral canal, when the solution can be injected. This may consist of plain water or salt solution alone, or containing an appropriate quantity of cocain, novocain, codein, or morphin; 6 or 8 ounces or more may be used. The method of its action is hard to explain, but seems to be due to the physical interference, as well as such chemical changes that may be induced by bathing the nerves in this space in the injected solution. Cathelin has personally had over 1000 cases treated by this method, and his associates many more. The results in incontinence of urine have been 49 per cent. cured, 35 per cent. materially improved, and 4 per cent. failures. It may be necessary to repeat the injection several times. There is usually no after-disturbance, as the injection does not enter the subarachnoid space, but it is extradural. The solution runs out of the many sacral canals, much of it into the pelvis, bathing the nerves in their course through these openings. A short rest in bed after the injection is the only after-treatment necessary. In the hands of the writer this method has given fairly good results. Its use as a means of anesthesia during labor and for pelvic operations has not been satisfactory. It often fails to produce the desired anesthesia. Its action is necessarily of limited duration, and unless timed to meet the fetus in the lower pelvic outlet would be of no assistance; however, some writers have used it and claim fair results. It has been used for the low application of forceps and to repair the perineum; it is, however, more used as a therapeutic than as a surgical aid. (See Experiments on the Movements of Solutions within the Epidural Space in chapter on Paravertebral Injections.)

CHAPTER XXI

PARAVERTEBRAL AND PARASACRAL ANESTHESIA

PARAVERTEBRAL ANESTHESIA

THE introduction of paravertebral anesthesia is quite a new departure among regional methods, and while even now beyond the experimental stage, having been used successfully by a number of operators, the method has not been sufficiently developed yet as a routine procedure, but when perfected may promise much for the future.

Undoubtedly the first attempt at a paravertebral injection was by Corning in 1885, who attempted to inject an anesthetic solution in close contact with the spinal cord by making a deep injection near the vertebræ, these experiments were the beginning of spinal anesthesia. It is possible that he got within the membranes, though he did not intend to.

The paravertebral methods of to-day were first conceived by Sellheim, who in 1905 anesthetized the abdominal walls by an injection made around the roots of the eighth to twelfth dorsal, iliohypogastric, and ilio-inguinal nerves.

The roots of the spinal nerves join within the intervertebral foramina, and immediately divide into anterior and posterior branches; from the anterior branch a filament is given off, which runs forward to communicate with the sympathetic system.

In making these paravertebral injections the object is to reach the nerves at their point of division, so as to anesthetize this communicating filament (Figs. 65, 73, 133).

From a study of the vertebral column of the average adult, with a view of obtaining information for the guidance of paravertebral injections, we find on its posterior aspect that if a vertical line is drawn down the tips of the spinous processes and lateral measurements made from this line the free interval between the transverse processes is about 1 inch on each side (Fig. 133). While the conformation of the vertebræ in the dorsal and lumbar regions is quite different, this measurement holds good along the entire dorsal and lumbar regions. As the intervertebral foramina are shielded posteriorly by the lateral projections of the articular processes, a point about $\frac{1}{4}$ inch

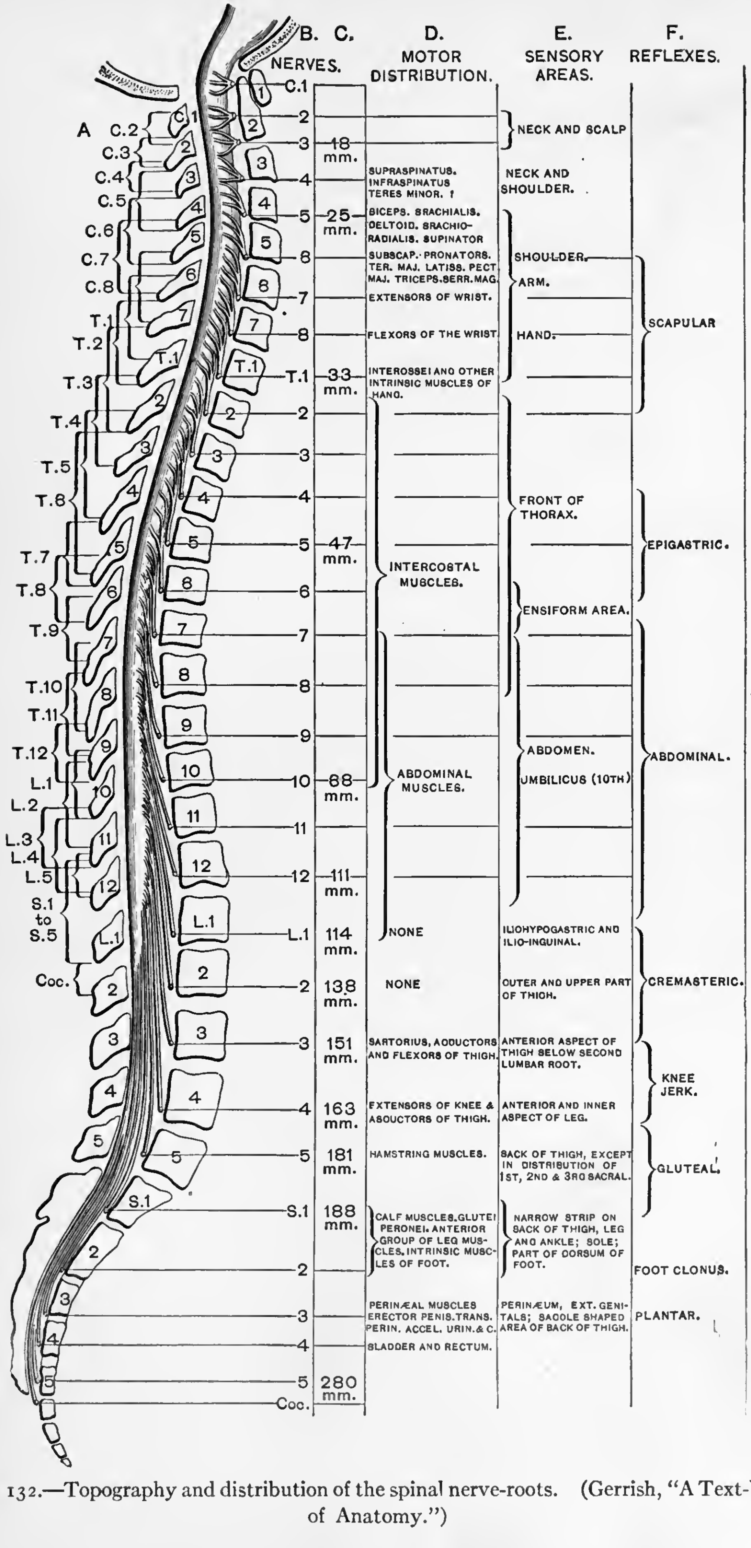

Fig. 132.—Topography and distribution of the spinal nerve-roots. (Gerrish, "A Text-book of Anatomy.")

further out, making $1\frac{1}{4}$ inches from the midline, is best selected as the point of puncture, so as to enable the needle to be directed upward and inward toward the intervertebral foramina.

The average interval between the transverse processes in the dorsal region is about $\frac{1}{2}$ inch, while the midpoint of this space lies in a vertical line about 1 inch from the midpoint of the space above or below it.

In the lumbar region the free space between the transverse processes is from $\frac{1}{2}$ to $\frac{3}{4}$ inch, and the distance from the midpoint of one space to that of the other is about $1\frac{1}{4}$ inches.

On the lateral aspect we find that measurements made directly inward, from a plane passing through the tips of the spinous processes, reach the intervertebral foramina at a distance of about $1\frac{1}{4}$ inches

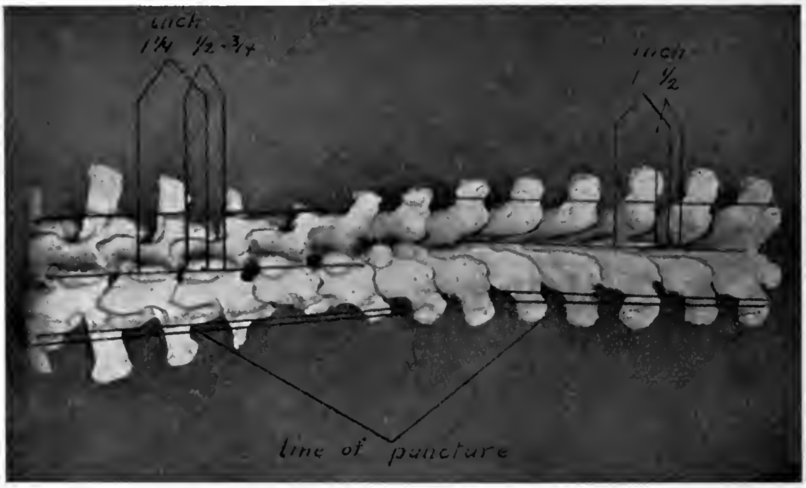

Fig. 133.—Posterior view of dorsal and lumbar spinal column with measurements for paravertebral injections. (See text.)

in the upper dorsal to about $1\frac{1}{2}$ inches in the lower dorsal and lumbar regions. To this distance we should add $\frac{1}{4}$ inch or more for soft parts, according to the stoutness of the individual (Fig. 134). It is further seen on the lateral view that the tips of the spinous processes in the dorsal region considerably overlap the vertebra below, this downward projection growing less in the lower region, so that no reliable guide is offered by these processes for the location of the space between the transverse processes; while in the lumbar region it may be fairly accurately stated that the lower border of any transverse process lies slightly below the level of the tip of the spinous process of the same vertebra, and that a needle directed inward and upward at the proper lateral position ($1\frac{1}{4}$ inches from the midline) and about on a level with the middle of the spinous process should pass freely between the transverse processes of that vertebra and the one above.

In the dorsal region, as we have no such guide, it is best to feel for the intertransverse space, with the point of the needle directed inward from a line $1\frac{1}{4}$ inches lateral from the tips of the spinous processes, and, having located this interval at any one point, the point

Fig. 134.—Lateral view of dorsal and lumbar spinal column with measurements. (See text.)

of puncture for the space above or below will be about 1 inch removed on the lateral line.

These measurements were made on the vertebral columns of several adult skeletons and utilized for verification on the cadaver, and, while subject to small variations, will, I believe, be found fairly accurate for the adult of average size.

Läwen, in 1911, performed a nephrotomy by blocking the intercostal and three upper lumbar nerves.

The most noteworthy articles upon this subject to date have been by Läwen, Kappis, Heile, Wilms, and Franke; but Finsterer's work on this subject has been particularly thorough and comprehensive.

One and 1½ per cent. solutions of novocain with adrenalin have been the strength usually employed. The total quantity of novocain used being 0.4 to 0.8 gm. Finsterer, in a case in which he used 0.4 gm., injecting the eleventh and twelfth dorsal and first and second lumbar nerves, reports that the duration of the anesthesia was two hours.

In extensive operations, where six or eight points are injected on each side, using approximately 5 c.c. at each point, which, combined with the skin injections at the puncture points, brings the total quantity of solution used up to 75 to 100 c.c., which, if it be a 1 per cent. solution, certainly would appear to exceed the safe limits of the drug.

While no mishaps have occurred, some patients have shown symptoms which have served as a warning note and has stimulated animal experimentation to determine the best methods of procedure. As some of the injected solution must reach the epidural space through the spinal foramina, rather free epidural sacral injections were made upon animals to study the movements of a definite quantity of solution injected within the epidural space.

Läwen and Gaza found with colored solutions plus adrenalin in epidural sacral injections that the solution often ascended as far as the lower portion of the thoracic cord, while Muroya, in a somewhat similarly made injection, found that the ascent of the fluid was often higher—to the cervical region and frequently into the skull.

The difference in the results obtained by these investigations may be accounted for, as Muroya states, by the quantity of the solution used and the pressure under which the injections are made. He, accordingly, timed the rapidity of his injections and used 10 c.c. per kilogram of body-weight of the rabbit, of a colored 5 per cent. novocain adrenalin solution, injecting 1 c.c. per minute, and found, as in his previous experiments, that the solution ascended often as high as the skull, and but seldom was found to stop at the middorsal region.

Muroya found that in rabbits paravertebral injections are relatively more toxic than subcutaneous; this may be explained in several ways: (1) The solution may ascend to the higher centers through the subdural space, or (2) the blood-vessels may more rapidly absorb it in this position; (3) it may be rapidly taken up by the large network of lymph-spaces which overlie the vertebral column, particularly in the abdominal cavity, as the colored solution has often been found in animals high up in the thoracic duct a few minutes after injection. This absorption through the lymph-spaces seems the most probable.

A comparison made by Muroya with subcutaneous and paravertebral injections of novocain colored with methylene-blue showed methylene-blue in the urine in ten to twenty minutes following subcutaneous injections, and in five to ten minutes following paravertebral.

From the work of Muroya upon rabbits, he concluded that the paravertebral injection is six times more toxic than the subcutaneous, but that this toxicity can be greatly reduced, making it about equal to the subcutaneous injection, by combining 5 per cent. gelatin with the adrenalin in normal salt solution, the adrenalin preventing or delaying its absorption through the blood-vessels, while the gelatin delays its diffusion into the cellular lymph-spaces.

By the use of this mixture its action at the point of injection is intensified, as the solution is more or less retained at the point of injection.

In drawing positive conclusions from the above it must be remembered that it is not always safe to apply the results of animal experimentation to man. In the first place the formation of the sacral canal may not exactly correspond to that of man, where the numerous large foramina for the exit of nerve-trunks permit any injected solution to readily escape in all directions, and besides the difference in the distance between the sacrum and skull in the rabbit and in man is considerable. These experiments are, however, more valuable for determining the movements of the injected fluid in epidural (sacral) injections.

Kappis has reported paravertebral injections of the cervical region. A line on either side of the spinous processes was anesthetized, and a long needle advanced forward until the transverse process was encountered. The interval between these processes is sought for by the point of the needle, which is advanced from 1 to 1½ cm. further and the injection made.

Kappis used 1½ per cent. novocain-suprarenin solution. The performance of paravertebral injections in such regions as the neck must receive further experimental study before it can be popularized; the likelihood of the solution reaching the phrenic nerve in effective quantity should not be lost sight of; its origin from the third, fourth, and fifth cervical is practically the center of the field, and after formation its course is more superficial. If the solution is effectively used this nerve should be paralyzed; however, unless the procedure is carried out on both sides, the temporary one-sided paralysis is not likely to be of consequence.

The paravertebral injection of the cervical region is carried out by Braun in a somewhat different way, following the suggestion of Heidenhain.

The injections are made from the side, between the third and fifth vertebræ, rather freely with a 0.50 per cent. novocain-adrenalin solution at the point where the nerves lie rather close together. A line is drawn on the neck from the transverse process of the atlas, which

Fig. 135.—*a* and *b*, points of injection on line drawn over transverse processes of cervical vertebræ. (From Braun.)

is felt under the point of the mastoid process downward over the transverse process of the sixth cervical vertebra (tuberculum carotidum).

This line represents the point at which the long axis of the transverse processes reach the surface, and forms a sharp angle with the edge of the sternomastoid as it gradually draws away from this muscle (Fig. 135).

Two points of puncture are made on this line—the upper one on a level with the lower border of the inferior maxilla, the lower one on a level with the promontory of the larynx.

From these two points of puncture the needle is carried directly inward, until it comes in contact with the transverse processes of the vertebra, injecting freely in the interval between the two points of puncture by injections made deep down, in a fan-like manner, using in all about 30 to 40 c.c. of a $\frac{1}{2}$ per cent. novocain-adrenalin solution. The great vessels of the neck are in no danger, as they lie somewhat in front of this line.

For operations on the midline of the neck both sides are injected, and where it involves the larynx the superior laryngeal is blocked in addition, as described in the chapter on the neck, and if the field of operation extend to the base of the lower jaw the third division of the fifth nerve is also blocked.

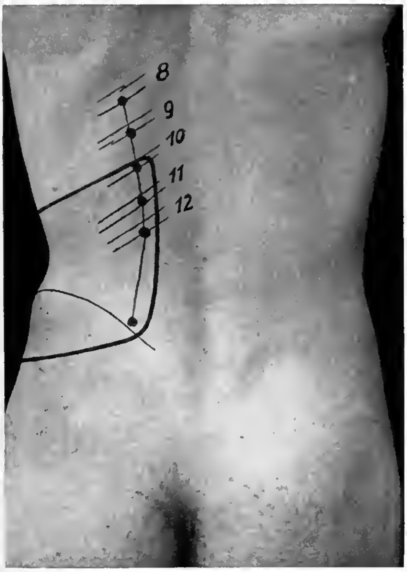

Fig. 136.

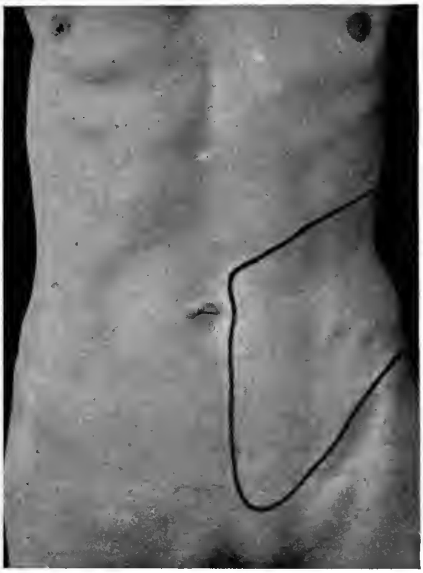

Fig. 137.

Figs. 136, 137.—Points of injection for paravertebral anesthesia for kidney operations, showing area of resulting anesthesia. (From Braun.)

Braun states that this method produces an effective surgical anesthesia for all major operations in this region.

Braun has performed three nephrotomies by paravertebral methods, and made accurate observations of the extent of the field of anesthesia.

The eighth to the twelfth dorsal nerves were injected each with 5 c.c. of a 1 per cent. solution; the line of puncture lay on a line which corresponded to the upward extension of the outer margin of the quadratus lumborum.

A point of anesthesia was now established over the crest of the ilium at the outer border of the quadratus lumborum; between this point and the point of puncture for the twelfth dorsal nerve was a rather free and deep injection made down to and including the fatty tissue around the kidney, using for this purpose 75 c.c. of a 0.50 per cent. novocain-suprarenin solution. The points of injection and distribution of anesthesia are shown in Figs. 136 and 137.

Braun states that the entire procedure was painless, including the luxation of the kidney, and while his patients were thin he believes that the anesthesia of this region by local methods has been conquered.

Finsterer, who has employed this method for 6 laparotomies and other major operations, gives his technic as follows:

The spine of the first lumbar vertebra is located, and a point on the skin from 3 to $3\frac{1}{2}$ cm. laterally is anesthetized; the needle marked in centimeters is passed vertically inward through this anesthetized point to a depth of from 4 to 5 cm., according to the stoutness of the individual, until the transverse process is struck; the upper border of the process is then felt for with the needle; when this point is reached the syringe is carried outward and downward, directing the needle-point upward and inward, when it is advanced about $\frac{1}{2}$ to 1 cm. further, and 5 c.c. of a 1 per cent. solution of novocain adrenalin is then injected in a fan-shaped area. Care should be exercised not to push the needle too deeply, as the anesthetizing fluid will pass beyond the ganglion and be useless.

The points for reaching the first, second, and third lumbar nerves will be at intervals of $3\frac{1}{2}$ to 4 cm. from each other, according to the size of the individual.

PARASACRAL ANESTHESIA

The anterior surface of the sacrum shows that the anterior sacral foramina lie almost always in a straight line, which from below up has a slightly outward angle. The distance between the midpoint of the first sacral foramina is $1\frac{3}{4}$ inches, and between the midpoint of the fourth is $1\frac{1}{2}$ inches (the fifth sacral foramen is formed by articulation with the coccyx, and does not appear as a separate opening), so that if a line is drawn down the midline of the sacrum a line running over the center of the foramina diverges but $\frac{1}{8}$ inch from the midline in passing upward from the fourth to the first foramina.

The distance from the free margin of the sacrum at its lower free border (sacrococcygeal junction) along the line passing over the center of the foramina is $\frac{3}{4}$ inch to the midpoint of the fourth foramen, $1\frac{1}{2}$ inches to the midpoint of the third foramen, $2\frac{1}{8}$ inches to the midpoint of the second foramen, and $3\frac{1}{8}$ inches to the midpoint of the first sacral foramen. This then makes the foramina the following distances apart: approximately $\frac{3}{4}$ inch from the fourth to the third and from the third to the second, and the first is 1 inch from the second (Fig. 138).

On the lateral view it is seen that if the needle is passed straight in over the lower free margin of the sacrum $\frac{3}{4}$ inch from the midline, and directed upward almost in a straight line, with a very slight outward inclination, that it will pass directly over the fourth, third, and

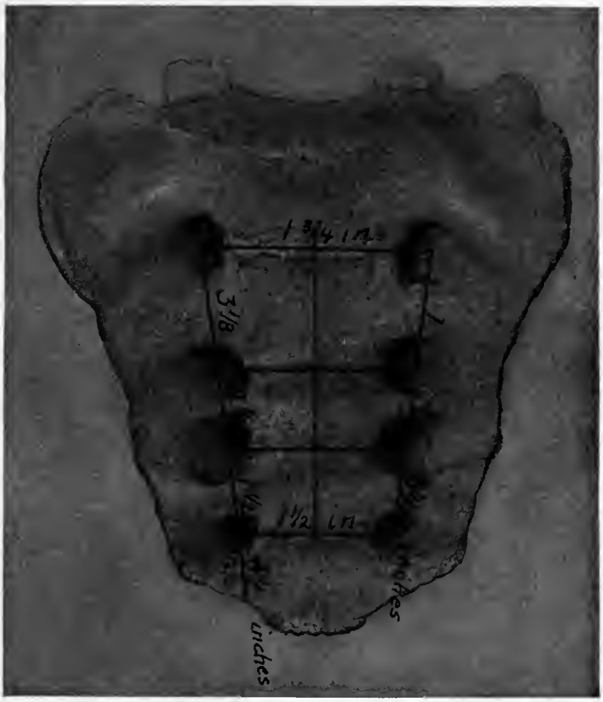

Fig. 138.—Anterior view of sacrum, slightly reduced, showing relative distances to foramen.

second foramina, when, after meeting the bone above this opening, if it will be slightly withdrawn and redirected, with the point elevated $\frac{1}{2}$ inch and advanced 1 inch further, that it will reach the first sacral foramina (Figs. 139, 140).

It is seen, after a study of numerous sacrums, that the intermediate foramina between the fourth and first in some few are placed somewhat outside of the straight line, passing over the center of the openings; this lateral variation is usually about $\frac{1}{8}$ inch, and was never seen to exceed $\frac{1}{4}$ inch.

As the nerves, as they emerge from the foramina run downward, outward, and forward (Fig. 141), it would seem best to slightly increase

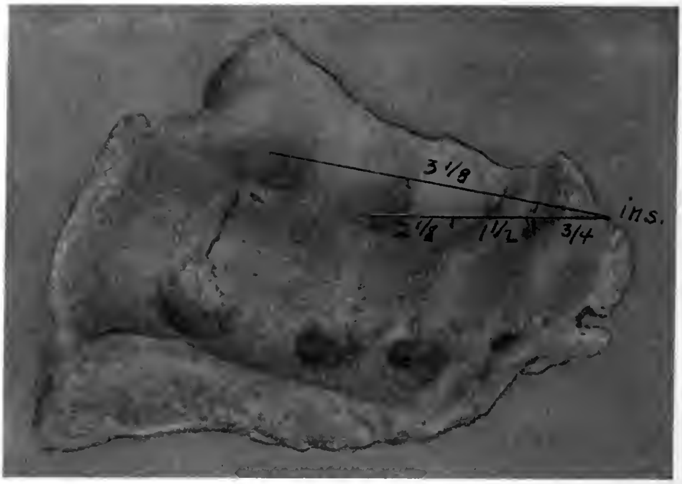

Fig. 139.—Distances and relative position of foramen on lateral view of sacrum.

Fig. 140.—Direction of long needle for parasacral injections. (From Braun.)

the lateral angle of the needle, so that at a depth of about 2 inches its point will be about $\frac{1}{4}$ inch lateral to the point of entrance; in this way

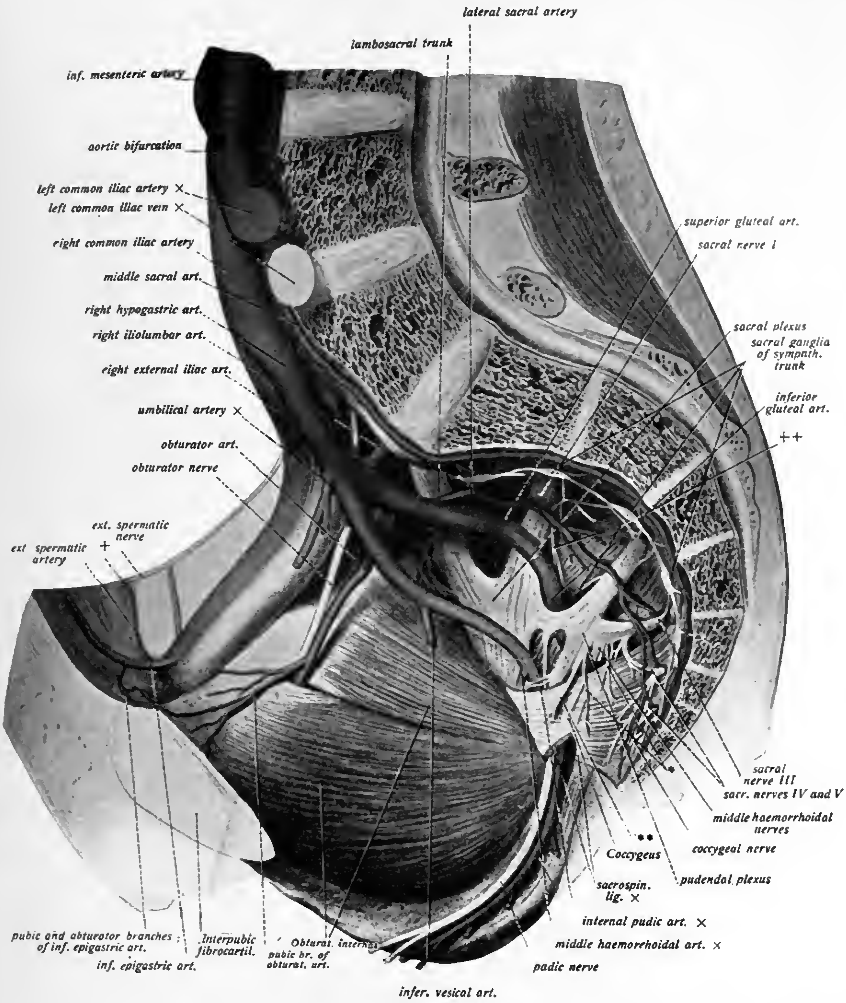

Fig. 141.—The blood-vessels and nerves on the right pelvic wall. The pelvis has been halved by a sagittal section and the genitalia removed. × = Branches to the coccygeus. ×× = Branch to levator ani. + = Site of abdominal inguinal ring. ++ = Branches to pyriformis. (Sobotta and McMurrich.)

the needle cannot go astray, and may even transfix these nerves though the foramina do not lie in a straight line.

SACRAL ANESTHESIA

This is made, according to Braun, as follows: With the breech of the patient well presented, the long fine needle (for this purpose it should be about 5 or 6 inches long) is entered about $1\frac{1}{2}$ or 2 cm. from the middle line, on a level with the sacrococcygeal joint. As the inner surface of the sacrum up to about the second foramina is but little curved, the needle is advanced straight up from the point of puncture, in close contact with the bone, until it impinges with it near the second sacral foramina; this point is about 6 to 7 cm. from the point of puncture at the sacrococcygeal joint in the adult, not counting the thickness of the soft parts.

One proceeds in the following manner: The needle is entered on the inner surface of the lower border of the sacrum and directed upward in a parallel direction seeking for the edge of the bone; the needle is then pushed along the inner surface, parallel with the middle line, until it reaches the bone at about the recognized depth; along the entire way, from the second to the fifth sacral foramina, 20 c.c. of 1 per cent. novocain-adrenalin solution is injected. The injections should not be made except when the needle is in contact with the bone. The needle is now drawn back to the edge of the bone and redirected at a slightly increased angle, but still parallel to the middle line toward the linea innominata; reaching the bone just above the first sacral foramina, about 9 or 10 cm. from the point of entrance (not including the soft parts), 20 c.c. of the 1 per cent. solution are injected here.

Before finally withdrawing the needle 5 c.c. are injected between the coccyx and rectum. The same procedure is repeated on the opposite side, using in all about 100 c.c. of solution. Braun states that there is no danger of injuring the rectum if empty, as it is pushed out of the way by the advancing needle, but a finger may be inserted within it if preferred for guidance.

This method produces an effective means of anesthesia for such operations as prostatectomy, prolapse of the uterus, and resections of the rectum, as well as other minor operations upon these parts, but it is not sufficient for a total hysterectomy, as here the upper part of the field is not reached by the pelvic nerves.

CHAPTER XXII

THE HEAD, SCALP, CRANIUM, BRAIN, AND FACE

"THE application of local infiltration and regional anesthesia to the major surgery of these parts is greatly hampered and hindered, in the hands of the average operator, by the difficulty of effectively reaching the most important nerve-trunks and by the inability to control the circulation except in a few favorable areas. Nevertheless, surprisingly brilliant results have been obtained with these methods by those who are adepts in their application, and who are alert for opportunities to substitute them for general narcosis. At one time it was thought that the head and face were particularly dangerous regions in the practice of cocain operations, and that extensive infiltrations with the drug were to be avoided on account of the close proximity of these parts to the brain and medullary centers. The evil repute of cocain in head surgery was traceable to the numerous accidents and fatalities which occurred in the earlier days of cocain anesthesia. In the hands of irresponsible or careless practitioners and others—dentists and specialists in rhinopharyngolaryngeal practice—toxic doses of appalling strength (10 to 20 and 30 per cent.), for the extraction of teeth or in securing the anesthesia of the upper air-passage, were frequently resorted to. Reclus, in his careful and masterly analysis of the mortality reports attributed to cocain in surgical practice, completely disposes of this alleged 'danger zone' of the head by conclusively showing that in each case in which death or alarming symptoms occurred the accidents could always be traced to overdosing with unnecessary toxic solutions. In this way he has rendered an inestimable service to the cause of local anesthesia. In consequence of the use of the stronger solutions of cocain, which were thought necessary in the earlier days of cocain anesthesia, the control of the circulation was a matter of far greater concern than it is at present, since the infiltration of weak solutions and a better knowledge of the possibility of the neural method have been more clearly recognized, and the introduction of the suprarenal preparations have added these valuable aids to our armamentarium, both for the control of hemorrhage as well as for prolonging and intensifying the anesthetic action.

"At present the control of the circulation is still desirable, not so much to diminish the dangers of intoxication, but to prolong and intensify the action of this narcotic drug in long operations. The demand for appliances to 'incarcerate the anesthetic' is shown by the invention of numerous devices, such as Corning's scalp rings, Corning's hemostatic fenestrated forceps for operations on the cheek, mouth, and breast, Noyes' ectropion forceps, Wright's clamp, etc. At present the introduction of Schleich's infiltration anesthesia has made these devices unnecessary, except in regions in which the anatomic configuration of the parts (scalp and auricle) will permit of easy elastic constriction, which is always advantageous if only from the hemostatic point of view" (Matas).

The surgery of the head with regional methods of anesthesia is one of the most attractive and fascinating in the entire body, and its operative procedure among the most brilliant in the entire domain of surgery. In itself a vast field for the application of intra- and paraneural methods, presenting an intricate labyrinth of foramina, canals, fissures, and tracts for the passage of the great nerve-trunks and their branches, always appearing in a new and interesting light, due to the many brilliant minds that have made this region a field of study, and have evolved new ways and means of access and approach to the great nerve-trunks at their basal foramina and even their injection within the skull.

In this vast field the work is of interest alike to physician and surgeon—to one for the alcoholization of the great nerve-trunks for the relief of neuralgia; to the other, for the purpose of regional anesthesia of the peripheral parts, as well as for the deep injections of alcohol, which, in its clinical application, should always be regarded as a surgical procedure. Whether devised originally for the therapeutic application of alcohol or the proximal cocainization of the nerve-trunks, both alike serve the same end in offering an approach to the nerve-trunks and can alike be used for both purposes.

From the earlier pioneer efforts in this direction to the present time are to be found a galaxy of brilliant names—Matas, Schlösser, Ostwalt, Hecht, Lowenstein, Killiani, Patrick, Bodine, Keller, Wright, Harris, Braun, Levy, Baudoin, Brissaud, Sicard, Taptas, and more recently Offerhaus, and particularly Härtel, in his latest approach to the gasserian ganglion and exhaustive presentation of this subject.

In originally undertaking this work I had hoped that at least this chapter would be from the pen of my distinguished chief, Professor Matas, an original worker in this as well as other fields, and whose brilliant achievements already fill many pages in the annals of surgery.

While deprived, at least for the present, of this benefit due to the press of other matters, we may hope that should this chapter be re-written it may come from his pen, and I hope that in this, as in

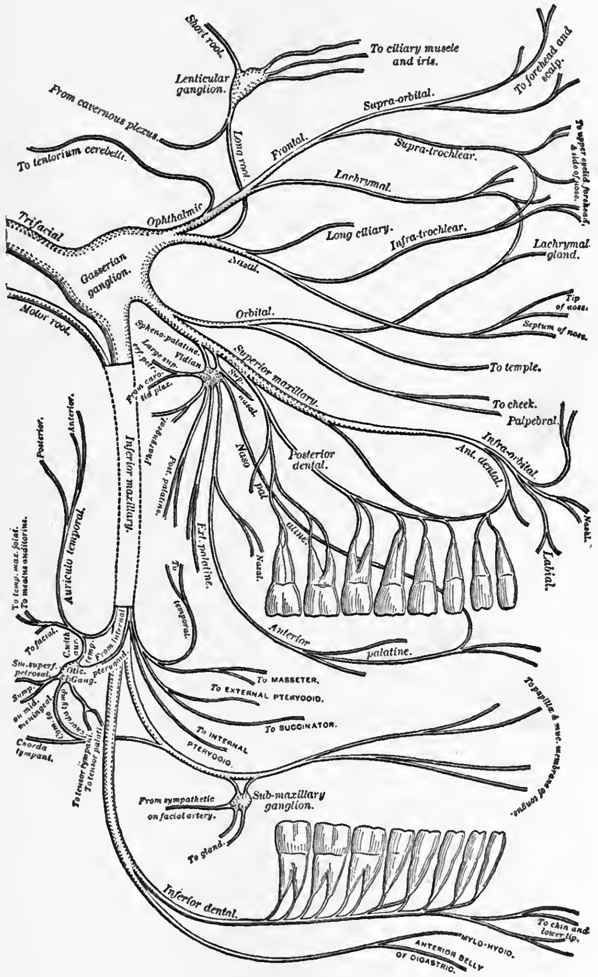

Fig. 142.—Diagram of the fifth cranial nerve. (From Flower.)

other chapters of this work in which I have so freely borrowed from his knowledge, I may in some small measure reflect credit upon his teachings.

A few of the original illustrations in this chapter are from the private collection of Prof. Matas, kindly loaned for this purpose and appear for the first time in these pages. These illustrations were prepared by my colleague, Dr. Urban Maes, who, in association with Prof. Matas, has done much work and developed great skill in this field.

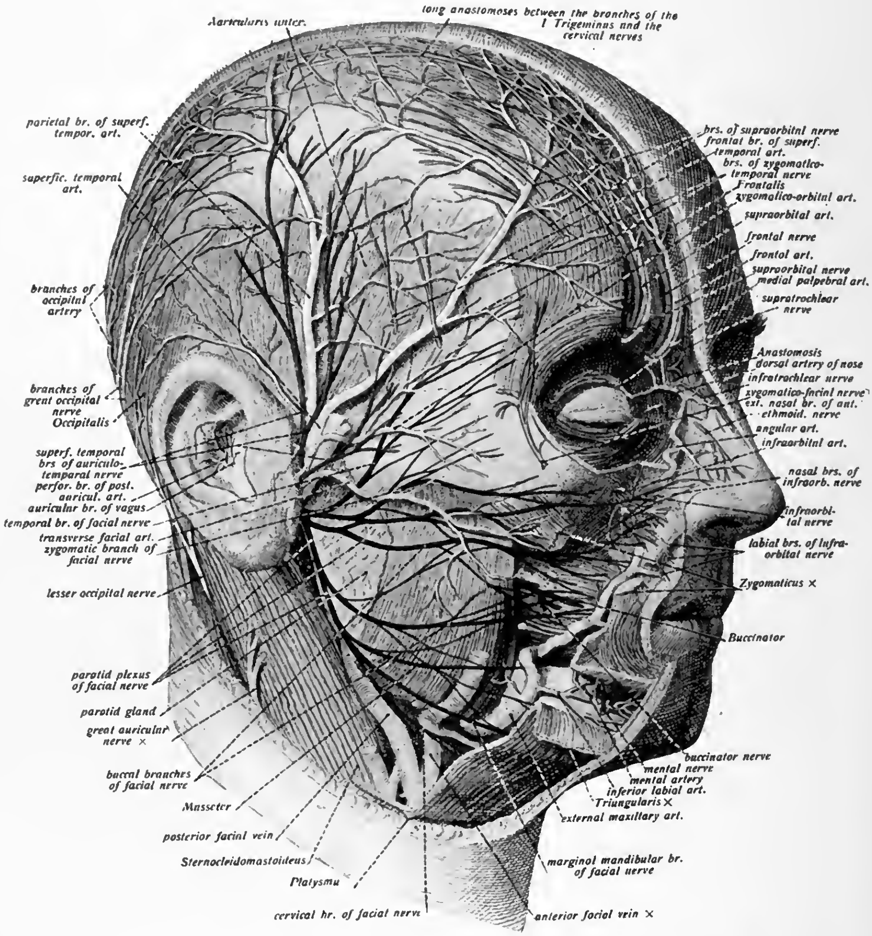

Fig. 143.—Superficial nerves and arteries of the face (deeper layer). Most of the parotid gland is removed. The facial muscles have been cut away, divided, or drawn downward. (Sobotta and McMurrich.)

For a thorough understanding of the methods of local and regional anesthesia applied to the head a thorough knowledge of anatomy is essential, with a study of the subject from every view-point; only then can we properly appreciate the difficulties and delicate technic necessary for the clinical application of these methods.

The Fifth Nerve and Its Branches (Figs. 142, 143).—The ophthalmic or first division of the fifth (Fig. 144) is a sensory nerve, supplying the eyeball, mucous lining of the eye, lacrimal gland, nasal fossa, the

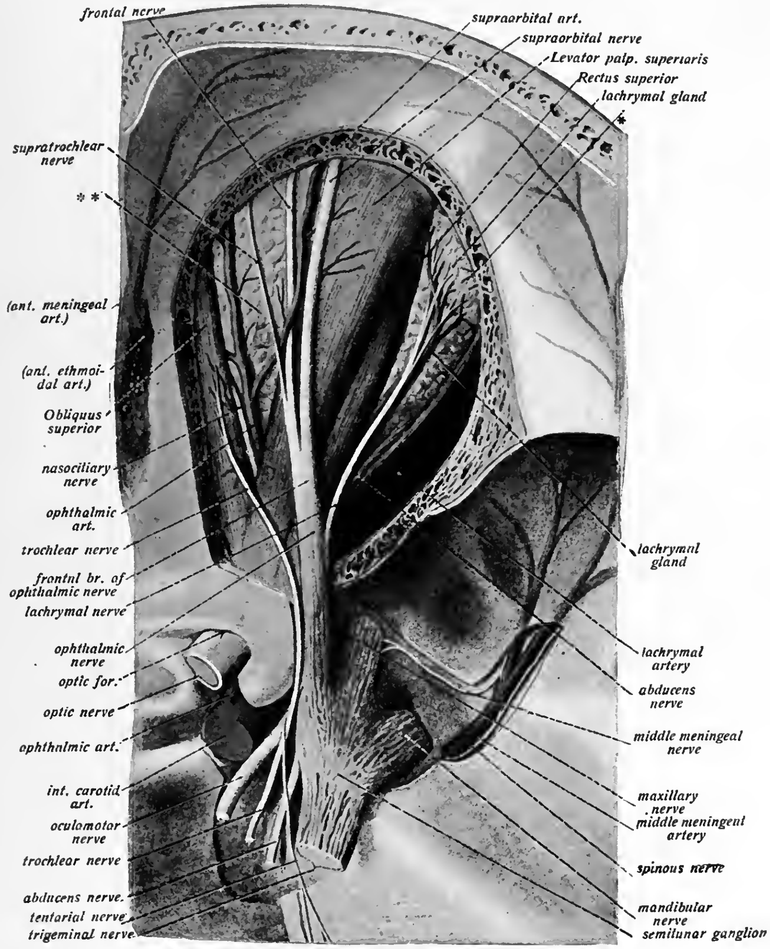

Fig. 144.—The nerves and arteries of the orbit (superficial layer). The roof of the orbit, the periorbita, and the upper portion of the outer wall have been removed. The dura mater has been divided along the middle meningeal artery and in the neighborhood of the semilunar ganglion and of the orbital nerves. * = Accessory vessels to the lacrimal gland from the zygomatico-orbital branch of the anterior deep temporal artery. ** = Orbital fat. (Sobotta and McMurrich.)

skin of the nose, forehead, and front portion of the vertex. After leaving the gasserian ganglion it passes forward along the outer wall of the cavernous sinus, below the other nerves, which pass here (Fig. 210), and just before entering the orbit through the sphenoidal fissure divides into lacrimal frontal and nasal branches. The *lacrimal* branch passes forward in a separate tube of dura mater, and enters the orbit at the narrowest part of the sphenoidal fissure (Fig. 164); it then runs obliquely forward and outward above the upper border of the external rectus to the lacrimal gland.

The *frontal*, the largest division of the ophthalmic, appears as a direct continuation of this nerve. It enters the orbit above the muscles through the highest and broadest part of the sphenoidal fissure, and continues forward in the midline between the levator palpebræ and the periosteum to about the middle of the orbit, where it divides into supratrochlear and supraorbital branches.

The *supratrochlear* (Fig. 143) escapes from the orbit between the pulley of the superior oblique and the supraorbital foramen; it curves up on the forehead, close to the bone, beneath the occipitofrontalis muscle, and is distributed to the skin of the forehead on either side of the middle line.

The supra-orbital nerve passes forward through the supra-orbital foramen, supplies the upper eyelid, and ascends beneath the occipito-frontalis muscle, and is distributed to the scalp and pericranium as far back as the parietal and occipital bones.

The *nasal nerve* enters the orbit between the two heads of the external rectus, passing between the two divisions of the third nerve, runs obliquely inward above the optic nerve, beneath the superior oblique and superior rectus muscles to the inner wall of the orbit, where it passes through the anterior ethmoidal foramen, giving off its infratrochlear branch here, and enters the cavity of the cranium, where it traverses a groove on the cribriform plate of the ethmoid bone and passes down through the slit on the side of the crista galli into the nose. Within the nasal cavity this nerve supplies the mucous membrane in its upper and anterior parts. The nerve then descends in a grove on the back part of the nasal bone, escaping between the lower border of this bone and the upper lateral cartilage to supply the end of the nose.

Its infratrochlear branch supplies the skin at the inner angle of the lids and side of the nose.

The *superior maxillary nerve* (Fig. 145) passes forward through the foramen rotundum into the sphenomaxillary fossa, passing obliquely forward and outward. It enters the orbit through the sphenomaxillary fissures, and passes into the infra-orbital canal and appears upon the face at the infra-orbital foramen, where it divides into three sets of branches—palpebral, nasal, and labial—which are distributed to these respective parts (Fig. 143). In the sphenomaxillary fossa this nerve gives off its temporomalar, sphenopalatine, and posterior superior dental branches.

The *temporomalar branch* enters the orbit, and divides at the back part of this cavity into temporal and malar branches. The temporal

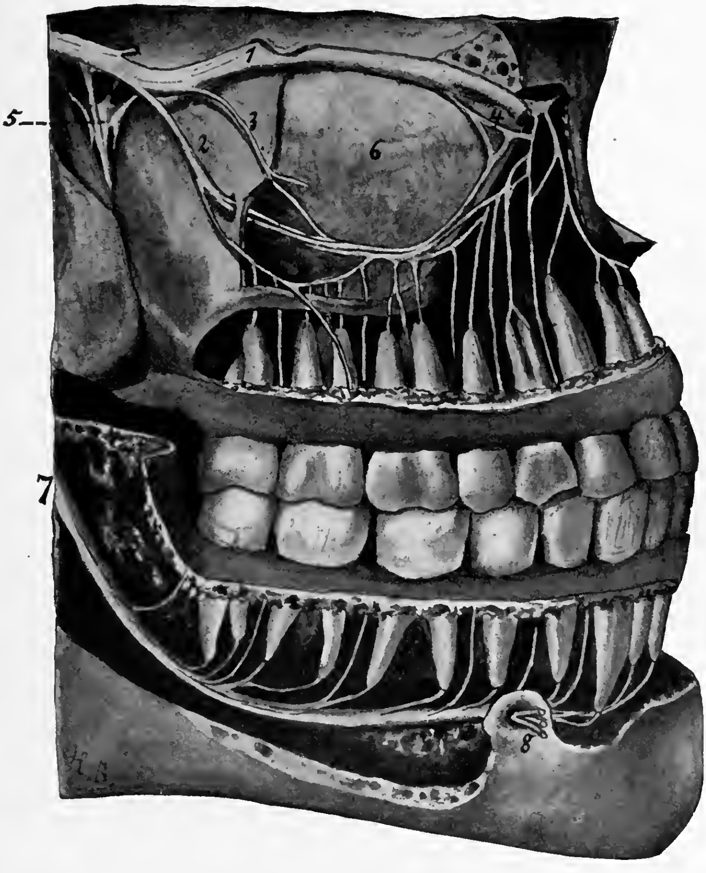

Fig. 145.—Innervation of the teeth (modified from Spalteholz). The outer wall of orbit and part of the outer wall of superior and inferior maxillæ have been removed: 1, Infra-orbital nerve; 2, 3, and 4, posterior, middle, and anterior superior dental nerves; 5, sphenopalatine ganglion and nerves; 6, lateral mucous membrane, antrum of Highmore; 7, inferior dental nerve; 8, mental nerve. (From Braun.)

branch passes through a foramen in the malar bone and enters the anterior part of the temporal fossa; it ascends between the bone and substance of the temporal muscle, piercing the muscle and temporal fascia about 1 inch above the zygoma, to be distributed to the skin of the temporal regions and side of forehead. The malar branch passes through a foramen in the malar bone, and appears upon the cheek at the opening of this canal (Fig. 143), on the anterior surface of the bone, about ½ inch below the rim of the orbital fossa, where it is distributed to the skin of the cheek.

The sphenopalatine descends to this ganglion, which lies just below the trunk of this nerve in the sphenomaxillary fossa.

The *posterior superior dental branches* are given off from the superior maxillary nerve in the sphenomaxillary fossa, just as it is about to enter the orbit; these nerves pass down over the tuberosity of the superior maxillary bone to enter the dental canals on the posterior surface of this bone about its middle; these nerves supply the three molar teeth.

The *middle and anterior superior dental* nerves are given off in the infra-orbital canal, the middle supplying the two bicuspids, the anterior branch the canine and incisor teeth.

The *descending* or *palatine branches* from the sphenopalatine ganglion are three in number—anterior, middle, and posterior. The anterior descends through the posterior or palatine canal to appear upon the hard palate at the posterior palatine foramen; it then passes forward in a grove at the junction of the hard palate and alveolar process, nearly as far as the incisor teeth, supplying the parts in the vicinity of its distribution. In the palatine canal it gives off branches to the nasal fossa. The middle and posterior branches are distributed to the soft palate and tonsillar regions.

The *nasopalatine nerve* is the only other nerve from the sphenopalatine ganglion which is of special interest. It enters the nasal fossa through the sphenopalatine foramen, passes inward across the roof of the nasal fossa to reach the septum, down which it runs to the anterior palatine foramen, and appears at the opening of this canal on the roof of the mouth to supply the surrounding soft parts.

The *inferior maxillary nerve*, largest division of the fifth, passes through the foramen ovale and divides into two trunks—anterior and posterior. It is joined at this point by its motor root, most of which passes into its anterior division, which divides into masseteric, buccal, and pterygoid branches, to be distributed to these muscles, the masseteric passing through the sigmoid notch to reach this muscle; the buccal branch, in addition to supplying this muscle, is distributed to the skin of the cheek as far forward as the angle of the mouth.

The *deep temporal branches*, given off just after the nerve emerges from the skull and running outward and upward, are distributed to the temporal muscle.

The *auriculotemporal nerve* curves upward with the temporal artery, between the external ear and condyle of the jaw, beneath the substance of the parotid gland, and, passing over the zygoma, divides into branches—auricular, superior, and inferior, and a branch to the meatus auditorius, which are distributed to these parts. The temporal branches pass upward with the temporal artery and supply the scalp as far as the vertex of the skull.

The *lingual nerve* reaches the inner side of the ramus of the jaw, down which it descends on the inner side of the dental nerve to the base of the tongue, crossing obliquely forward and inward to this organ, running along its side as far as the tip. Where the nerve passes from the ramus of the jaw to the base of the tongue it is quite superficially situated beneath the mucous membrane, and is quite easily reached in this position, particularly if the tongue is drawn forward and to the opposite side.

The *inferior dental nerve* passes obliquely downward, forward, and outward with the inferior dental artery to reach the dental foramen on the inner side of the inferior maxilla. In the dental canal it gives off branches which supply the teeth, and a mental branch, which appears at the mental foramen and supplies the lower lip and the soft parts of the chin.

In addition to the branches of the fifth the lower part of the face receives branches from the cervical nerves. The side of the head receives the auricular branch of the pneumogastric, which passes upward between the mastoid process and external auditory meatus to the back of the ear. The occipital region is supplied by the occipitalis major and minor and the auricularis magnus. These nerves will be spoken of in dealing with their areas of distribution.

Anesthesia.—To anesthetize the supra-orbital and supratrochlear nerves an injection of about 2 drams of solution No. 2, 0.50 per cent. novocain, and a few drops of adrenalin to the ounce should be made just over the supra-orbital notch, beneath the deep frontal fascia, transversely for about 1 inch; or, where both nerves are to be injected, this can be done by a subfascial injection, extending across the base of the forehead, as indicated in Fig. 146, the shaded portion indicating the anesthetic area; on the margins of this area for some distance back there is lessened sensibility. While it is quite feasible to practice strictly regional anesthesia for the entire scalp by blocking the supra-orbital nerves in front, the occipital nerves behind, and the temporal nerves on the side by a line of anesthesia just above the zygoma, extending from the ear to the angle of the orbit and carried down to beneath the temporal fascia, thus rendering the entire scalp anesthetic. This procedure limited to one side produces an anesthesia reaching almost to the vertex, where the nerves of the opposite side lap over. Such an extensive area of anesthesia is, however, not often called for, while those parts supplied by the supra-orbital and occip-

Fig. 146.—Resulting area of anesthesia after blocking supra-orbital and supratrochlear nerves along heavily shaded line. (From Braun.)

ital nerves will more often be found quite useful, easily and quickly carried out; but where the field of operation is more or less central on the scalp, it will, however, usually be found simpler and require less solution to surround the operative area by a wall of anesthesia carried

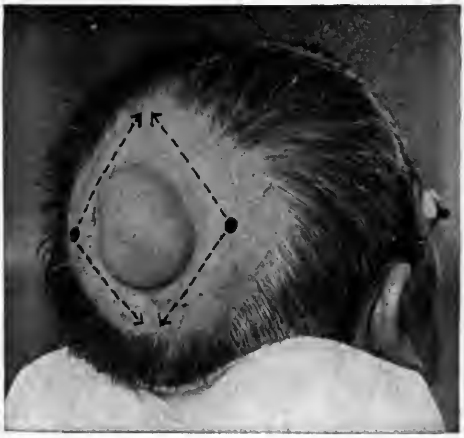

Fig. 147.—Surrounding tumor of the scalp with zone of anesthesia. (From Braun.)

well down to the pericranium, which will meet and anesthetize all nerves entering the area and permit any contemplated operation upon the soft parts, as well as resections of the bone and operations upon the underlying dura and brain (Figs. 147, 148).

Here the operative field is surrounded by an area of anesthesia, and at several points along this surrounding zone the long needle is entered and passed down to the bone through the points indicated by the heavy dots, injecting the solution as the needle is advanced.

However, it is to be recommended, as a general rule, that all extensive operations upon the soft parts or underlying bone in the region supplied by the fifth nerve be operated by injections of ganglion gasseri, or its nerves at their foramina of exit; the injection of the ganglion has the advantage that it anesthetizes the dura through its meningeal branches as well as the overlying bone and soft parts.

Fig. 148.—Surrounding a compound fracture of skull with zone of anesthesia. (From Braun.)

As the occipital nerves are several in number, and reach the scalp at different points, they may be dealt with collectively. If a line of anesthesia (solution No. 2, with 5 drops adrenalin to the ounce) is produced, extending from ear to ear across the base of the mastoid processes, and carried well down to the deep tissues, it will block all branches of the occipital nerves, as well as branches from the auricularis magnus, and result in an anesthetic area, as indicated in Fig. 149 (the white line shows the line of infiltration), or the nerves may be dealt with more or less individually in the following way:

The occipitalis major and minor and the auricularis magnus may be blocked by making injections at their points of emergence at the occiput (Fig. 150); the occipitalis minor and auricularis magnus behind

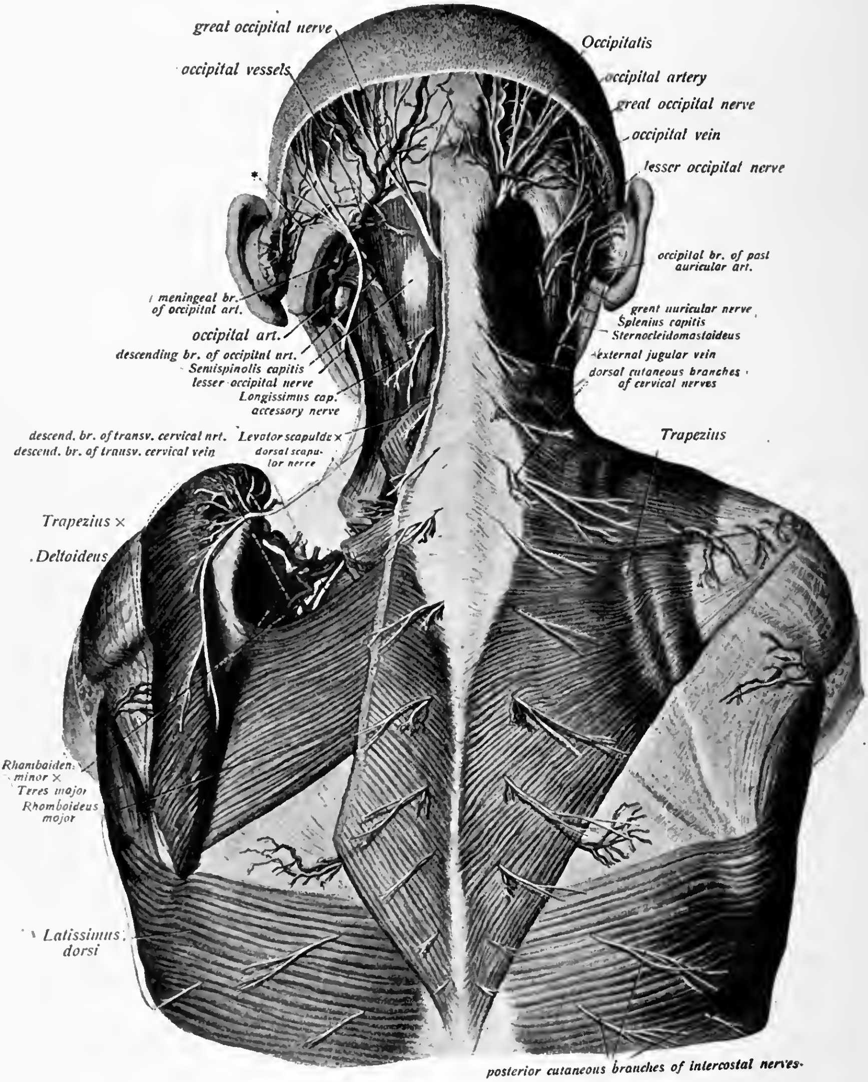

Fig. 149.—The superficial and middle layer of the nerves and vessels of the nuchal region. Upon the left side the trapezius, sternocleidomastoideus, splenius, and levator scapulæ have been divided. * = Occipital root of external jugular vein. (Sobotta and McMurrich.)

the posterior margin of the insertion of the sternocleidomastoid. The occipitalis major emerges upon the surface of the occiput through a cleft in the trapezius muscle, along with the occipital artery, the third occipital, sometimes an independent nerve, passing slightly nearer the midline; to reach both of these nerves a deep line of infiltration can be carried from the posterior occipital protuberance one-third of the distance toward the auricle. As emphasized by Härtel, and referred to by Bier and Krause, in intracranial operations regional methods of anesthesia should be preferred to infiltration around the operative area in such operations where the electric excitability of the cerebral cortex should not be disturbed, as in operations for epilepsy. When performing such operations under infiltration anesthesia the diffusion of the anesthesia may reach the cerebral cortex and interfere with

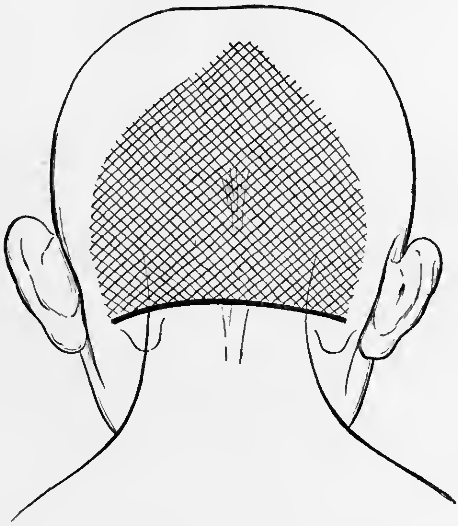

Fig. 150.—Line of subcutaneous infiltration blocking occipital and auricularis magnus nerves and resulting area of anesthesia.

electric tests. It must be remembered that here as elsewhere bone is insensitive to pain after the periosteum has been anesthetized or denuded, and it can be freely operated upon with trephine, chisel, rongeur, or saw without the least discomfort, beyond the fact that the patient hears and feels the jar of the manipulations. The dura is insensitive to wounds inflicted through incisions or the application of forceps, but is sensitive to traction should it be pulled upon, consequently it can be freely incised and turned back without pain. This statement holds good for the vertex and lateral surfaces of the brain, the areas most frequently operated upon; however, at the base of the skull, where the dura is attached to the bone, some painful sensations are experienced, requiring infiltration of the dura here to permit of its incision or removal from the bone, but the operative procedures in these areas are comparatively few.

It is a remarkable fact that the brain, the great sensory organ of the body, should itself be devoid of painful sensations. The entire cerebral cortex of animals has been irritated and stimulated in many ways without ever exciting any response indicative of pain, and we have often removed considerable areas from the brain of a thoroughly conscious patient without ever exciting any pain.

The knowledge of these facts permits us to undertake in suitable cases many operations under local anesthesia upon the skull and cortex of the brain which might otherwise seem impossible. In any extensive operation upon the cranium it may prove desirable to use circular constriction, with rubber tubing around the base of the cranium; this, however, while often advisable with general anesthesia, is superfluous with local methods, for here the use of adrenalin proves an effective hemostatic, besides the constriction is often in the way, and may prove annoying or painful to any but a patient under general anesthesia unless the entire circumference of the cranium were anesthetized. Usually in severe traumatisms of the skull, such as extensive or simple depressed fractures, the patients are often in a state of unconsciousness from shock or brain injuries, which permit of painless operating with very little local anesthesia, On the other hand, many of these patients are in a condition of noisy delirium or turbulent restlessness, which makes any operation under local anesthesia, even if painless, inadvisable, and forces a resort to general anesthesia.

Omitting the above class of patients, there are a large range of operations which permit of the use of local anesthesia. *Simple abscesses* will require nothing further than a line of infiltration over the proposed incision.

Wounds.—For the cleansing and suture of incised, contused, and lacerated, stab or superficial gunshot wounds, the most satisfactory plan is, after a preliminary cleansing of the surrounding parts, to create a wall of anesthesia around the wound, cleansing it later with a more liberal cleansing of the entire area after the anesthetizing process has been completed, as described in the chapter on Principles of Technic.

Sebaceous cysts may be removed the same way, by a surrounding wall of anesthesia and excising a triangular or oblong piece of the skin with the tumor attached, approximating the gap with sutures; or by infiltrating a line over the long axis of the cyst and splitting it open and pealing out the sac. While this is a simple and thoroughly effective method in non-infected sacs, in the event of infection it will leave a suppurating wound.

Benign tumors may be dealt with by the same method, also malignant growths when superficial and limited, as in epitheliomas, but if extensive or deeply infiltrating had best be left to regional methods or general anesthesia. In those cases of malignancy suitable for local methods care should be exercised in making the injections to keep well away from the growth, and surround it by a wall of anesthesia, extending down to the cranium, so that this may be resected if the growth is found attached.

As this same technic is applicable to *all operations upon the scalp* and underlying bone, it is sufficient to state that it is suitable in depressed fractures and for the evacuation of epidural or subdural hemorrhage, intracranial abscesses, and for the removal of necrotic areas of the skull. Osteoplastic flaps of considerable extent are also just as easily raised with local anesthesia and operations performed upon the cortex of the brain. Here local anesthesia possesses decided advantages over general anesthesia, particularly ether, which greatly congests the entire cranial circulation, and is particularly troublesome when operating within the skull on account of the persistent oozing which occurs from even the smallest vessels, and greatly adds to the danger of postoperative hematoma. This entire picture is changed when operating with local anesthesia; instead of the tremendous congestion encountered, with ever-ready tendency to troublesome hemorrhage difficult to control, with possible later oozing, the brain and its circulation is found normal, and hemorrhage either does not occur, or is easily controlled, with little or no tendency to postoperative oozing.

For this reason, if for no other, it is advised to consider local anesthesia in all suitable intracranial operations, and when very extensive to perform them by a two-stage operation, raising the osteoplastic flap in the first stage under general anesthesia; this is then returned to its place and lightly held with sutures, to be again raised at a subsequent sitting, next day or later, the dura opened, and the intradural procedure executed.

The advantage of this method is illustrated by the following reports:

Mr. S., very stout, short man, weighing over 200 pounds, gave symptoms of tumor near left motor area. Under general anesthesia a large osteoplastic flap was raised, exposing the entire left motor area. The patient was very full blooded, and the entire circulation of the head, face, and cerebrum became greatly congested; the cerebral and meningeal vessels were everywhere turgid with blood, and would certainly have given trouble if the operation had been proceeded with; accordingly the wound was loosely closed, after securing all bleeding-points in the external soft parts, and the patient returned to bed. The next day, after lightly injecting a cocain solution into the incision, the sutures were loosened and the flap raised; beyond this point no cocain was used. The operation was everywhere painless, the patient conversing with us during the different steps of the deeper procedure. A vast difference was now seen in the condition of the meningeal and cerebral circulation, the vessels which previously had been turgid with blood were now hardly to be seen, only a few small vessels of normal size encountered here and there. The brain, which had previously been tense and bulging from the wound, now seemed shrunken by comparison and lay well within the skull.

Two tumors were located back of the motor area and removed with a surrounding margin of brain, resulting in a paresis of the right side of the body and tongue. The patient was able to indicate during the entire procedure that he felt no pain. The wound was then closed with a small drain, the patient making a satisfactory recovery, but died about six months later from a recurrence of the malignant process. This case illustrates clearly the advantages of a two-stage operation, or the entire procedure could have been performed at one sitting with local anesthesia. The subsequent stage could, however, have been done without any anesthesia, a preliminary hypodermic of an eighth or quarter of morphin would have sufficed to relieve the fears and uneasiness of the patient; the raising of the flap by the second day would not have caused any amount of pain, and, as the deeper parts are without sensations, the second stage may possibly have been performed this way.

This and many other experiences have strongly convinced me of the advantages of using local anesthesia in suitable cranial and intracranial operations upon favorable patients, where it is known beforehand just what is going to be done and the parts are all fairly accessible.

The following case illustrates a very satisfactory and fairly extensive operation for the removal of necrotic bone and drainage of an epidural abscess:

G. W. L. entered our service in the Delgardo Memorial, March, 1911, with a history of a luetic infection nine years before. There were multiple gummas about the head, with a sinus over the right ear which ran down to the bone, also a fluctuating mass 3 inches above, which seemed to communicate with the sinus Operation under local anesthesia (the patient in poor physical condition), a wall of anesthesia was created with solution No. 1, which ran from the ear below to the midline of the vertex above and measured about 3 inches across; this wall of anesthesia was carried well down to the pericranium. In a few minutes anesthesia in the central area was complete. An incision was made down to the bone connecting the swelling above with the sinus below; the swelling was found to be broken-down gumma over a necrotic area in the skull which communicated with the sinus below; the bone was removed between these two points, and revealed multiple areas of necrosis on the inner table of the skull with numerous small sequestra; in all an irregular area of the skull was removed which measured about 2 by 3 inches. The outer surface of the dura, which was covered with foul granulations, was then cureted and the wound packed and skin edges approximated. The patient was later given 606, and discharged when the wound in the head had healed. He returned again the following October with a similar condition near the site of the first operation, and was operated on in a similar way. Both operations were entirely painless, and were performed as thoroughly as would have been the case under a general anesthetic.

A very interesting case of a similar nature, illustrating the advantages of a two-stage operation, or of performing the entire operation under local anesthesia, is the following, reported by Drs. Thomas and Cushing in the "Journal Amer. Med. Assoc.," March 14, 1908: The case, a rather dangerous one, had been operated on four times for a tumor of the upper posterior Rolandic area. Much difficulty was experienced from hemorrhage, due to the fulness of the vessels produced by the anesthetic and forced an abandonment of the operation, the patient also doing badly under the anesthetic. One operative intervention was made necessary for the removal of clots which resulted from the free oozing from the congested vessels.

The fifth and last operation, at which time the cyst was removed, was done under cocain anesthesia, a preliminary hypodermic of $\frac{1}{8}$ gr. of morphin and $\frac{1}{100}$ gr. of atropin given a short time before. The following are extracts from Dr. Cushing's notes:

"Although the undertaking, as Dr. Thomas has said, was premeditated, etc., in consequence of our previous unfortunate experience in administering general narcosis to this patient we must confess to surprise at its successful accomplishment. Contrary to all expectations, the dura proved to be insensitive to such manipulations as were necessary to freely open it. Only when it was put under tension or displacement was any discomfort occasioned, otherwise it seemed to be absolutely free from sensitivity. The conditions were similar in many respects to those which are present in the visceral peritoneum, which, according to Lennander, as well as our own observations, seem to possess no sensory nerves, pain being occasioned only when the viscera are so dislocated as to put the parietal serosa under abnormal tension.

"The danger of doing all the operation at one stage, owing to hemorrhage, made greater by the congestion brought about by the anesthesia. If it should prove to be possible, however, to carry out the second stage of an intracranial exploration without an anesthetic, this would be a stronger argument for the two-stage procedure than the mere avoidance of shock.

"It was truly remarkable in this patient's case to find that the extensive manipulations which were essential to the removal of the tumor could be carried out while the patient was perfectly conscious, and was chatting and taking a lively interest in the progress of the operation."

Numerous other cases could be mentioned in our own practice, as well as in that of others, but the above will suffice to illustrate the technic and possible extent of many cranial and intracranial operations. In Fig. 151 is outlined the operative area for subtemporal decompression, the deep parts to be anesthetized as indicated by the heavy dots. In this area it would, however, seem best to inject the gasserian ganglion. In Fig. 152 is figured the operative area and points of injection for operations upon the occipital region, as well as for exposing the surface of the cerebellum.

To locate the **supra-orbital, infra-orbital, and mental foramina,** Gray gives the following directions: "The supra-orbital foramen is

Fig. 151.—Points of injection and line of infiltration for craniotomy in temporal region. (From Braun.)

situated at the junction of the internal and middle third of the supra-orbital arch, between the internal and external angular processes. If a straight line is drawn from this point to the lower border of the inferior maxillary bone, so that it passes between the two bicuspid teeth in both jaws, it will pass over the infra-orbital and mental foramina, the former being situated about 1 cm. ($\frac{2}{5}$ inch) below the margin of the orbit, the latter varying in position according to the age of the individual. In the adult it is midway between the upper and lower borders of the inferior maxillary bone, in the child it is nearer the lower border, and in the edentulous jaw of old age it is close to the upper margin" (Fig. 158).

The infra-orbital and mental nerves can be reached at the foramina through the mouth or from without for paraneural injections. The *infra-orbital foramen* is located by the tip of the finger, and is found just above the root of the first bicuspid, about ½ to 1 cm. below the rim of the orbital fossa (Fig. 156). With the finger held at this point, the lip is raised and the needle entered high up slightly posterior to

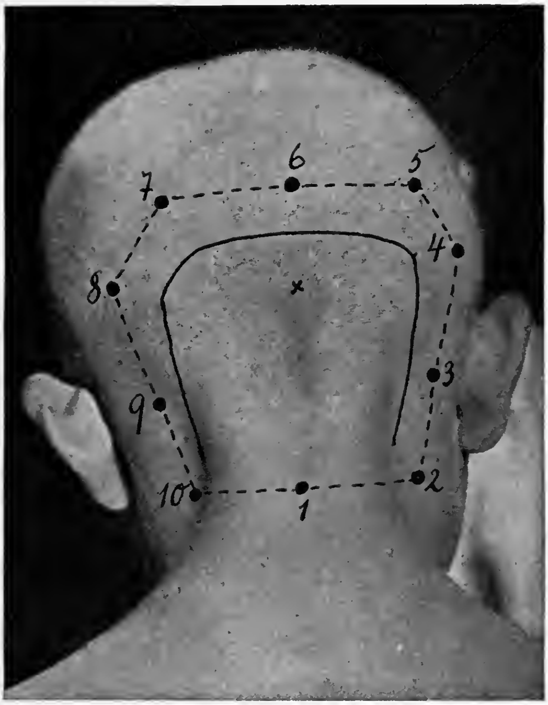

Fig. 152.—Points for deep injections and line of infiltration for craniotomy over cerebellum. (From Braun.)

the root of the canine tooth, and some little distance from the bone nearer the labial than the alveolar attachment of the mucous membrane, so that the needle in being advanced can be directed slightly backward and upward (Fig. 157). The solution is injected as the needle is advanced, until its point is felt just under the palpating finger which locates the foramen; as the nerve hugs the bone in this position, dividing into palpebral, nasal, and labial branches, the injection must be made deep down in close contact with the bone; about 2 drams of a 1 per cent. novocain-adrenalin solution is required, and in about ten minutes, if properly made on both sides, should produce an area of anesthesia, as shown in Fig. 158. This injection when well made diffuses back into the infra-orbital canal and reaches the anterior superior dental nerves, which are given off but a short distance back of the foramen and supply the canine and incisor teeth (Figs. 144–160).

The infra-orbital foramen is situated about 1 cm. below the orbital margin, about midway between the inner and outer angles, its axis directed downward, forward, and inward, a continuation of this line passing just over the middle incisor teeth.

The foramen is subjected to considerable variations, more particularly as to size, often being so small as to be difficult of entrance with a needle when exposed by open dissection; its position and axis also very slightly. However, the above will be found approximately correct in the great majority of skulls.

If a point of anesthesia be established on the cheek over the recognized position of this foramen, and the needle advanced from the middle line below, keeping the syringe in contact with the midline of the lip, and injecting as the needle is advanced, when after coming in contact with the bone the canal can be sought for and often entered when sufficiently patulous; when this cannot be done the injection should be made deep down in close contact with the bone and just below the known position of the foramen; 1 to 2 c.c. of a 2 per cent. novocain-adrenalin solution, when deposited at this point on both sides, produces anesthesia after five to ten minutes. The anesthetic area is shown in Fig. 159, as well as the underlying bone.

Paraneural Injections at the Mental Foramen Made Through the Mouth.—The mental foramen is situated at the base of the alveolar process, between the first and second bicuspids. The lip is reflected, and the needle advanced in this direction from the depth of the mucous fold close down to the bone (Fig. 157), injecting as the needle is advanced, depositing about $\frac{1}{2}$ to 1 dram of 1 per cent. novocain-adrenalin solution over the foramen.

As the terminal fibers of the inferior dental nerve, both within the bone at the symphysis as well as after emerging from the mental foramen, freely intermingle with the branches of the opposite side, it is necessary in operating in this region to inject both sides.

The free intermingling of the nerve, which takes place at the symphysis, limits the extent of anesthesia, which takes place following the injection of the inferior dental nerve of one side to about the position of the first bicuspid of that side, but can be made to extend well beyond the middle line by a mental injection of the opposite side.

Paraneural injections at the mental foramen made from without are done in the following manner: after locating the approximate position of the foramen, which is directed upward and forward and lies between the two bicuspids at a variable distance from the inferior margin of the maxilla, depending upon the age of the individual, in infancy being near its lower border; in adult life, about 1 cm. or slightly more above; in edentulous old age, lying near the alveolar margin.

The needle is directed obliquely downward, backward, and inward in the axis of the foramen, injecting as it is advanced; after reaching the bone the foramen is searched for, and, if possible, entered; if not, the injection made over its orifice.

If the injection can be made within the canal or time allowed, ten to fifteen minutes, if the injection is made over the foramen, the solution diffuses into the canal, and the resulting anesthesia, when injecting on both sides, involves the lower lip and tissues of the chin, the gum on its labial side, the teeth between the two foramina, and the involved bone; the mucous membrane and gum on the inner side are not anesthetized, as their nerve supply is from the lingual.

THE FACE

In superficial and minor operations upon the soft parts of the face infiltration anesthesia of the area involved is usually the method employed, and should be preferred for such operations as the removal of moles, nævi, cysts, etc., and for the closure of superficial wounds or opening of abscesses.

For such lesions as epitheliomas, carbuncles, etc., some form of regional anesthesia should be employed; this will depend upon the location of the lesion; if on the nose and superficially situated, the field is surrounded by a zone of anesthesia made well outside the limits of the growth, passing the needle down, and injecting into the deep tissues at one or more points, as shown in Fig. 153.

In Fig. 154 the method of anesthetizing the upper lip and nose is shown. This plan will be found simple and effective for the removal of nævi, cysts, and superficial operations. For such operations on the lower lip a point of anesthesia is established over the midpoint of the chin below, and the long needle with large syringe entered at this point; with the finger in the mouth as a guide, it is advanced between the skin and mucous membrane toward the angle of the mouth, infiltrating as the needle is advanced with solution No. 2 (0.50 per cent. novocain and adrenalin); the needle is now partially withdrawn and redirected in the opposite direction and the procedure repeated (Fig. 155). This

Fig. 153.—Method of procedure for anesthetizing area of tumor on external nose. (Braun.)

embraces the intervening area between two walls of anesthesia, which in a few minutes diffuse to skin and mucous membrane.

Superficial operations upon limited areas of the lower jaw may be conveniently performed by surrounding the area by a wall of anesthesia

Fig. 154.—Outline of points of injection and line of infiltration for anesthetizing nose and upper lip. (Braun.)

Fig. 155.—Method of procedure for anesthetizing lower lip. (Braun.)

in a similar manner, carrying the infiltration well down to the bone. Such an operative area is outlined in Fig. 156, which shows the points for entering the long needle and advancing it in the deeper planes. In more extensive involvement of the bone this superficial infiltration should be supplemented by blocking the inferior dental nerve at the lingula, as referred to later. For operations upon the soft parts of the face, advantage may be taken of the superficial position of the infra-orbital and mental nerves as they emerge from their foramina and block them at these points.

On the face all three branches of the fifth may enter the field (Fig. 142). At the inner angle of the lower lid we have the infra-trochlear branch of the nasal and, approaching the ala of the nose, branches from the nasal; over the malar region of the temporomalar nerves these form the first division of the fifth; in the infra-orbital region, the second division, and over the side of the cheek the masseteric and buccinator branches form the third division; below the line of

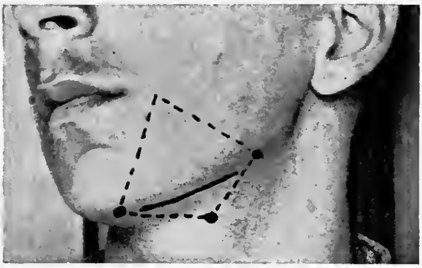

Fig. 156.—Points of injection and area of infiltration for minor operations on inferior maxilla. (Braun.)

the mouth we have only the third division, but here the field is also supplied by ascending branches from the superficial cervical nerves.

In operations in the infra-orbital region, extending down to and involving the bone, as for malignant disease so frequently met with in this region, the superior maxillary nerve may first be blocked by the Matas intra-orbital or one of the lateral routes. The Peuckart medial puncture of the orbit may now be used to control the nasal nerve and its branches on the inner side of the lower lid and upper inner angle of the face; if a wall of anesthesia is now carried down from the malar prominence to below the line of the mouth, and made well down into the subcutaneous tissues, it will effectively control the malar, masseteric, and buccinator nerves.

If the field is below the line of the mouth the inferior dental or mental nerve may be blocked at their respective foramina, and the cervical nerves controlled by a subcutaneous line of infiltration over the lower border of the inferior maxilla.

For the areas of distribution of the branches of the fifth nerve to the maxillæ, teeth, gums, and hard palate see Figs. 160–163, while the points of emergence of the peripheral branches upon the

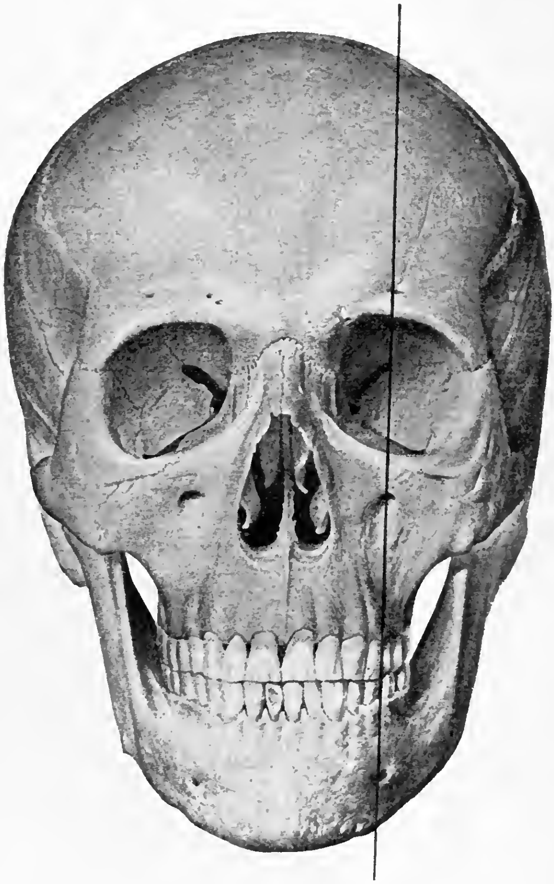

Fig. 157.—The supra-orbital foramen is located at the junction of the inner and middle thirds of the supra-orbital margin; a line drawn from this point, passing between the two bicuspids of the upper and lower jaw, should pass over the infra-orbital and mental foramina. (After Sobotta and McMurrich.)

face and head is shown in Fig. 142. A study of this figure will prove very useful for operations upon the peripheral soft parts. For the innervation of the mucous passages and accessory sinuses a study of Fig. 191 will be found very useful.

Operations upon the peripheral ends of the fifth nerve can be easily done, as in resections for neuralgia. The foramina are first exposed by an incision and an injection of solution No. 2 made into the canal, advancing the needle very cautiously, injecting as it is advanced so as

Fig. 158.—Conductive anesthesia by way of infra-orbital foramen. (After Fischer.)

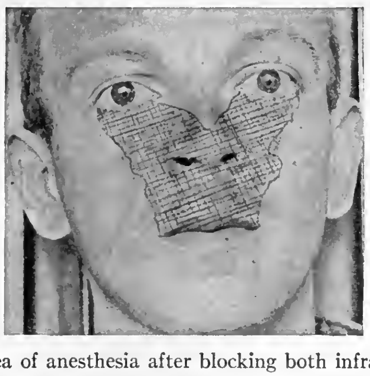

Fig. 159.—Resulting area of anesthesia after blocking both infra-orbital nerves at infra-foramen. (Braun.)

to progressively anesthetize the deeper parts of the nerve as they are reached by the needle; $\frac{1}{2}$ dram of solution used in this way will often flow back into the canal for some distance and anesthetize the nerve far beyond the field of operation. After anesthetizing in this way, the bony opening to the canal can be enlarged and the nerve reached further back and excised; divulsion may also be practiced in a limited way, but this method of anesthesia is not suited to severe traction upon the nerve.

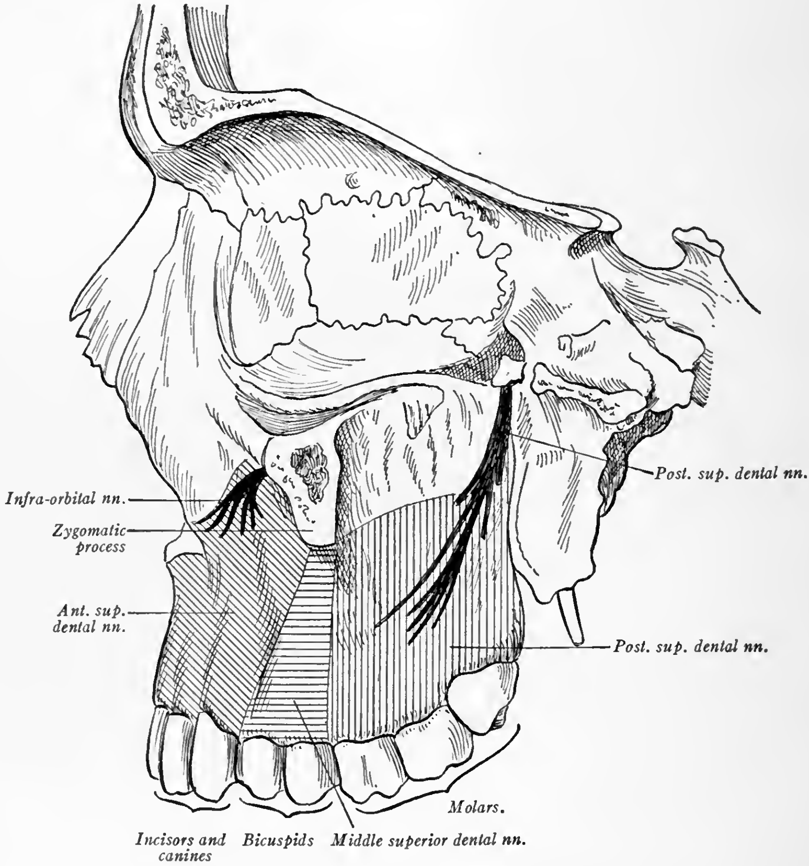

Fig. 160.—Areas of nerve supply of maxilla. Oblique shading: anterior superior dental nerves (incisor and canine region). Horizontal shading: middle superior dental nerve (bicuspid region); vertical shading: posterior superior dental nerves (molar region). (After Fischer.)

While neuralgias in general, but especially facial neuralgia, were among the first conditions for which cocain was used, its employment in this way being almost as old as the discovery of cocain, nevertheless there have occurred apparent cures from its use alone; it would, therefore, seem not inadvisable to bear it in mind, as the single injec-

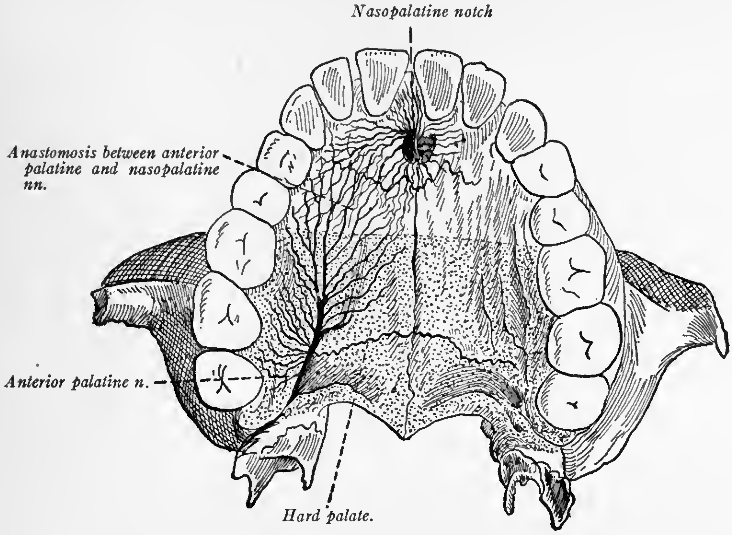

Fig. 161.—Areas of nerve supply of palatine surface of maxilla, upper area, nasopalatine nerve. Lower area: anterior palatine nerve (molar region). (After Fischer.)

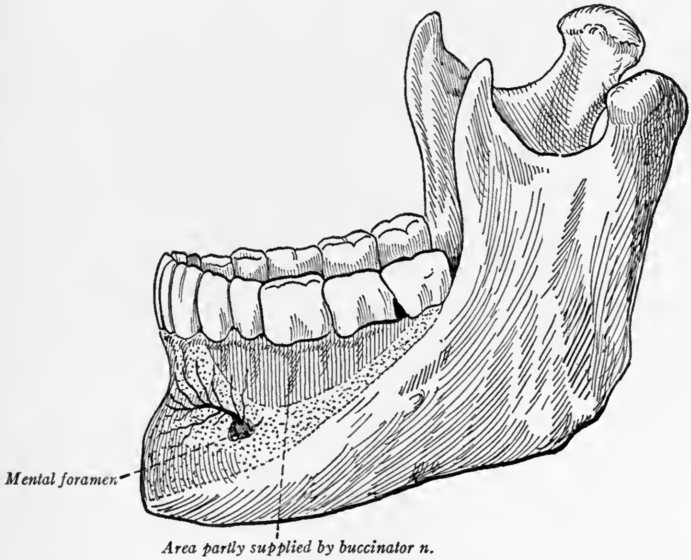

Fig. 162.—Area of nerve supply of anterior section of mandible. Dotted area: inferior dental nerve. From the mental foramen emerges the mental nerve. The mucous membrane in the molar region is partly supplied by sensory fibers of the buccinator nerve. (After Fischer.)

tion of medicinal doses cannot possibly prove harmful. It must, however, further be remembered that its use for this purpose has nearly always been in pure water, as well as in the present case reported, as we know aquapuncture itself exerts this influence; it may, therefore, in this and other cases not have been the cocain at all which accomplished the cure. The case in question is one by Fitzmiller, which is said to have been very severe and in which all other remedies had failed to afford relief (he does not state if aquapuncture had been used): The patient a woman, aged thirty-two, had suffered almost constantly with attacks often lasting a week in length; a 0.17 per cent. watery solution, containing a few drops of adrenalin, was used; of this solution a half Pravaz syringeful was injected at the points of emergence of the supra-orbital, infra-orbital, mental, and occipital nerves. It is stated that immediate relief was afforded, the pain being as if

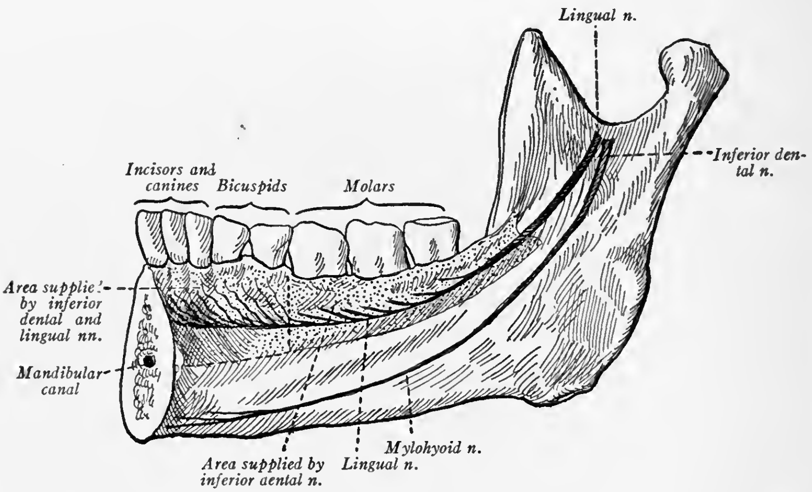

Fig. 163.—Area of nerve supply of lingual section of mandible. Dotted area: inferior dental nerve. The mylohyoid nerve branches off at inferior dental foramen. (Fischer.)

"blown away," leaving only a temporary feeling of numbness in the areas of distribution of the nerves. During the next three weeks the return of the pain required nine other injections, after which there was no further return when last seen six months later. This case is merely cited to call attention to its possible use in this way.

Since the introduction of novocain this agent has been similarly used, either in plain water or in salt solution with adrenalin, and the relief obtained from these injections has often been of prolonged duration. Its use for this purpose is not limited alone to facial neuralgia, but seems to be equally beneficial when used elsewhere, as for sciatica, when infiltrated around this nerve, and for neuralgia of the spinal nerves as in intercostal neuralgia; here the solution had best be used as a paraneural injection about the nerve-roots, thoroughly saturating the nerve-roots for one or two nerves above and below the involved area; in the hands of the author this method has often furnished prolonged relief.

In operations within the mouth which are not readily accessible, as in lesions far back on the tongue, cheek wall, pillars of the pharynx, etc., we often slit the cheek back to the ramus of the jaw, thus securing greater room and freer access for work on these deeper parts. Such incisions in the cheek, when properly closed, leave simply a linear scar.

Extirpation of the Tongue.—Such mutilating operations are rarely indicated under local anesthesia. While possible in the hands of a skilful operator, the physical effect is no doubt severe even upon the most stoical. If the condition is one of malignancy, as is usually the case, and well advanced, local methods of infiltration are contraindicated if they in any way encroach upon the diseased area.

Well-localized growths, when situated upon the anterior part of the tongue, may be quite satisfactorily removed by creating a wall of anesthesia—across the tongue, proximal to the lesion, and involving its entire thickness; or, if the lesion is situated on the side near the tip, a wall of infiltration anesthesia may be carried down the long axis of the organ from its tip to beyond the lesion and joined at right angles by a line of infiltration from the side; or, if limited to the anterior two-thirds of the organ, the area of distribution of the lingual, this nerve may be blocked on each side near the lingula.

To remove the entire organ the lingual and dental nerves should be blocked on each side; this is preferable to blocking the inferior maxillary higher up or to a ganglion injection, as the lingual receives other nerve-fibers from its communications after it is given off from its parent trunk.

As the base of the tongue receives fibers from the superior laryngeal and glossopharyngeal to its posterior one-third both of these nerves must be dealt with. Block the superior laryngeal on both sides by injections into the thyrohyoid membrane, as described in the chapter on the Neck, and carry a line of subcutaneous infiltration through the soft parts above the hyoid bone from side to side, to meet the ascending branches of the superficial cervical.

The glossopharyngeal is anesthetized by blocking the submucous tissues below and in front of the tonsil toward the base of the tongue on each side; then, with a finger in the floor of the mouth, the long needle is passed in beneath the maxilla, and, guided by the finger in the mouth, the root of the tongue on each side is infiltrated.

After a few minutes' delay anesthesia should be complete and the inferior maxilla divided at its symphysis, or an incision made into the mouth from beneath as preferred.

The author has never used local or regional methods for the removal of **tonsillar tumors,** as, in my opinion, this region when the seat of malignant disease, as most of these growths are, had best be operated by general anesthesia; however, the method as outlined below is quoted from Härtel:

"**Operations for Tonsillar Tumors.**—In the sensory innervation of the tonsils the following nerves have a share—the nervus maxillaris with the nervus palatinus medius, the nervus lingualis with the rami isthmi faucium, the nervus glossopharyngeus with the ramus tonsillaris. While conduction anesthesia can easily be induced in the nervus maxillaris and lingualis, this is impossible for the trunk of the glossopharyngeus, because bone-points suitable for its location are lacking. We must content ourselves with an infiltration of the peripharyngeal connective tissue situated laterally to the tonsils, and reach this region from a puncture point which is situated in the most posterior point of the vestibulum oris laterally from the ligamentum pterygomandibulare, which is there palpable; from here the tissue situated laterally behind the tonsils is infiltrated in a divergent direction. Also from the lateral region of the neck, tonsillar tumors, which usually are connected with collections of glands in this region, can easily be infiltrated accompanied by simultaneous palpation from within."

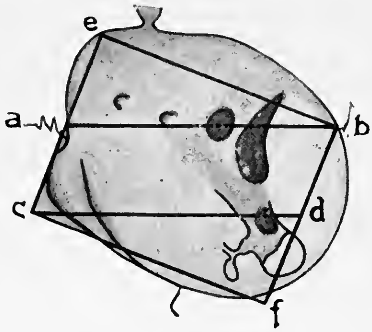

Fig. 164.—Schematic representation of the orbital planes according to Härtel. (Härtel.)

The **orbits** are two quadrilateral pyramidal cavities at the upper and outer parts of the face, their bases directed forward and outward, their apices backward and inward; their axes, passing through the optic foramen, if continued backward, would meet over the body of the sphenoid bone. The base of this pyramid viewed from in front presents somewhat of a rectangular appearance (Figs. 164 and 170), the plane of this rectangle sloping downward, backward, and outward from the middle line of the face.

The roof of the orbit, triangular in shape, presents a perfectly smooth concave surface, which slopes from the orbital margin first upward, then downward, backward, and inward.

The superior margin presents at its inner extremity a depression for the pulley of the superior oblique, sometimes marked by a spicule of bone. External to this point on the margin, at the juncture of the internal and middle thirds, is the supra-orbital notch or foramen. On the lateral anterior surface, behind the orbital ridge, is the depression for the lacrimal gland.

The inner wall, after the lacrimal groove is passed, presents a smooth, irregular, slightly convex surface, directed almost directly backward. This wall is extremely thin and paper-like in consistence, forming the delicate bony external wall of the ethmoid and sphenoid cells.

At the angle of the junction of the roof and inner wall, in the suture between the frontal and the ethmoid bones, are seen the anterior and posterior ethmoidal foramina; the anterior, situated about the midpoint of the depth of the orbital wall, transmits the anterior ethmoidal vessels and nasal nerve; the posterior foramen is placed about midway between the anterior and the orbital foramen and transmits the posterior ethmoidal vessels.

At the internal inferior angle is seen the lacrimal canal.

The floor presents an irregular smooth surface, sloping outward and forward, slightly convex in its middle part, and concaved in front as it approaches the orbital margin. It is crossed from before, backward, and outward by the ethmoid maxillary suture. The bony surface of the floor, like the inner wall, is extremely thin and forms the roof of the antrum of Highmore.

The outer wall, sometimes deficient at the sphenomalar articulation, presents a fairly smooth, slightly concave surface, which slopes sharply backward toward the foramen lacerum anterius; on it are seen the orifices of the malar canals.

The sphenomaxillary fissure extends about two-thirds of the distance along the angle of junction between the external wall and floor of the orbit. It runs obliquely backward and inward to the sphenomaxillary fossa. This fissure is widest in front, becoming narrower and somewhat serpentine in direction behind.

It is formed above by the lower border of the orbital surface of the great wing of the sphenoid, below and internally by the external border of the orbital surface of the superior maxilla and a small part of the palate bone.

At its internal extremity this fissure joins at right angles with the pterygomaxillary fissure. This fissure forms a means of communication between four fossæ—the orbital in front, sphenomaxillary behind and internally, the temporal and zygomatic externally and behind. Through this fissure pass the superior maxillary nerve and its orbital branch, the infra-orbital vessels, and ascending branches from the sphenopalatine or Meckel's ganglion.

At the apex of the orbital fossa, below and external to the orbital foramen, is seen the foramen lacerum anterius or sphenoidal fissure, formed internally by the body of the sphenoid, above and internally by the lesser wing of the sphenoid, below and externally by the greater wing of the sphenoid.

Through this fissure pass the third, fourth, the three divisions of the ophthalmic division of the fifth (lacrimal, frontal, and nasal), and sixth nerves, some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, a recurrent branch from the lacrimal artery to the dura, and the ophthalmic vein.

The relative position of these structures is seen in Fig. 165.

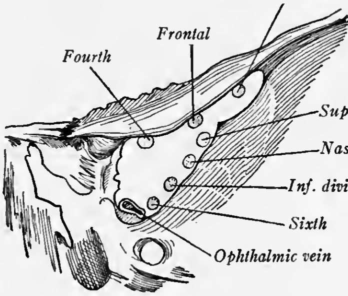

Fig. 165.—Relations of structures passing through the sphenoidal fissure. (After Gray.)

In making deep orbital injections for the purpose of blocking those branches of the trigeminus which pass through this fossa on their way to other parts, we should try to select such routes of puncture as lie along smooth and regular bony surfaces, using these surfaces as a guide in approaching the deeper parts, and always keeping the needle-point in close contact with the bone; in this way, by keeping well toward the peripheral limits of the orbit, we are in the zone outside of the eye and its attached muscles. This idea of utilizing the orbit as a means of approach to the intra- and retro-orbital nerve-trunks may appear to the inexperienced as a hazardous procedure; this, however, is a misconception, as the puncture under proper technic should be a perfectly innocent undertaking, except in the known dangerous region of the orbit—in its axis or at its apex. In extensive operations upon the eye, as in enucleation, these regions are intentionally invaded. (Figs. 166, 167 show the arrangement of the nerves within the orbit.)

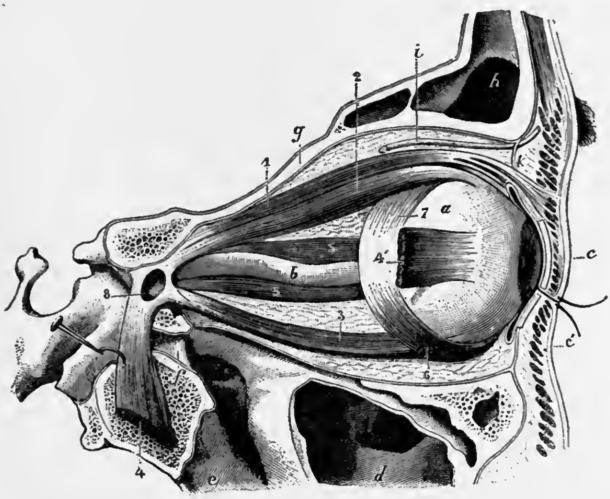

Fig. 166.—Ocular muscles viewed after removal of lateral wall of orbit: *a*, Eyeball; *b*, optic nerve; *c*, *c′*, eyelids; *d*, maxillary sinus; *e*, pterygoid plate; *f*, foramen rotundum; *g*, roof of orbit; *h*, frontal sinus; *i*, supra-orbital nerve; *k*, septum orbitale; 1, levator palpebræ superioris; 2, 3, superior and inferior recti; 4, 4′, portions of the cut external rectus; 5, internal rectus; 6, inferior oblique; 7, insertion of superior oblique; 8, annular ligament or tendon of Zinn. (Testut.)

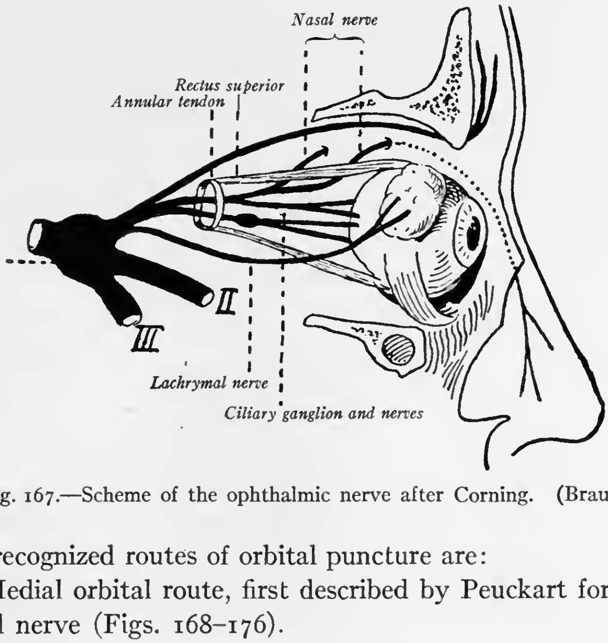

Fig. 167.—Scheme of the ophthalmic nerve after Corning. (Braun.)

The recognized routes of orbital puncture are:

(1) Medial orbital route, first described by Peuckart for reaching the nasal nerve (Figs. 168–176).

Lateral orbital route of Braun for reaching the frontal and lacrimal branches of the ophthalmic (Figs. 168, 169).

(3) Orbital route, through sphenomaxillary fissure to spheno-maxillary fossa, to reach the second division of the fifth at the foramen rotundum, the Matas route (Figs. 177–179).

(4) The retrobulbar methods of infiltration for bulbar operations —the methods of Seigrist, Löwenstein, and others.

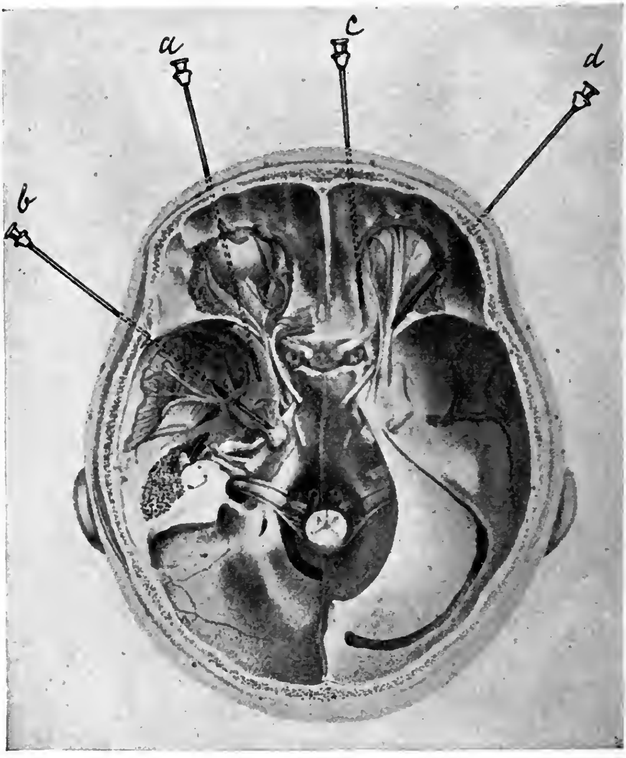

Fig. 168.—Base of skull with cranial nerves, from Arnold. Needles *a* and *b* same as Fig. 212, *c* to nasal nerve, *d* to frontal and lacrimal nerves. (Härtel.)

(5) In the method of Levy and Baudoin for reaching the ophthalmic division of the first through the orbit, the needle is entered on the outer wall of the orbit at the level of the inferior extremity of the external angular process of the frontal bone and advanced backward and inward beneath the lacrimal gland, hugging the bone to a depth of from $3\frac{1}{2}$ to 4 cm.

Discussing the orbit and its various points of puncture, Härtel has presented this subject with much thoroughness and detail, often surpassing in his clearness of presentation original routes advocated by others. For this reason I quote him as follows:

"The puncture of the orbit from the front, as Braun rightly indicates, may be undertaken only under continuous contact with the bone, in order to avoid injury of the eye. But now appear certain difficulties, from the fact that the bony orbital margin bordering the orbit in front has a shorter diameter than the cavity of the orbit situated behind it, and also in its shape it in no way conforms to this. On this account there exist in the walls of the orbit concavities which

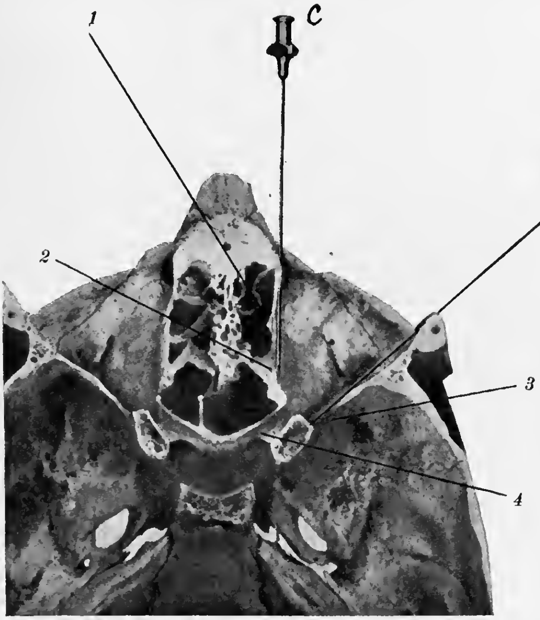

Fig. 169.—Horizontal section of skull in upper horizontal plane seen from above. Needle *c* is at the ethmoidal foramina (nasal nerve); needle *d* at the superior orbital fissure (frontal and lacrimal nerves); 1 and 2, anterior and posterior ethmoidal foramina; 3, superior orbital fissure; 4, optic foramen. (Härtel.)

thwart 'bone-feeling.' Only in certain places do plane surfaces variable in the individual present themselves to us, which we can utilize for routes for injection. The walls of the orbit are in a high degree dependent on the pneumatization of the adjacent facial cavities (ethmoid cavity, frontal sinus, sphenoid sinus, antrum of Highmore). This is the cause of the extraordinary variability of the orbital walls. On account of these relationships 'bone-feeling' as the single guide of our needle is often problematic, particularly as the paper-thin walls often do not offer satisfactory resistance. We need, therefore, here also the adherence to certain *instruction for direction* as well as for definite *depth*.

"The deepest concavities of the orbit lie above behind the margo supraorbitalis and outward under it, while the medial wall (lamina papyracea), the lateral wall (orbital surface of the malar bone and great wing of the sphenoid bone), and the medial part of the inferior wall (orbital surface of the upper jaw) usually afford plane relationships. We obtain, therefore, a *medial*, a *lateral*, and an *inferior* plane surface of the orbit. From the medial plane surface we reach the for-

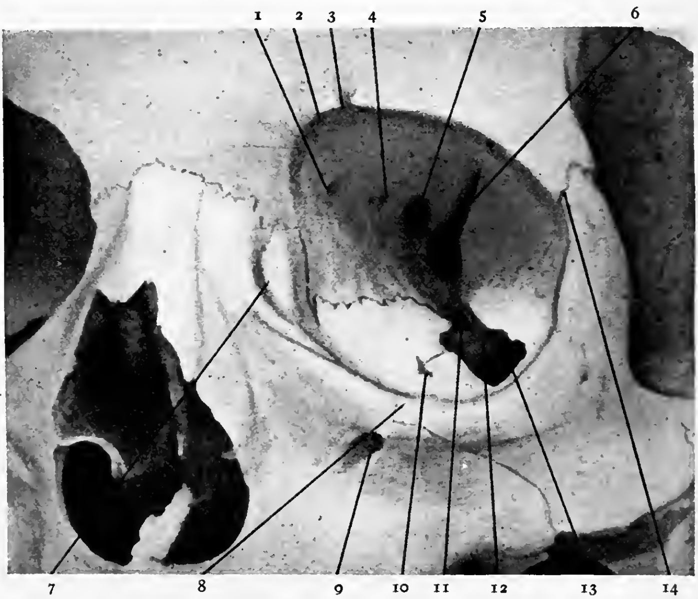

Fig. 170.—Orbit from in front (photo from a skull with wide fissures): 1, Ant. ethmoid. for.; 2, frontal notch; 3, supra-orbital notch; 4, post. ethmoid. for.; 5, for. opticum; 6, sup. orbital fissure; 7, lacrimal fossa; 8, malar-maxillaris suture; 9, infra-orbital foramen; 10, infra-orbital canal; 11, foramen rotundum; 12, planum pterygoideum; 13, inf. orbital fissure; 14, malar-frontal suture. (Härtel.)

amina ethmoidalia, from the lateral plane surface the fissura orbitalis superior with the entrance of the nervus ophthalmicus, from the inferior plane surface the nervus maxillaris and the foramen rotundum.

"Concerning the quality of the plane surfaces, Table II, Nos. 15, 16, and 17, gives explanation. According to that, the medial plane surface offers the most favorable relationships (80 per cent. completely plane way; in the other 20 per cent. a very slight concavity or convexity of the planum, not interfering with puncture). Less favorable relations are found in the lateral and the inferior plane surfaces.

"As the concavities of the orbit, as we have seen, lie in its anterior part close behind the orbital margin, in every case information concerning the quality of the plane surfaces is possible by palpation. Therefore, before the puncture we can seek out the most favorable place by examination, and, by shoving the bulbus to one side, we can carry the needle into the depth, even if the relations are not entirely plane, without injuring the bulb.

"If we now observe the orbital margin (Fig. 170) in the choice of our puncture point, its configuration in the individual is so varied that even to-day the anatomists are not united concerning the designation of the margins and corners. For us it is important to note definite points palpable through the skin. They are these: the sutura malar-maxillaris on the inferior margin, the sutura malar frontalis above laterally, the lacrimal fossa, as well as the usually palpable incisuræ supra-orbitalis and frontalis. We compare the orbital margin to an obliquely placed rectangle (*c*, *e*, *b*, *f*, Fig. 164), whose corners are formed—laterally above (*b*), by the sutura malar maxillaris, toward the median line; above (*e*) by the incisura frontalis, toward the median line below (*c*) by the lacrimal fossa, laterally below (*f*) by the rounded orbital margin. In most cases three of these corners are palpable. Now this rectangle lies diagonally, so that the horizontal line drawn through the superior outer angle (*b*) (sutura malar maxillaris) meets the opposite short side in the middle (*a*), and the horizontal line, drawn from the inner inferior angle (*c*) (middle of the lacrimal fossa), the middle of the outer short side (*d*). We designate these two lines *ab* and *cd* as superior and inferior horizontal lines of the orbit, and we shall find that the horizontal planes passing through these lines offer the following important relations to direction for the puncture of the orbit:

"If we observe the orbit exactly from the front, so that our direction of vision corresponds to the central axis of the orbit, then we perceive as the middle point (Fig. 171) of the orbital infundibulum the inferior wide part of the fissura superioris. It lies exactly between the two horizontals of the orbit. In the upper horizontal plane lie, from the outside toward the median line, the upper part of the fissura orbitalis superioris, the foramen opticum, the foramina ethmoidalia, posterior and anterior. In the lower horizontal plane lies the foramen rotundum. If we keep our needle in the horizontal planes, then we assuredly avoid the puncture of the broad inferior end of the fissura superioris, which contains the nerves of the muscles of the eye and large veins. On puncture in the upper plane we encounter laterally the place of entrance into the orbit of the nervi frontalis and lacrimalis, medially the place of entrance of the nasal nerve. In this connection precaution is to be observed only in so far as danger exists of injury of the nervus opticus by going too deep. In the lower horizontal plane we encounter the nervus maxillaris and its orbital branch, the temporomalar.

"Fig. 172 shows the orbit with bulb, conjunctival sac, palpebral fissure (after Merkel), as well as the horizontals *ab* and *cd* specified by us, and the puncture-points for medial (1), lateral (2), and inferior (3) orbital puncture.

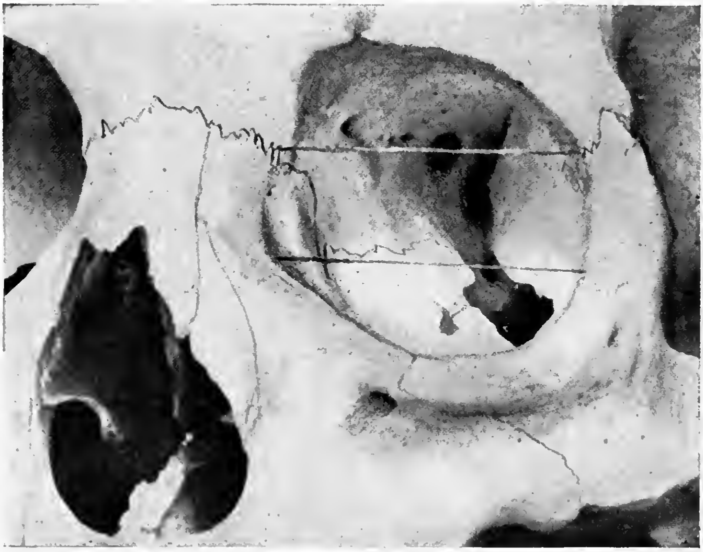

Fig. 171.—Orbit from in front, same specimen as Fig. 170 with the horizontal planes outlined. (Härtel.)

"If we ask ourselves how the palpebral fissure is related to our puncture points, then we must remember this, that only the inner angle of the palpebral fissure is a fixed point, while the external angle, when the eye is opened, moves upward several millimeters. The inner angle of the palpebral fissure lies in the region of the lacrimal fossa, and the palpebral fissure occurs varying in its height, in any case always in the region situated between the two horizontal planes of the orbit. With the eye moderately opened the superior and inferior palpebral margins should correspond to the two horizontal planes. Therefore, the puncture point for the medial puncture as well as the puncture point for the lateral puncture lies *above* the palpebral fissure, as is evident from Fig. 172.

"Further, we must bear in mind that the central axes of the two orbital cavities converge posteriorly; consequently, the lateral orbital wall runs diagonally from in front backward toward the median line at an angle that deviates about 45° from the sagittal. The projections of the straight lines drawn along the outer orbital walls meet in the region of the dorsum sellæ at right angles. The medial orbital walls, on the other hand, run approximately sagittally and diverge but little from behind forward.

"If we observe the rules here mentioned, then on making the orbital punctures we can *assuredly avoid an injury of the bulb and of the nervus*

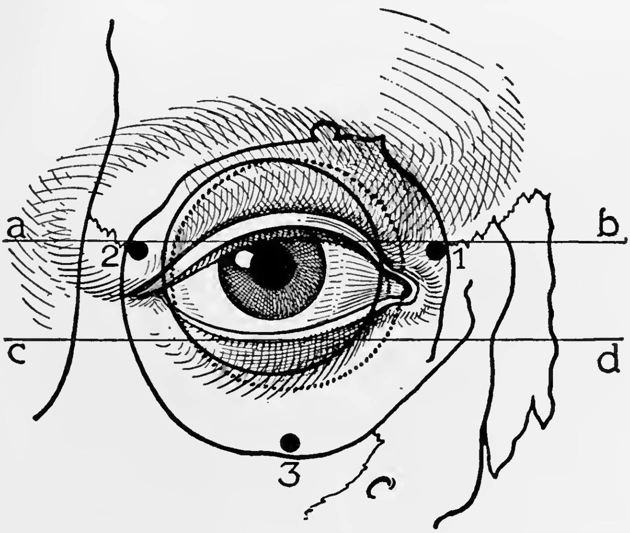

Fig. 172.—Orbit and eye, showing outlines or orbital margin. Heavy circle shows limits of the bulb; dotted circle, limits of conjunctival sac. *a–b*, Upper horizontal plane; *c–d*, lower horizontal plane; 1, median point of puncture for injecting nasal nerve; 2, point of puncture for injecting frontal and lacrimal nerves; 3, point of puncture for orbital injection of foramen rotundum. (After Merkel.)

opticus. In practice we displace the bulb with the finger from the point of entrance, and carry the needle into the depth between the orbital wall and the finger-tip that protects the bulb. By this means we keep the needle in the region of the horizontal planes mentioned, and guard against the point of the needle entering the region bounded by both planes and from getting accidentally into the point of the orbital infundibulum. On lateral orbital puncture the axis of the needle is at 45° from the sagittal direction, on medial and inferior puncture approximately sagittal.

"If the injury of the bulb and nervus opticus is thus technically avoidable, this, however, is not true with equal certainty of the vessels of the orbit. These are related in detail as follows: On medial orbital puncture we come in contact with the terminal branches of the ophthalmic artery, while the trunk of the artery itself lies within the muscular infundibulum of the orbit and is avoided by keeping in contact with the bone. On lateral puncture we may encounter the lacrimal artery; on puncture of the foramen rotundum the anterior infra-orbitalis and the communication of the ophthalmic vein with the deep veins of the region of the cheek. One may say that, with cautious work and by constant contact with the bone, the appearance of hematoma during the orbital punctures is very rare. However, it is not to be excluded, and while these puncture-hematoma are accompanied by no danger, yet they cause temporary exophthalmus and leave behind suffusions of the lids and of the conjunctiva which are visible for several days. For this reason we should use nerve punctures in the orbit only for the anesthesia of major procedures.

"(1) *Medial Orbital Puncture* (*Peuckart Route*). *Anesthesia of the Nervi Ethmoidales* (Figs. 168, 169*c*, 176).—Where the upper horizontal plane touches the wall of the orbital cavity, the foramina ethmoidalia and the foramen opticum lie in one line. In front the same plane meets the root of the nose. The *puncture-point*, therefore, lies on the inner orbital margin at the height of the root of the nose. The needle is entered in an exactly horizontal and approximately sagittal direction in constant contact with the bone. The distance of the *foramen ethmoidale anterius* from the inner margin of the orbit amounts, according to Table II, No. 19, to from 15 to 22; on the average, 18.5 mm.; therefore, for the anesthesia of the nervus ethmoidalis anterius (nasal nerve) we will carry the cannula in to the depth of about 2 cm. The nervus ethmoidalis anterius (nasal nerve) is distributed to the superior and anterior parts of the nasal mucous membrane (compare Table I) and to the tip of the nose. In order to strike the nervus ethmoidalis posterior, which is distributed to the ethmoidal cells and the sphenoidal cavity, we must carry the needle to greater depth. The *foramen ethmoidale posterius* lies at a distance from the inner margin of the orbital cavity (see Table II, No. 20) of from 29 to 42; on the average, 34 mm. This is not so typically placed and constant as the foramen ethmoidale anterius; it is often met with double. Concerning its relation to the *foramen opticum* which, as we saw, is situated in the same plane, the following is true: In a series of cases the medial orbital wall curves forward somewhat in consequence of pneumatization of the small wing of the sphenoid bone, so that behind the foramen ethmoidale posterius the cannula strikes against bony resistance. But this is the case only in half of the skulls (Table II, No. 18). The distance of the anterior margin of the foramen opticum from the inner margin of the orbital cavity amounts to 37 to 47; on the average, 40.8 mm.; in 1 case it amounted only to 33 mm. (compare Table II, No. 21). If we compare with this the values found for the depth of the foramen ethmoidale posterius, then we see that on anesthesia of the nervus ethmoidalis posterius we come into dangerous proximity to the optic nerve. Therefore, we do well to carry the inner orbital puncture not deeper than 3 cm., and to forego the deeper penetration to the diffusion of the injected solution.

"(2) *Lateral Orbital Puncture* (*Braun Route*). *Anesthesia of the Nervi Frontalis and Lacrimalis* (Figs. 168, 169, 176).—In the upper horizontal plane of the orbit is the lateral end of the fissura orbitalis superior with the passageway of the frontal and lacrimal nerves. We reach this point by the lateral orbital puncture after *Braun*, and particularly by a puncture-point which is situated at the upper lateral corner of the orbital margin (sutura malar-frontalis), or, with poor development of the lateral plane surface, somewhat deeper on the outer orbital margin. If we proceed from here with the needle in horizontal position, and deviating from the sagittal direction about 45 degrees toward the median line in constant contact with the bone into the depth of the orbit, we strike the outer end of the superior fissure, and on the further side of this in most cases encounter bone-resistance on the superior roof of the orbit (small wing of the sphenoid bone). Only with a wide superior fissure does the danger exist that the cannula without resistance may penetrate into the cranial cavity. According to Table II, No. 22, we find this relationship in 14 per cent. of the skulls. The distance of the outer end of the superior fissure from the lateral orbital margin is very variable; according to Table II, No. 23, it amounts to from 27 to 40 mm.; on the average, 33.5 mm. This relationship makes the lateral puncture of the superior orbital fissure somewhat uncertain, so that I do not believe that it will ever come into consideration for the injection in cases of neuralgia. For local anesthesia I advise penetration to a maximum depth of about *3 cm.*

"(4). *Axial Puncture of the Foramen Rotundum. Orbital Way to the Second Branch of the Trigeminus* (*the Matas Route,* Author) (Figs. 177, 178).—If we observe the anterior surface of the sphenoid bone, which is turned toward the orbit (Fig. 173), then we discover the following details: the foramen opticum, the superior fissure, and underneath this a surface shaped like an irregular triangle, the anterior wall of the process pterygoideus. This surface, which we wish to name 'planum pterygoideum,' is limited above, opposite the orbital surface of the large wing of the sphenoid bone, by a clearly perceptible sulcus. This sulcus forms the path by which the nervus maxillaris, leaving the foramen rotundum, reaches the sulcus infra-orbitalis. Likewise, on the back of the upper jaw, a groove lies opposite this sulcus, so that, by the closing together of these two half-grooves, a kind of canal is formed. At the back end of this canal, in the body of the sphenoid

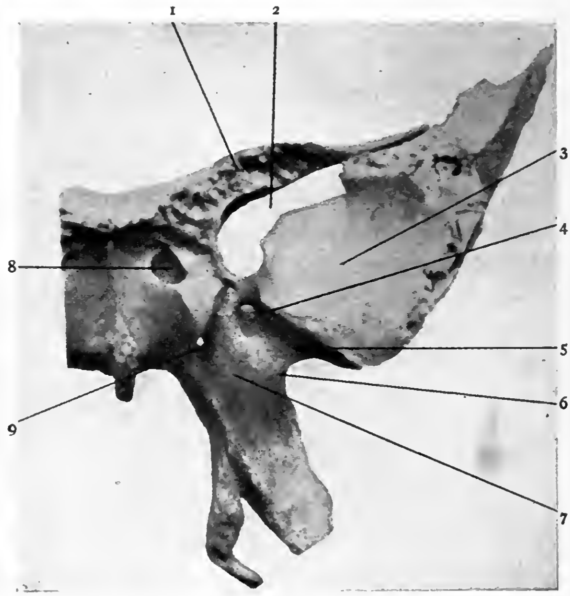

Fig. 173.—Left half of sphenoid bone seen from in front: 1, Lesser wing; 2, superior orbital fissure; 3, orbital surface of greater wing; 4, foramen rotundum; 5, groove for second division of fifth nerve; 6, sharp bony edge; 7, anterior surface of pterygoid process; 8, sphenoid cells; 9, vidian canal. (Härtel.)

bone, lies the foramen rotundum, at its anterior end, in the upper jaw, the canal infra-orbitalis. The lower outer margin of the planum pterygoideum forms a sharp bone-corner, the limiting ridge; beyond this lies the fossa infratemporalis.

"If on the skull we carry a cannula from the lateral part of the inferior orbital margin sagittally into the depth, then we arrive through the fissura inferior at the canal just mentioned, between the sphenoid bone and the upper jaw, at the end of which canal lies the foramen rotundum. Previously, however, the needle encounters bone-resistance on the planum pterygoideum of the sphenoid bone. If we now feel with the point of the needle along this resistance upward and medially, then we must reach the foramen rotundum. The supposition, by all means, is that the inferior fissure is wide enough and is not too tortuous. On this account, the way described is, according to our examinations (Table II, No. 24), accessible only in 89 per cent. of the skulls; in the rest of the cases it is obstructed by the inferior fissure.

"The distance of the foramen rotundum from the inferior orbital margin amounts (Table II, No. 25) to from 39 to 51 mm.; on the average, *45.4 mm.* For the direction of the cannula the following is of value: the foramen rotundum never lies higher than the inferior horizontal plane of the orbit. The cannula, when carried into the foramen rotundum on lateral observation, points to the superior margin of the auricle (Fig. 174); on observation from in front, it points with much

Fig. 174.

Fig. 175.

Figs. 174 and 175.—Front and lateral views of needle in position in the orbital injection of foramen rotundum. Front view shows long axis of needle reaching upper inner angle of the orbit; on lateral view it is seen to reach upper margin of ear. (From a cadaveric specimen.) (Härtel.)

shorter axis to the inner superior angle of the orbit, the incisura frontalis (Fig. 175).

"For the orbital puncture of the foramen rotundum the following is important: The foramen is very narrow, and is completely filled by the nervus maxillaris, hence, on introducing the cannula we have to reckon with the resistance of a tolerably firm mass of tissue, so that the injection demands a certain pressure. If this resistance is lacking and the needle glides easily into the depth, then we must suppose that we have gone beyond the foramen rotundum into the superior orbital fissure. In the living subject the most important guide for our puncture is the subjective statement of the patient regarding radiating pain in the region of the second branch of the trigeminus." (See Table I.)

The axial injection of the foramen rotundum, the Matas route through the orbit and sphenomaxillary fissure, has been erroneously credited by Braun, Härtel, and others to Payr; this, however, is an error, as the conception of this method of approach and its first application undoubtedly belong to Prof. Matas, who first used it in 1898, and it was published by him in his report on "Local and Regional Anesthesia," etc., to the Louisiana State Med. Soc., April, 1900. Quotations from this report are given later on.

This successful application stimulated other efforts in this direction, and much of the work which appeared in the few years following along these lines undoubtedly received the idea and stimulus from this procedure.

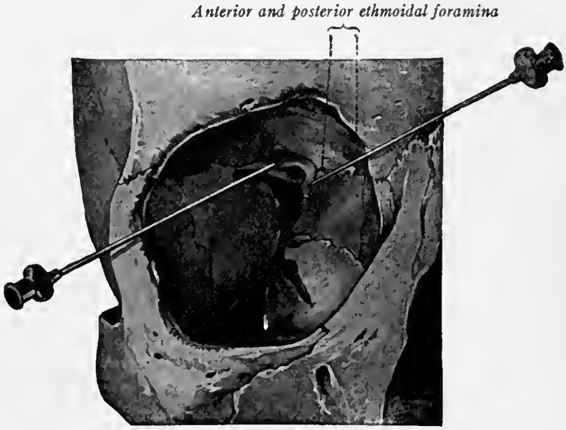

Fig. 176.—Median and lateral orbital injections. (Braun.)

In studying the orbit, with a view of the application of the various methods, we see that the foramen rotundum is concealed from view just below the floor of the orbit, and that if this plane were used as a means of reaching it the needle, if directed toward the apex of the orbit medially along the floor, would pass into the superior orbital fissure, and meeting no bony resistance here may, if advanced too far, pass backward into the cranial cavity. This route, however, is discussed by Härtel (Fig. 179).

This would seem a more dangerous route, and not likely to lead to the foramen rotundum, but above it.

The original route, as advocated by Prof. Matas, traverses the orbit for but a short distance, as the needle soon passes out of this cavity into the sphenomaxillary fissure (Figs. 177, 178).

If the sphenomaxillary fissures are observed, they will be seen to run at right angles to each other and about on a horizontal plane;

their axes if continued back would meet over the body of the sphenoid bone, and if projected forward would emerge at the inferior external angle of the orbit; also, that the axis of this fissure, if raised to a slightly

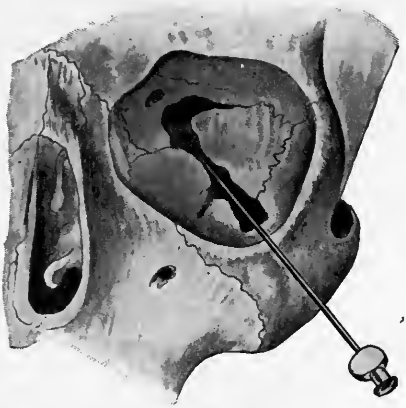

Fig. 177.—Matas' intra-orbital route to foramen rotundum. (Braun.)

elevated plane, would pass through the orbital foramen or superior orbital fissure at the apex of the orbit.

The axis of the foramen rotundum, if viewed from within the skull, passes downward, forward, and outward, and passes through the

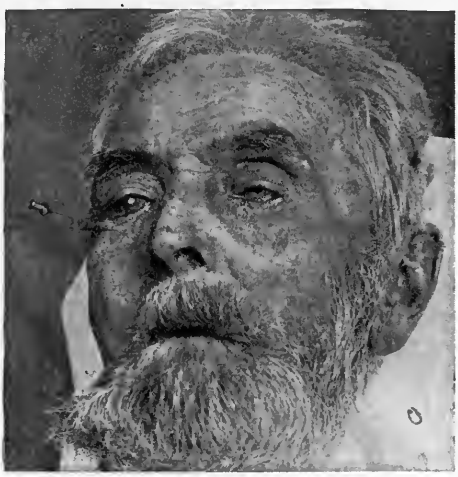

Fig. 178.—Needle in position in Matas' intra-orbital injection within foramen rotundum. (Braun.)

sphenomaxillary fossa, and for a short distance through the spheno-maxillary fissure, and emerge upon the rim of the orbit just internal to its inferior external angle, at a distance of from 4 to 5 cm., varying somewhat in different skulls.

It will be seen from the above that undoubtedly the safest method, as well as the surest of approach to the foramen rotundum is by the Matas route, for if a plane above this route is taken the needle may pass on without resistance into the cranial cavity, but if the route is followed by passing through the sphenomaxillary fissure that the needle-point impinges upon the body of the sphenoid bone, on the

Fig. 179.—Horizontal section of left half of skull in lower horizontal orbital plane, seen from above, with needle in foramen rotundum: 1, Infra-orbital sulcus; 2, zygomatico-maxillary suture; 2, infra-orbital fissure; 4, foramen rotundum; 5, foramen ovale. (Härtel.)

posterior surface of the sphenomaxillary fossa; and if unable to enter the foramen rotundum through insufficient play of the needle, due to the narrowing of the sphenomaxillary fissure, is at least in immediate contact with the nerve; but, if after reaching the posterior wall of the fossa the foramen is felt for, by gentle manipulation immediately around the axis of the needle, the foramen may often be entered, when the needle may be advanced a few millimeters further and the injection made.

The proof of contact of the needle with the nerve is recognized by the radiating pains along the branches of this nerve, felt on the cheek, in the upper teeth, and in the nose.

Having reached with certaintly the position of the nerve, 2 c.c. of a 2 per cent. novocain-adrenalin solution are injected, or if the point of the needle be less accurately placed and injection of a slightly larger quantity of a weaker solution (1 to 2 drams of a 1 per cent.) will flood the sphenomaxillary fossa and reach the nerve and all its branches. According to the studies of Härtel the foramen rotundum is accessible in about 89 per cent. of skulls.

The following case illustrates the early use of this method by Prof. Matas, and is his first report of the use of this route ("Local and Regional Anesthesia," etc., Prac. Louisiana State Med. Soc., 1900):

"A white man, laborer, aged forty-eight, addicted strongly to alcohol for years and suffering with advanced arteriosclerosis, was admitted to Ward 7, Charity Hospital (April 29, 1899), for treatment of a recurrent epithelioma of the palate, involving the anterior alveolar arch and both upper maxillary processes. The neoplastic infiltration extended to the right half of the palate and along the entire incisor region to the first right bicuspid; the anterior half of the hard palate also presented a large ovoid swelling caused by malignant periosteal invasion. I decided that I would try to remove the entire hard palate, including both palatine processes of the upper maxillæ, the floor of the antrum, and the septal cartilage of the nose. A hypodermic of morphin, $\frac{1}{4}$ gr., was given twenty minutes before the operation. In order to anesthetize the maxillaries and the palate, the sphenopalatine fossæ were filled with a No. 1 Schleich solution, introduced by a long needle through the sphenomaxillary fissures. The needle was directed as closely as possible through the fissure in the right orbit toward the infra-orbital nerve as it enters the infra-orbital canal. In this way it was expected that not only the entire superior maxillary division of the trigeminus could be anesthetized, but that Meckel's ganglion with its palatine branches would be 'blocked' by the anesthetic. In a few minutes we tested the sensibility of the cheeks, lips, and alæ of nose, and were gratified to find the entire cutaneous distribution of the infra-orbital had been completely anesthetized on the corresponding (right) side. Encouraged by this result, the left sphenopalatine fossa and infra-orbital nerve were treated in the same manner with identical results. Fully 50 minims of Schleich's No. 1 solution, reinforced by 25 minims of 1 per cent. cocain, were injected into each sphenopalatine fossa. The nasal septum, which is supplied by the nasopalatine and the nasal branch of the ophthalmic, was controlled by a separate infiltration, a long needle being introduced through the frenulum of the upper lip into the root of the columna and septal cartilage of the nose. The anesthesia of the posterior palatine nerves was also reinforced by direct infiltration in the palate. When the last injection had been completed the patient said that his palate and face felt entirely 'numb,' and gave the impression of a 'dead block of flesh' wedged in his head. The anesthesia of the jaws was then tested by extracting a perfectly sound right canine which was firmly implanted in its socket. The patient was surprised when he saw his tooth, saying he had not felt the least pain in its extraction. The upper lip was then divided in the median line and detached from the nose by two lateral incisions, which were carried along the lower border of the columna nasi and to the nasolabial groove. The lips were then dissected away from the gums and jaws as far back as the tuberosities of the maxillæ. The two halves of the upper lip were then reflected outward, and then held out of the way with loops of strong silk which acted as retractors. A very sharp McEwen's chisel was then driven by hand into the body of the right maxilla on a level with the floor of the nose. With a few sharp strokes of the mallet the palatine process, including the tuberosity, was divided, and the antrum was exposed; the same process was repeated on the other side, and the separation of the septum nasi from the jaws completed the line of osseous section. In this manner the lower half of both upper jaws and the entire hard palate with the attached growth were mobilized and displaced downward en bloc, the connections with the soft palate being severed with a long pair of strong curved scissors. After the removal of the palate, both antral cavities and nasal fossæ were widely exposed. The bleeding was very profuse in the last stage of the operation when the palate was being detached, the palatine arteries spurting vigorously. A large tampon of iodoform gauze, impregnated with compound tincture of benzoin, was immediately packed into the palatine region and promptly arrested the hemorrhage. The lining mucosa of the right antrum was subsequently removed in its entirety. During the intra-oral part of the operation the patient's head was kept low, in Rose's position. Throughout the whole procedure, which lasted over forty minutes, the patient gave us great assistance by spitting out clots and altering the position of the head as we directed. He said that while the chisel was being used he felt the jar of the instrument, the detachment of the vomer gave him some pain, but what gave him more alarm than anything else was the sight of the blood that he spat out."

"In this case the preliminary injection of morphin was of decided assistance in diminishing psychic anxiety. Fully 180 min. of Schleich's No. 1 ($\frac{1}{5}$ of 1 per cent.) solution and 60 min. of a 1 per cent. solution were used in the operation. After the removal of the palate the lip was still completely anesthetized, and the facial (cutaneous) and intra-oral (mucous) sutures were introduced without pain. The patient was very much exhausted by the ordeal he had undergone, but, after taking a good drink of whisky and a hypodermic of strychnin, he sat up, and said that, apart from the jarring of the chisel and the excitement of the operation, he had suffered comparatively little pain. The pulse was 110 and there was little shock."

The use of any but straight needles in making these deep orbital punctures is to be advised against, as cautioned by Braun; however, these are very useful for retrobulbar infiltration according to the Löwenstein technic, but should not be used for other injections.

Such injections, made according to the proper technic, should not effect the innervation of the bulb, optic nerve, ciliary nerve, or its ganglion; to reach these the injection should be made retrobulbar.

The following excellent description of the position of the inferior dental foramen and the method of making a paraneural injection here has been taken from Fischer:

This, one of the most accessible of the cranial nerves, is not as accurately reached as one might suppose, and in the hands of even skilful surgeons, who resort to this procedure but occasionally, many failures may occur. It is far easier to make an accurate injection in contact with the parent trunk (third division of the fifth) at the base of the skull than to accurately inject this nerve here, both for purposes of anesthetization as well as alcoholization in cases of neuralgia.

In the one case the end may be obtained by using a large amount of anesthetic fluid, but this as it diffuses in all directions produces a very unpleasant sense of paralysis of the throat, which is quite terrifying to some patients, particularly if it occurs during the progress of an operation.

An alcohol injection, if too liberally made at this point, may result in a more or less prolonged trismus through the action of the alcohol upon the masticatory muscles.

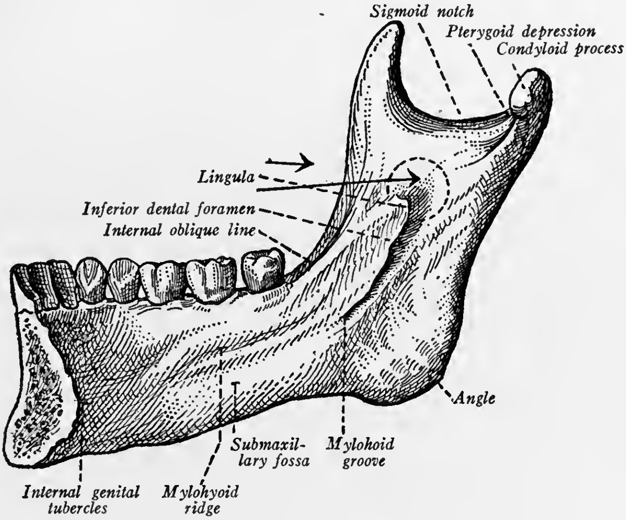

Fig. 180.—Side view of inner surface of right half of mandible. The long arrow indicates the direction in which the needle should be pushed forward over the lingula. The dotted circle indicates the area of injection. (Fischer.)

The inferior dental or oblique mandibular foramen in the internal surface of the ascending ramus permits the passage of the inferior dental nerve, which, with the inferior dental artery, passes forward in the dental canal of the mandible as far as the mental foramen, where it divides into two terminal branches, incisor and mental. For the technic of injection in the oblique foramen the relationship of the body of the jaw to the ascending ramus and that of the muscles to the foramen is of vital importance.

In adults the ascending ramus begins a little behind the third molar, sometimes in an abruptly ascending surface. At its basis, which must be regarded as resting upon the alveolar process, the ascending ramus, in front view, shows an outer buccal anterior ridge, representing the last ascending portion of the external oblique line. (See Figs. 180–182.) About 0.5 cm. inward and backward of this line runs a ridge bordering the lingual surface, the internal oblique line, which gradually loses itself in the posterior section of the coronoid process. Between these two lines in the bony surface is situated a more

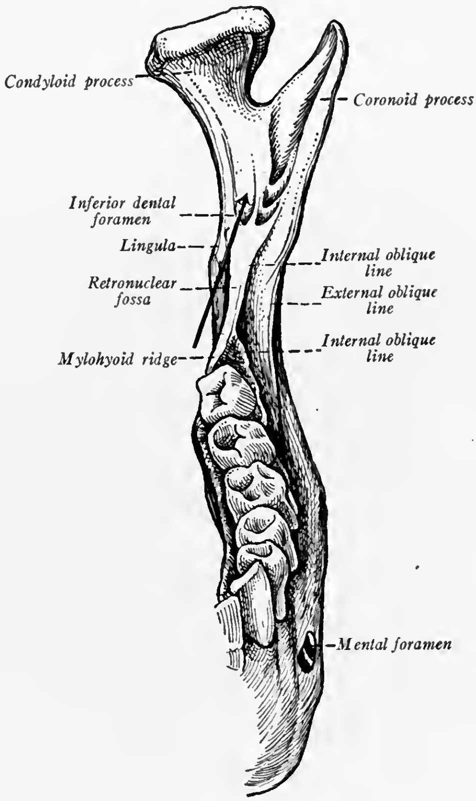

Fig. 181.—Relationship of the ascending ramus to the body of the jaw. The arrow indicates the direction in which the syringe should be advanced to the inferior dental foramen. (After Fischer.)

or less pronounced deep groove, which we might call the retromolar fossa (Fig. 181). Above this fossa the mucosa is slightly depressed, in what might be called the retromolar triangle.

About the middle of the internal surface portion of the ascending ramus the large inferior dental or mandibular foramen is situated, extending downward and forward, at the same time marking the termination of the mylohyoid groove which ascends from below anteriorly to above posteriorly. The orifice of the foramen itself is more or less protected anteriorly by a spicule of bone varying in size, the mandibular lingual (Figs. 180–182).

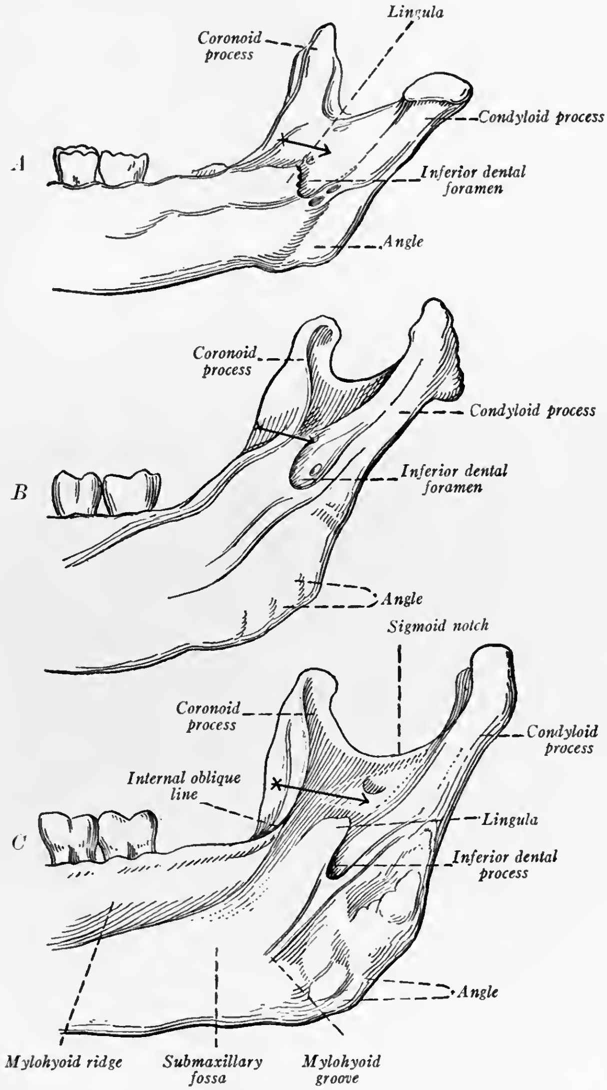

Fig. 182.—Variations of the inferior dental foramen at different ages: *A*, Mandible of a child, aged seven years (the needle should be inclined slightly downward); *B*, mandible of a youth, aged eighteen years; *C*, mandible of a male adult, aged thirty years. The arrows indicate the direction of the needle. (After Fischer.)

This lingula may be developed as a pointed plate of bone, or as a tongue-like cover, or only as a thickened process on the anterior margin.

Sometimes the lingula is connected with the lower free margin of the orifice of the foramen by a small spicule or bridge.

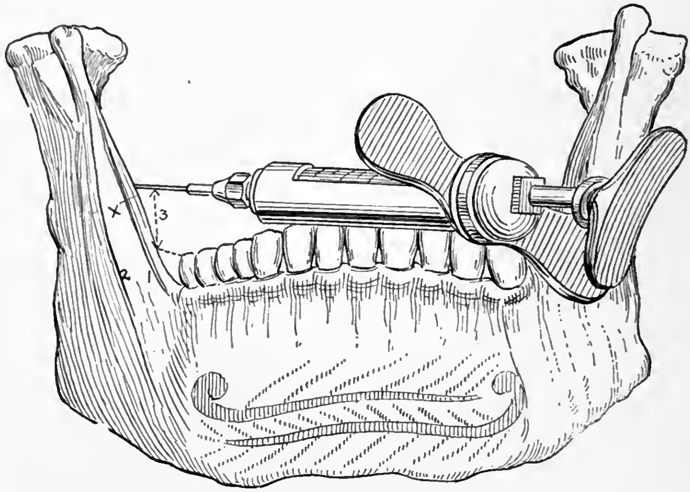

Fig. 183.—Front view of position of syringe in mandibular anesthesia: 1, Internal oblique line; 2, external oblique line; 3, insertion of needle about 1 cm. above masticating surface of molars. (After Fischer.)

The foramen itself, in adults, is always situated above the alveolar ridge and in a horizontal plane, about 1.5 cm. from the anterior ridge of the jaw (the external oblique line) (Figs. 182–184).

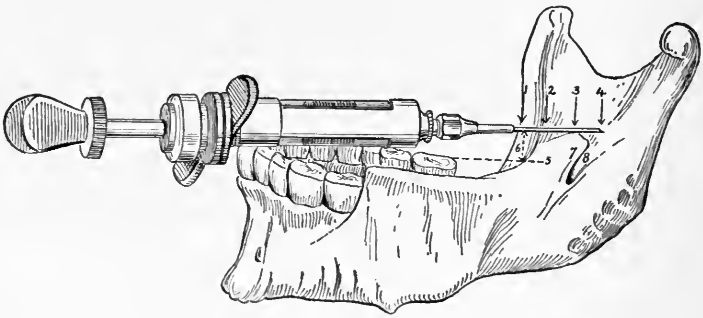

Fig. 184.—Position of needle in mandibular anesthesia: 1, External oblique line; 2, internal oblique line; 3, position of needle at superior margin of lingula; 4, most suitable length of needle behind lingula (a further advancement would result in failure); 6, position of needle, 1 cm. above level of masticating surfaces of molars; 7, lingula; 8, inferior dental foramen. (After Fischer.)

"The two halves of the mandible, when viewed from in front, gradually diverge toward the angle, so that the inner surface of the angle with the mandibular foramen is inclined posteriorly and pharyngeally, and appears to be entirely covered by the internal oblique line. (See Figs. 181, 182, 185, 186).

"*Position of Syringe.*—The line of the body of the mandible is not horizontally continuous in a straight line to the ascending ramus, but presents a lateral bulging at the angle, so that the internal surface of the ascending ramus is not parallel with the lingual surface of the body of the jaw. (See Figs. 181, 185, 186.) The ramus opens posteriorly. (See Figs. 183, 184, 185, 186.) If, therefore, the oblique

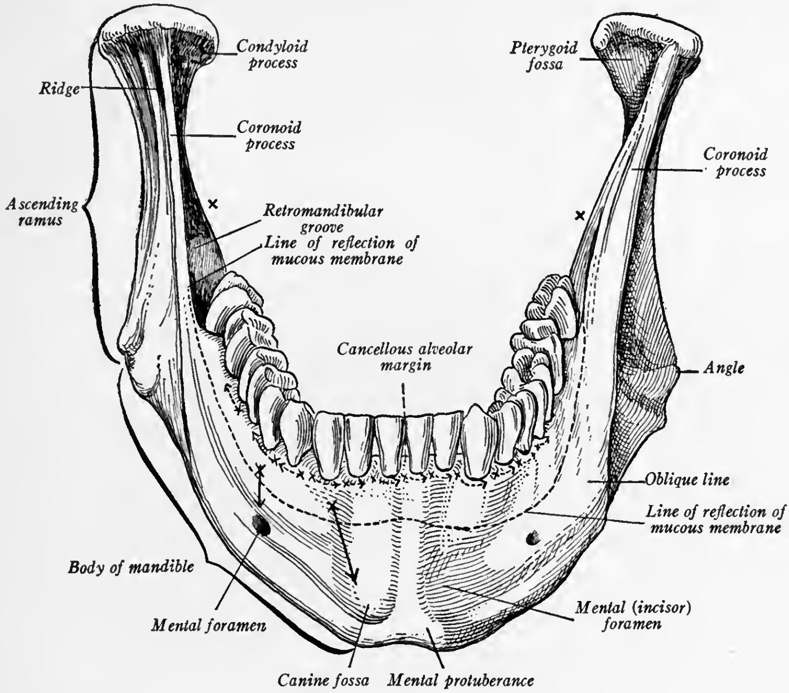

Fig. 185.—Points of injection for mucous anesthesia in external surface of mandible. The crosses indicate points of injection; small arrows, direction of needle; two large arrows, direction of needle for injection in mental foramen and fossa. On the internal surface of the ramus are marked the points for injection at mandibular foramen. (After Fischer.)

foramen is to be reached, we must never advance posteriorly parallel with the teeth (Figs. 187, 188), but with the internal surface of the ramus, at an acute angle to the plane of the teeth (Figs. 183, 187, 188, 189). If the direction of the ascending ramus is projected anteriorly, the line will meet with the other side in the canine region, between the canine and the bicuspids (Figs. 183, 184, 187, 188, 189). Thus, in order to reach the inferior dental foramen the syringe must be rested behind the canine on the opposite side. (See Figs. 183, 187, 188, 189.) The foramen in adults is situated at a higher level than in children. The horizontal direction of the needle must, therefore, be modified in children by slightly lowering it posteriorly and pharyngeally in order to reach the foramen directly. (See Fig. 182, A, B, C.)

"*Character of the Tissues.*—The character of the tissues encountered is most favorable for injection in the oblique foramen.

"The temporal and external pterygoid muscles are inserted above, the internal pterygoid below, the foramen, leaving the close proximity of the foramen free from muscular fibers. (See Fig. 190.)

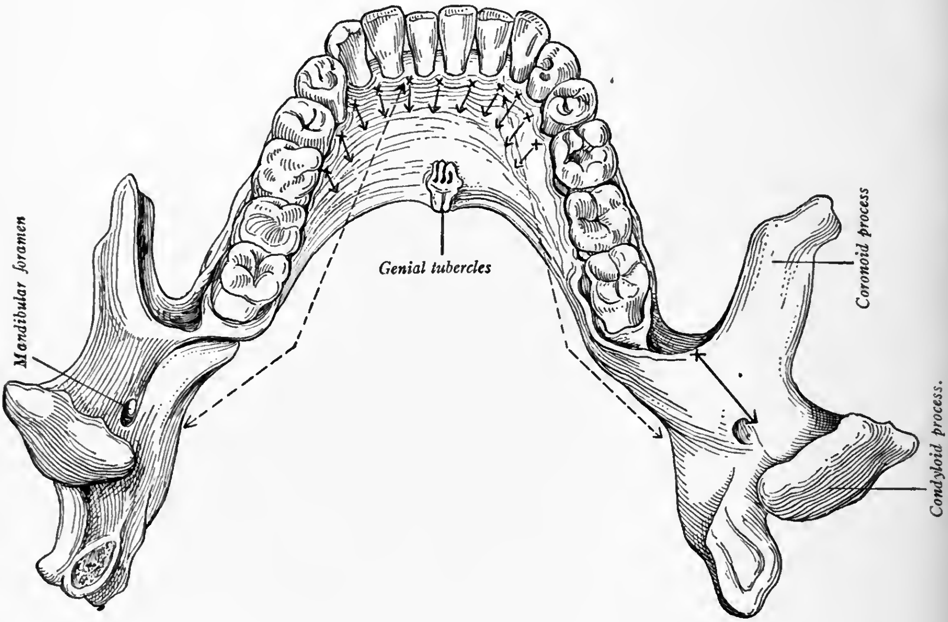

Fig. 186.—Lingual points of injection for mucous anesthesia of mandible. Crosses indicate points of injection; arrows, direction of needle; black line of dashes, the angle of the ramus to the body of the jaw. (After Fischer.)

"Instead we find considerable accumulations of loose interstitial connective and adipose tissue, which readily absorbs and retains the injected solution. (See Fig. 191.)

"This cushion of tissue is situated about 1 or 2 cm. above the alveolar process.

"*Technic of Injection.*—With the left index-finger the anterior portion of the base of the ascending ramus is palpated, the patient's mouth being opened widely. Two very marked bony ridges are felt here, one anterior external, the external oblique line, and one posterior internal, the internal oblique line (Figs. 183, 184, 187, 188).

Between these two lines at the root of the ascending ramus a shallow bony grove is situated, which might be properly called the retromalar fossa, into which the palpating finger-tip sinks (Figs. 183, 187, 188, 189.) The mucous membrane is caved in over this fossa in somewhat triangular shape; Braun, therefore, calls it the retromolar triangle.

"The internal oblique line is fixed with the finger-nail, and the needle inserted close to the nail into the mucosa near to, yet not immediately at, the edge of the bone (Figs. 183, 187, 188).

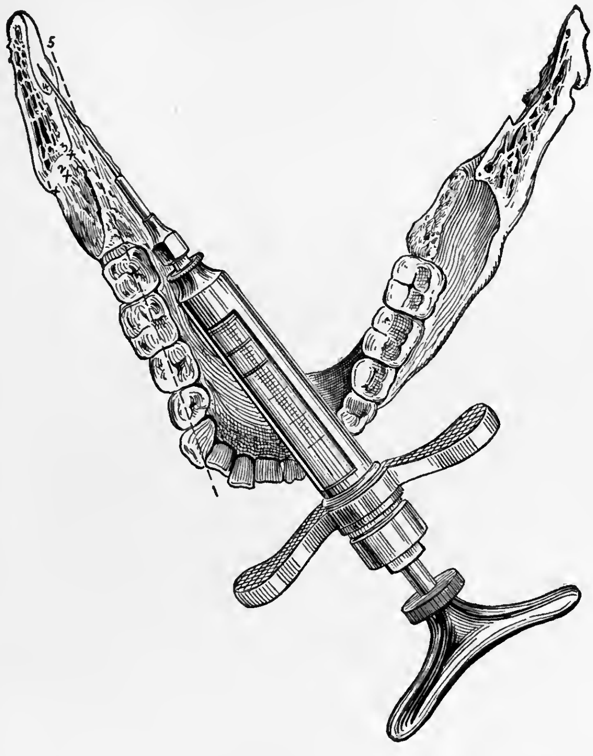

Fig. 187.—Position of syringe for injection at mandibular foramen: 1x, External oblique line; 2x, retromolar fossa; 3x, internal oblique line; 4, mandibular foramen behind lingula; 5, incorrect position of syringe, parallel to teeth. (After Fischer.)

"The syringe is pushed forward horizontally and posteriorly from the canine, on the opposite side along the internal surface of the mandibular half to be anesthetized (Figs. 183, 184, 187, 188, 189).

"The needle should be introduced to a depth of not more than from 1.5 to 2 cm. under the mucosa, lest it advance too far beyond the foramen and the correct point for the disposition of the solution be missed.

"The injecting solution is then deposited, beginning to inject soon after insertion of the needle, in order to anesthetize the lingual nerve at the same time (if this be desirable). The bulk of the solution, however, should be injected in the mandibular foramen.

"*Insertion of the Needle.*—The point of the injection is selected so that the needle is introduced in the mucous triangle, about 1 cm. above the level of the masticating surfaces of the molars (Figs. 187, 188, 190, 192); in children and youthful persons, advancing a little farther posteriorly while slightly lowering the needle; in old persons, slightly raising the long needle (Fig. 182).

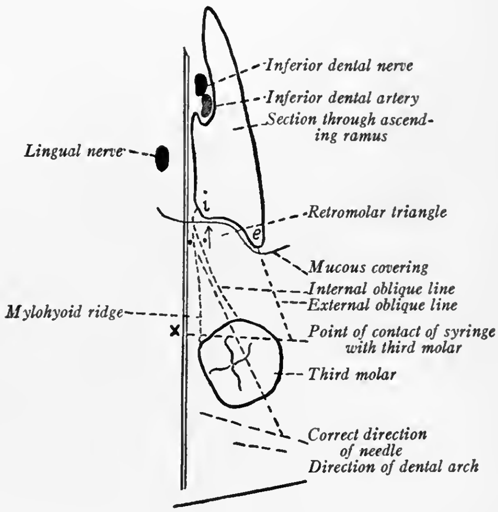

Fig. 188.—Horizontal section through ascending ramus. Diagram showing position of syringe and needle: *i*, Eminence of internal oblique line; *e*, eminence of external oblique line. (After Fischer.)

"*Difficulties.*—The technic of this form of injection offers some difficulties, which, however, after some practice are easily overcome; above all, it must be observed that the insertion of the needle is made not directly at the edge of the bone in the internal oblique line, but somewhat lingually from the bone. Behind this internal ridge the bony substance bulges still farther lingually, running over into the lingula after having first formed a second convex excrescence (Figs. 184, 187, 188).

"After the correct point of insertion, about 1 cm. above the level of the masticating surface of the last molar, has been found the oblique foramen is reached, just above the lingula, with the needle (Figs. 184, 187, 188).

"The distance from the anterior margin of the internal oblique line to the posterior margin of the lingual is about 15 mm.

"During the injection it is best, as has been correctly emphasized by Williger, to rest the syringe barrel on the bicuspids or between

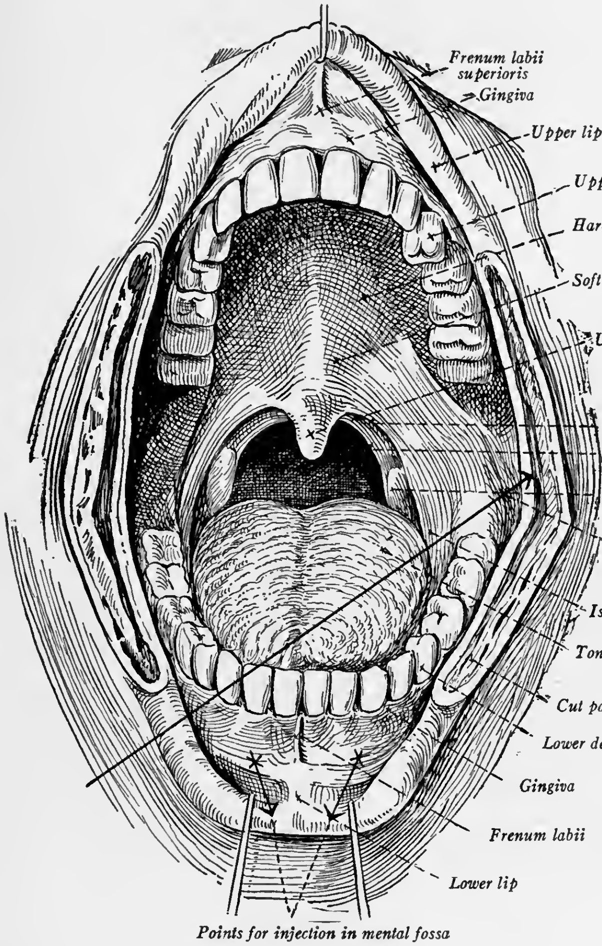

Fig. 189.—Oral cavity, widely opened. The solid black line indicates the correct position of the syringe for mandibular anesthesia. The arrows at the anterior portion of the mandible indicate the points of insertion of the needle in the reflection of mucous membrane for injection in canine fossa. (After Spalteholz.)

the canine and first bicuspids of the opposite side, thus securing a certain support for the syringe and an indication for the correct level for the insertion of the needle. (See illustrations.)

"*Management of the Needle.*—After insertion the needle is advanced to the bone without entering the peritoneum (Figs. 187, 188). A certain touch is soon acquired as to whether the needle is being advanced in the correct direction, not too far pharyngeally, yet closely enough to the bone. If, in case of a very sharp angle of the bone, the periosteum is found to offer resistance, even though moderately, the needle should not be advanced any farther, and under no condition use force, else the needle bores into the periosteum of the bone and is sure to break. It is best to carefully withdraw the needle for a short distance, and, after slightly altering its direction pharyngeally, to advance again posteriorly.

"The bone should not be reached before the needle has gone for a certain distance from the point of introduction (Figs. 184, 187, 188), yet not immediately at the internal oblique line, as has already been demonstrated.

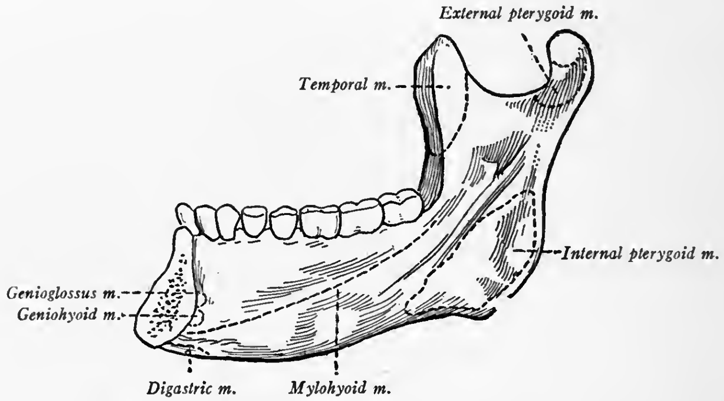

Fig. 190.—Origins and insertions of muscles upon inner surface of mandible. (Rauben and Kopsch.)

"*Injection of Solution.*—The solution should be emptied slowly and carefully, beginning immediately upon insertion of the needle in order to anesthetize simultaneously the lingual nerve (should this be desired—Author), which descends in front of the inferior dental nerve (Fig. 188). The bulk of the solution, however, is deposited at the oblique foramen. Penetration of the muscles in this region is out of the question, as has been shown above (Fig. 190).

"Neither is there any danger of puncturing the artery, which possesses thick walls, is protected by the lingula, and has enough space to evade into the loose surrounding tissues or into the depth of the inferior dental canal (Fig. 188). The corresponding vein is arranged around the artery in form of an intricate plexus and is equally well protected. The injection in the left ramus offers somewhat greater difficulties. While in the right oblique foramen the retromalar triangle is palpated with the left hand and the injection is made with the right, it is advisable to use the left hand for injection on the left side, according to Peuckart's suggestion, palpating and fixing the retromalar triangle with the right.

"*Effect of Injection.*—About three minutes after the injection the patient perceives a slight tingling in the lip and tongue on the in-

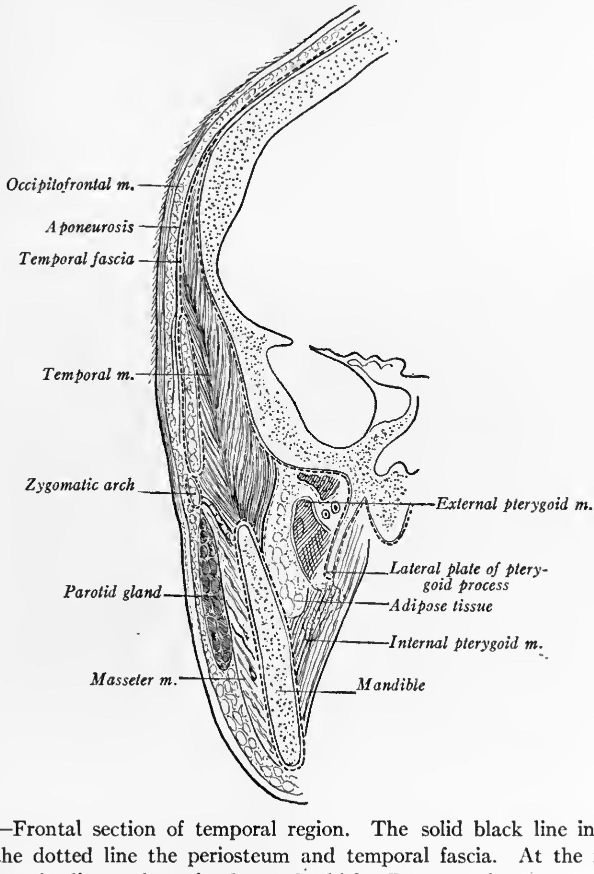

Fig. 191.—Frontal section of temporal region. The solid black line indicates the aponeurosis, the dotted line the periosteum and temporal fascia. At the mandibular foramen a mass of adipose tissue is observed which offers no resistance to the advance of the needle. (After Merkel.)

jected side. The tingling is the best indication as to the correct execution of the injection.

"The sensation gradually increases, and a certain numbness of the entire half of the jaw ensues. The lip on the anesthetized side depends slightly, exhibiting symptoms of partial paralysis, and the patient usually feels as if it were greatly swollen. Difficult deglutition is absent if the technic has been executed correctly. Its presence indicates that the injection has been too far pharyngeally and posteriorly. The concomitant symptoms persist for about one hour, after which they gradually subside, the former normal condition being re-established after about three hours."

For **anesthesia of the hard palate and roof of the mouth** advantage can be taken of the points of emergence of the palatine nerves upon the hard palate. (See Fig. 161.) These can be easily reached by in-

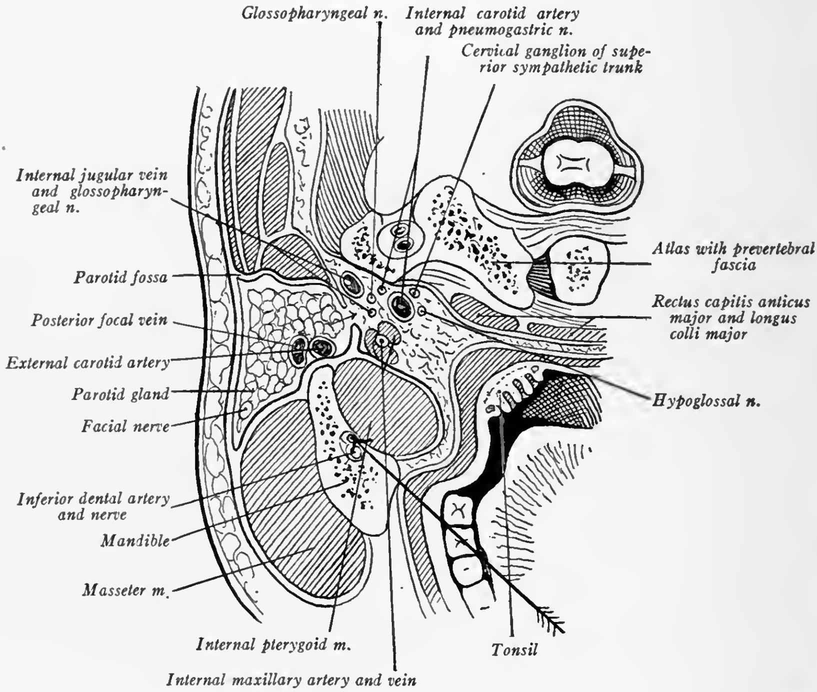

Fig. 192.—Horizontal section through lower portion of oral cavity. Relationship of lower teeth to ascending ramus and mandibular foramen. The large arrow indicates the correct position of syringe and needle for mandibular injection. (Corning.)

jections over the opening of the anterior and posterior palatine canals, the anterior just behind the incisor teeth in the middle line and the posterior just to the inner side of the last molar tooth, where the hard palate joins the alveolar process, in each case making the injections deep down in close contact with the bone.

In using this method it will often be necessary to secure perfect anesthesia to block the posterior palatine nerves on both sides, as the branches from each side cross over beyond the middle line.

The tongue can be anesthetized by blocking the lingual nerve with a paraneural injection. This nerve lies quite superficial under the mucous membrane, where it crosses from the ramus of the jaw to the base of the tongue; if the tongue is drawn forward and to the opposite side this fold of mucous membrane is put upon the stretch. A needle passed just under the surface of the anterior edge of this fold to a depth not to exceed $\frac{1}{4}$ inch, and $\frac{1}{2}$ to 1 dram of solution No. 2 (0.50 per cent. novocain) injected in this position will block the nerve; the opposite side can be similarly treated, thus anesthetizing the anterior two-thirds of the tongue, the field of distribution of the lingual, when

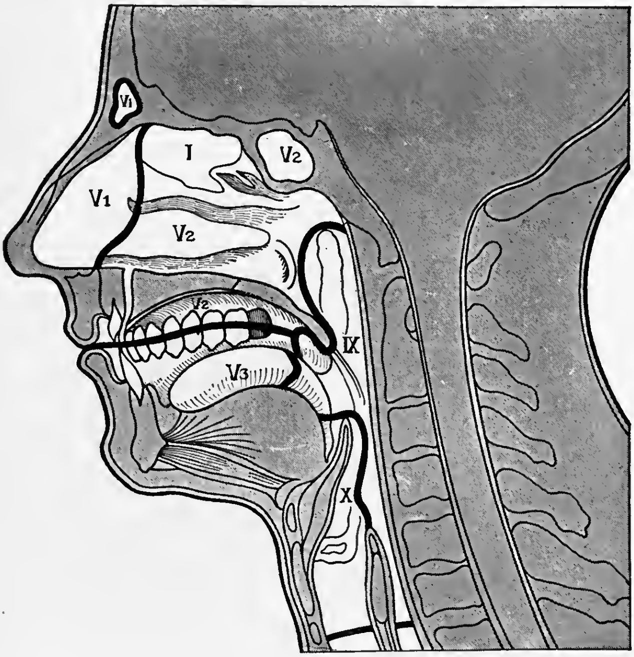

Fig. 193.—Sensory innervation of the mucous passage of the head and throat. (Hasse.) Nerves shown in Roman characters, branches of the fifth in Arabic. (Härtel.)

resections or any operations needed can be performed. The floor of the mouth receives nerves from other sources, and will have to be separately anesthetized if the operative field encroaches upon this region.

The alcoholization of nerves for the treatment of neuralgia had its beginning in experiments undertaken by Schlösser in 1900. He found that the injection of sensory nerves with 1 to 2 c.c. of 80 per cent. alcohol produced a burning pain of momentary duration, followed after a few minutes by numbness and anesthesia, which in the course of a week disappeared and was followed by a return of tactile sensation, but the pain sense remained absent. Following these experiments Schlösser's first report on the treatment of neuralgia appeared in the "Transactions of the Heidelberg Ophthalmologische Gesellschaft," 1903. Unfortunately, he does not state very clearly his technic, for the reason, as stated, that this method of treatment had not yet been given sufficient trial to determine its merits. Somewhat later he goes more into detail and describes a transverse puncture from beneath the zygoma; he also describes a method for reaching the foramen ovale with a finger in the mouth, locating the pterygoid process behind the tuber maxillare. The needle is entered through the mouth and pushed through the mucous membrane, under guidance of the palpating finger, and advanced some distance upward and backward beyond the external pterygoid plate to the region of the foramen ovale.

In the buccal method of Ostwalt for reaching the foramen ovale he enters the needle through the mucous membrane at a point opposite the last molar tooth, and advances it along the external pterygoid process toward the foramen ovale.

In the buccal route of Offerhaus he determines the position of the foramen ovale from the last molar tooth as representing approximately an angle of 130 degrees, in which direction he enters the needle.

It is possible that by the intrabuccal routes of Schlösser, Ostwelt and Offerhaus the ganglion was often reached, but never with the same degree of certainty as by the Härtel route. Härtel uses practically the same route, except he adopts the more aseptic point of puncture upon the cheek, and safeguards the passage of the needle in the right direction by advancing it at determined angles and to a definite depth, and from a position certainly less trying and unpleasant to the patient.

Among the first to report direct injections of the gasserian ganglion was Harris (Royal Soc. of Med. Neurolog., Feb., 25, 1909). He demonstrated the successful injection of the ganglion with his technic by using colored solutions upon the cadaver. This line of puncture varies little from that used by him to reach the trunk of the third division beneath the skull, only that the needle is entered at a lower level, so that its axis will be more nearly that of the foramen ovale. A line is drawn from the ala of the nose to the incisura notch (of the ear). This line on the average skull passes over the lower border of the sigmoid notch of the inferior maxilla with the mouth closed.

The needle is entered on or slightly below this line and below the midpoint of the zygoma, and directed obliquely upward and inward through the sigmoid notch, and feels its way along the base of the skull toward the foramen ovale, within which the needle is felt to slip. By injecting the ganglion by this route there is danger of wounding the cavernous sinus or carotid artery within the skull. (See Anatomic Illustrations.)

The transverse methods of approach to the third division of the fifth nerve by Alexander, Patrick, Kiliani, and others are practically the same with minor modifications, and are well illustrated by the procedure of Braun, which, to the author, seems established on somewhat better anatomic lines.

Dr. Hugh T. Patrick, in speaking of deep alcohol injections made beneath the foramen ovale and rotunda for trifacial neuralgia, after an experience of over 300 injections with 85 per cent. alcohol, states: "The danger of the operation is as nearly nil as can well be. I know of no fatality, and think none has ever been recorded, nor have I heard of a single case of infection."

The only complications he had which would be at all likely to occur when injecting a non-irritating anesthetic solution into these parts was the rare appearance of a hematoma. As Patrick uses a rather large needle for these injections, the likelihood of injuring the vessels is greater, but if a small caliber needle with blunt point, such as is ordinarily used for spinal puncture, is substituted, this danger will be largely overcome.

In making these injections it is best to use specially constructed needles and syringes. The needle should be of small caliber and strongly made and with a short beveled point, combined with aids for determining and controlling distance. Such an outfit, as designed by Härtel, is seen in Fig. 233.

The area on the base of the skull within which lie the foramen rotundum and foramen ovale is within a very limited space, yet their approach is very often surrounded by many difficulties, which may not be the same in any two skulls, due to the individual variations in the osseous arrangement of the parts. For this reason no method of approach that has yet been devised, or is likely to be, will guide us to the desired point with unerring accuracy, and no method of computing these variations in the position of the basal foramina from a study of the variations of the external configuration has been found reliable. Much study has been spent upon this subject and many skulls measured, with a view of obtaining some accurate information to guide us in the proper direction. Many ingenious methods have been devised, the more notable and recent of these are the Offerhaus and Härtel routes, which, added to the information previously possessed on this subject, have placed our methods of approach on a more accurate footing, and now enable us in the great majority of cases to make intraneural and even intraganglionic (gasserian) injections, instead of contenting ourselves with paraneural injections, which were often the best we were able to accomplish in the past in reaching the third division of the trigeminus.

The problem of reaching the second division with accuracy was solved by Matas, in 1898, by the intra-orbital puncture of the foramen rotundum, although this has by some writers been erroneously attributed to Payr.

The foramen rotundum lies within the sphenomaxillary fossa, at the point of junction of the sphenomaxillary and the pterygomaxillary fissures. The foramen ovale, at the base of the skull, lies just behind the zygomatic fossa at the base of the external pterygoid plate.

Either foramen may be approached from in front or laterally—in the case of the foramen rotundum, by the Matas route through the orbit, and for the foramen ovale by several routes through the mouth, or the Härtel route through the cheek. The lateral or transverse approach to either foramen is from above or below various points on the zygoma through the temporal or zygomatic fossæ.

Viewed from below (Fig. 196) we find the region of the foramen ovale to have the following points worthy of note. Beginning forward and laterally, on the great wing of the sphenoid at the pterygoid ridge, and proceeding downward, backward, and inward toward the foramen, we see a slightly concave surface at the base of the external pterygoid plate, the area of attachment of the external pterygoid muscle; this surface is perfectly smooth, and leads downward, backward, and inward over a smooth convex rim of bone into the foramen ovale.

Approaching the foramen from below and in front, along the external surface of the external pterygoid plate, we find this surface likewise smooth and even and leading downward and backward into the foramen ovale.

The external pterygoid plate, like the other parts concerned here, is subject to a certain range of variations. Some of these, met with by Härtel, are shown in Fig. 194.

This information is useful in the following way: If the needle is advanced from in front through the cheek or mouth, and its point carried rather low, meeting the external pterygoid plate, it must be advanced upward and backward along the smooth surface, feeling its way to the foramen; if the point is directed high up, and first meets the under surface of the sphenoid at the base of the pterygoid process, it must be advanced backward and inward over the bone, and, as this surface slopes downward, backward, and inward as the needle successively feels its way backward, it must be gradually withdrawn in following the downward slope of the bone.

The posterior margin of the foramen is formed by a sharp ridge of bone, which is directed downward, forward, and outward, running from behind, near the foramen spinosum, forward and inward, to be

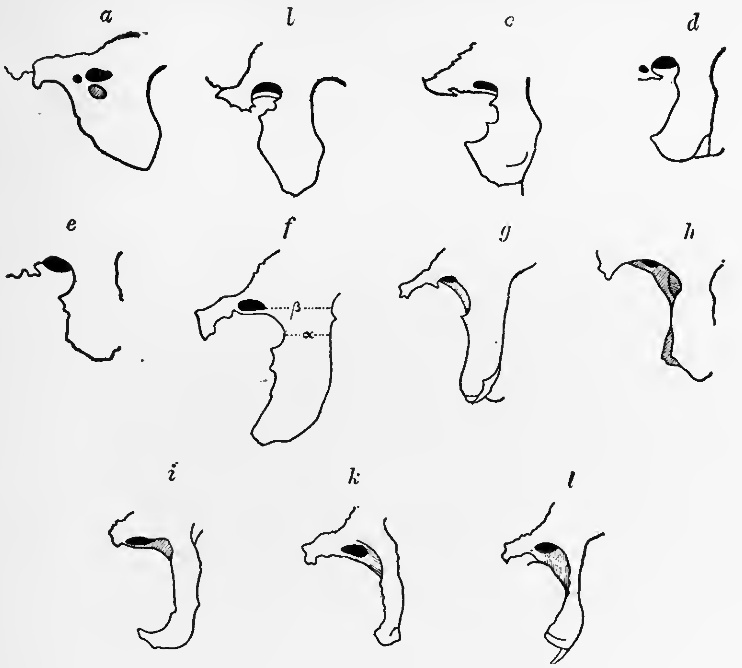

Fig. 194.—External lamina of pterygoid process and foramen ovale on right side of skull seen from the side: *a*, The external lamina and spina angularis are grown together and form the foramen Civinini; *b–f*, broad form of external lamina; *g–l*, narrow form of external lamina. Between the foramen ovale and external lamina can be seen more or less of the deeper situated parts forming the base of the skull (pterygoid and scaphoid fossæ). (Härtel.)

lost in the pterygoid fossa. On a plane just back of the foramen ovale we find the sharp irregular spinous process of the sphenoid, which gives attachment to the internal lateral ligament of the jaw and tensor palatine muscle. The foramen spinosum is seen running through the spinous process for the passage of the middle meningeal artery; it usually lies just behind and external to the foramen ovale.

At the apex of the petrous portion of the temporal bone, and internal and behind the foramen ovale, is the foramen lacerum medium.

Slightly internal to the foramen spinosum, and behind the foramen ovale, is seen the canal for the Eustachian tube and tensor tympani muscle; the anterior external boundary of this canal is formed by the short ridge of bone which forms the posterior internal margin of the foramen ovale, consequently it is seen that the Eustachian tube and middle meningeal artery lie on a plane just posterior to the foramen ovale. The posterior internal wall of the Eustachian canal is formed by the hard, rough, and uneven convex surface of the petrous portion of the temporal bone. The situation of the Eustachian tube just back of the foramen ovale is of much importance. If the point of the needle is advanced too far posteriorly, and comes in contact with the rough and irregular surface bordering this tube, it should be at once recognized and withdrawn and redirected more anteriorly. A puncture of the Eustachian tube is recognized by its producing a sharp pain in the ear, and if the solution is injected it escapes downward into the pharynx.

Just back of the Eustachian canal, in the petrous portion of the temporal bone, is seen the carotid canal, usually lying in a line directly back of the foramen ovale from $\frac{1}{4}$ to $\frac{1}{2}$ inch, the Eustachian tube lying between. Directly back of the carotid canal is the jugular fossa. The internal jugular is formed within the jugular foramen by a juncture of the inferior petrosal and lateral sinuses. The three nerves—glossopharyngeal, pneumogastric, and spinal accessory—lie in the above order in front and to the innerside of the jugular within the foramen.

The distance of the carotid foramen from the foramen ovale is, according to the measurements of Härtel, minimum, 8 mm., maximum, 17 mm., with an average of 12.7 mm., and from the foramen ovale to the jugular foramen 15 to 28 mm., with an average of 20 mm. (See Table II, No. 4.)

It is seen from the above that the entire bony surface lying in front and to the sides of the foramen ovale is smooth, and even while the bony surface behind it is rough and irregular; consequently, if the needle as it is advanced feels the smooth undersurface of the sphenoid it means we are still within safe territory, and that the needle must be gradually insinuated backward, but if we are come into contact with the rough and irregular surface lying posteriorly we are on dangerous ground and the needle must be withdrawn and reinserted further forward.

Lateral to the foramen ovale, on its outer side, is seen the eminentia articularis, and on its outer extremity, on the lower margin of the zygoma at its root, is seen the articular tubercle, which is usually on the same lateral plane as the foramen ovale.

For a further description of the anatomy of this region I quote the following from Härtel, who, in his classical presentation of this subject in the "Archiv. für Klin, Chir.," vol. c, 1912, in a discussion of the various routes, with a presentation of his own method, contributes an exhaustive study of this region which must remain for all time as a monumental contribution to the surgery of the head, and through whose kind permission I am permitted to quote him in this chapter. In conjunction with the description of this region, see Fig. 196.

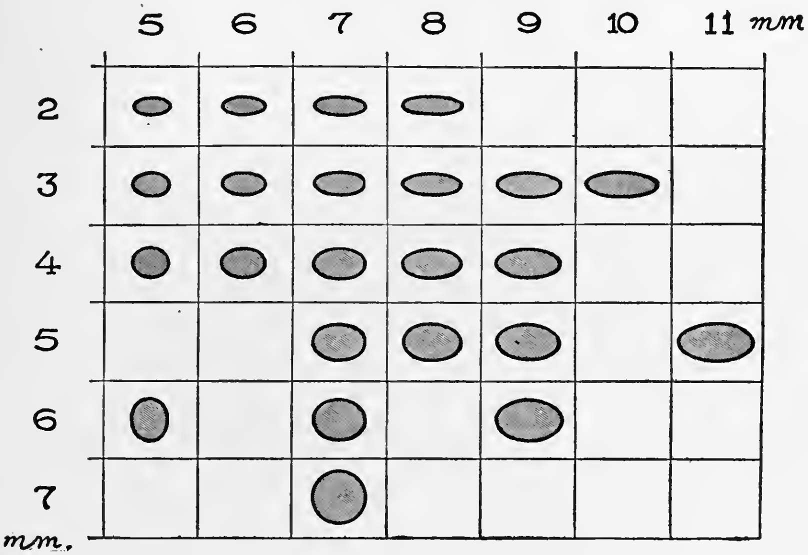

Fig. 195.—Schematic representation of the differences in size and shape of the foramen ovale obtained from 116 examinations, shown in natural size. (Härtel.)

"The form and size of the foramen ovale vary extraordinarily. Scarcely a skull is found whose foramina ovalia are equal to each other. The shape varies from the small longitudinal slit to the circular form; there occur also transverse, oval, as well as occasionally roll and kidney forms. The length, on the average 6.9 mm., varies between 5 and 11 mm. (Table II, No. 1), the breadth between 2 and $7\frac{1}{2}$ mm., with an average of 3.7 mm. (Table II, No. 2).

"The accompanying Fig. 195 shows the size relationships of the foramen ovale found by us in 116 examinations. According to this, the way through the foramen ovale must always stand open for the cannula (0.8 mm. thickness); still, according to my experience, a breadth under 3 mm. means a difficulty in puncturing. We found this unfavorable breadth in 8 per cent. of the skulls examined (Table II, No. 3). Occasionally the foramen ovale is not bony all the way around, and stands in open connection with the foramen spinosum or

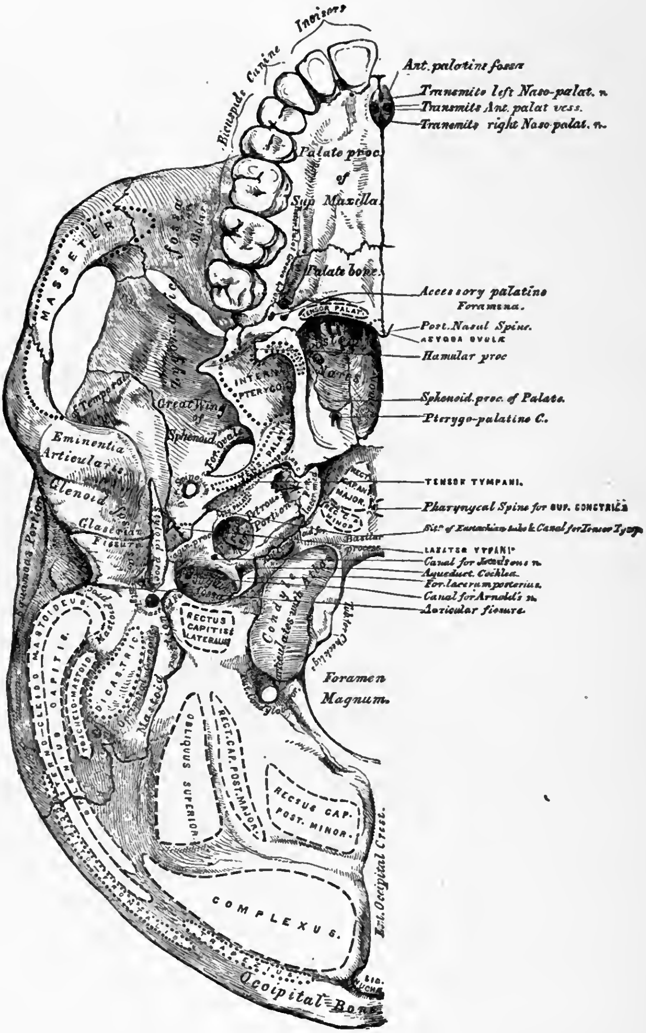

Fig. 196.—Base of the skull, external surface. (After Gray.)

lacerum or both (Table II, No. 3). On the other hand, a multiple foramen ovale, which Offerhaus found unusually frequent (5 per cent.), we could not observe in any case, nor are any similar cases mentioned in the anatomic literature (Poirier, Testut). On the other hand, atypical venous emissaries (foramina innominata, venosa, Vesalii) are frequent in the neighborhood of the foramen ovale.

"The entrance to the foramen ovale is overhung on the anterior end by the lamina lateralis of the pterygoid process; behind, by the

Fig. 197.—The development of the foramen Civinini from the ossification of the Lig. pterygospinosum. (Photo from a specimen in the Anatomical Collection): 1, Foramen ovale; 2, foramen Civinini. (Härtel.)

spina angularis. In cases of strong development these ridges of bone are united by a ligament which many times ossifies (ligamentum Civinini spina pterygospinosum) (Fig. 194). This ossification need not

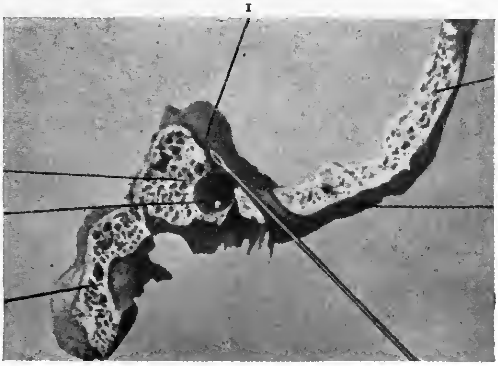

Fig. 198.—Sagittal section through the foramen ovale. The section lies in a somewhat obliquely placed vertical plane corresponding to the direction of the needle to reach the ganglion: 1, Impressio trigemini; 2, petrous bone; 3, carotid canal; 4, occipital bone; 5, great wing of sphenoid; 6, planum infratemporal; 7, needle in foramen ovale. (Härtel.)

present a hindrance to puncturing. If the foramen ovale lies medially from the foramen Civinini, then the transverse way (from beneath the zygomatic arch) must first go through the foramen Civinini in order to reach the nervus mandibularis, which in practice must involve difficulties. Likewise the way from in front through the cheek or mouth can be obstructed by an ossified ligamentum pterygospinosum accompanied by narrowness of the foramen ovale. However, we have found this relationship only once among 134 examinations (Table II, No. 3), while we observed the ossification itself 9 times (7 per cent). The distance of the posterior margin of the foramen ovale from the foramen spinosum is also subject to great variation; it varies between 0 and 6 mm. (Table II, No. 4). The shorter this distance, the greater, theoretically, is the danger of injuring the arteria meningea media. We avoid this danger in puncturing as we seek the foramen from before, always feeling our way very gradually.

"The foramen ovale presents really not a hole, but a bone-canal of about 1 cm. in length (Testut and Jacob), which penetrates the wing of the sphenoid bone (at this place about 7 mm. thick) in diagonal direction in front from below laterally; behind, upward toward the median line. If we observe the orifice of this canal from the under surface of the skull, then we find on the anterior outer side of it and on its long side a smooth curvature gradually passing over into the planum infratemporale, while the posterior inner circumference is bounded by a sharp ridge which rises sharply posterior to the fissura sphenopetrosa, the bed of the tuba Eustachii. Therefore, for a convenient introduction of the cannula the anterior outer long side offers the best chances, for here the needle glides over a broadly curved bone-surface and catches the foramen from the broad side (Fig. 198, diagonal vertical section through the left sphenoid bone and petrous portion of the temporal bone). In addition I might remark that the planum infratemporale in the cadaver skull, with soft parts *in situ*, always offers to the puncture needle a completely smooth and hard bone surface, while the vicinity of this planum posteriorly and inwardly is covered unevenly, roughly, by cartilage and fibrous tissue, and, therefore, gives to the needle the characteristic feel of a rough, grating resistance. *We must come into the foramen on a smooth, hard, bony way; if we feel the grating unevenness we are wrong, and must retreat forward and outward.*

"This deviation of the needle on the inequalities of the pyramid of the petrous portion of the temporal bone, of the foramen lacerum, or of the fossa pterygoidea can easily occur if one confines himself exclusively to the angle between the lamina externa of the wing of sphenoid and the planum infratemporale. One should consider always that the foramen ovale is located outwardly from this angle, and that in many cases the lamina externa is so small that between its posterior margin and the foramen ovale a considerable portion of way still remains open, which may be as large as 8 mm. Figure 194 shows some skull variations which illustrate this relation between the foramen ovale and the pterygoid process. If one seeks to find a measurable expression for these relations by measuring the breadth of the outer wing of the sphenoid bone at the base, in other words, the distance of its anterior margin from the foramen ovale, then the numerical relations described in Table II, No. 5, result.

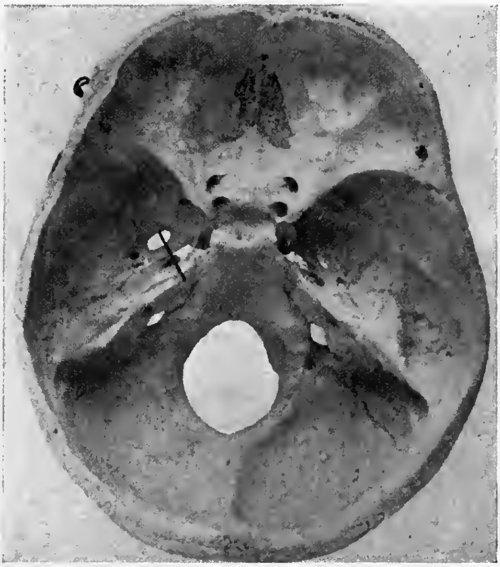

Fig. 199.—Härtel method for the injection of the gasserian ganglion. Base of skull seen from above with the needle passing through foramen ovale to the impressio trigemini. (Härtel.)

"The rule, therefore, which is to be observed for the sense of bony resistance from the planum infratemporale to the foramen ovale is as follows:

"One goes gradually from before backward, maintaining a position laterally from the lamina externa, and never deviates from the smooth, hard substratum. In so doing the point of the needle describes an outwardly convex curve.

"Let us now follow the way further into the skull. For the accurate puncture of the ganglion Gasseri we have established the requirement of adherence to the so-called axis of the trigeminus; that is, a straight line going from the middle of the impressio trigemini of the petrous portion of the temporal bone through the middle of the foramen ovale (Figs. 199, 200). Only a cannula introduced into the skull in this direction avoids collateral injuries of the tissues adjacent to the cavum Meckeli (Figs. 207, 208), namely, of the sinus cavernosus, of the carotis interna, of the sinus petrosus superior, and of the brain. If, as we have said above, the foramen ovale is not a simple hole, but forms a bone-canal about 1 cm. long, so we find now that the long axis of this canal corresponds to this axis of the trigeminus; in other words, passes parallel to the anterior surface of the pyramid of the petrous portion of the temporal bone (Fig. 201); if

Fig. 200.—Same as Fig. 199, seen from the side, showing needle passing into foramen ovale between ascending ramus of lower jaw and maxillary tubercle. (Härtel.)

it should not do this, and, for example, should pass more steeply (Fig. 201, *b*), then the cannula would penetrate, not into the ganglion, but through the dura into the temporal lobe; if it passes more on a level, then the danger exists that the cannula from above, through the foramen lacerum, may prick the carotis interna. The latter situation we never found; the former, less dangerous, situation, very seldom (3 times in 114 examinations); and even in these cases of incongruence between the inclination of the pyramid of the petrous portion of the temporal bone and the long axis of the canal of the foramen ovale it suffices practically, if the needle, coming from below outward, then upward and inward, traverses the canal of the foramen ovale in diagonal direction, and thereby arrives in the direction of the inclination of the petrous portion of the temporal bone (Fig. 201, *b*, *c*, *d*).

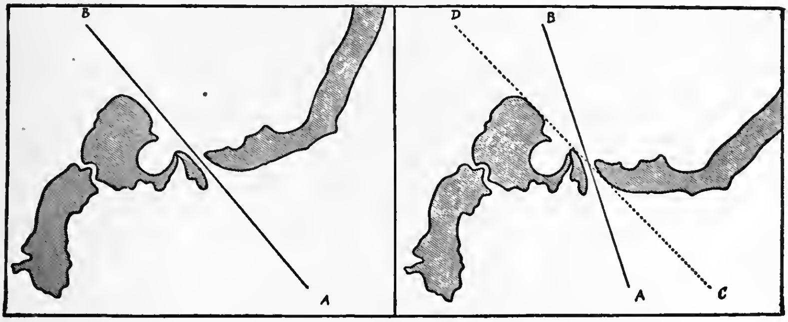

Fig. 201.—Schematic representation of the trigeminal axis and the direction the needle should take to the gasserian ganglion: *a*, Normal type. The long axis of the bony canal of the foramen ovale and the inclination of the petrous bone lie in the direction *A*, *B*; *b*, occasional variation. The long axis of the bony canal of the foramen ovale *A*, *B* stands more steeply than the inclination of the petrosa *C*, *D*. (Härtel.)

"The question is of importance as to how deeply we may go into the foramen ovale with the needle. We must, therefore, measure the

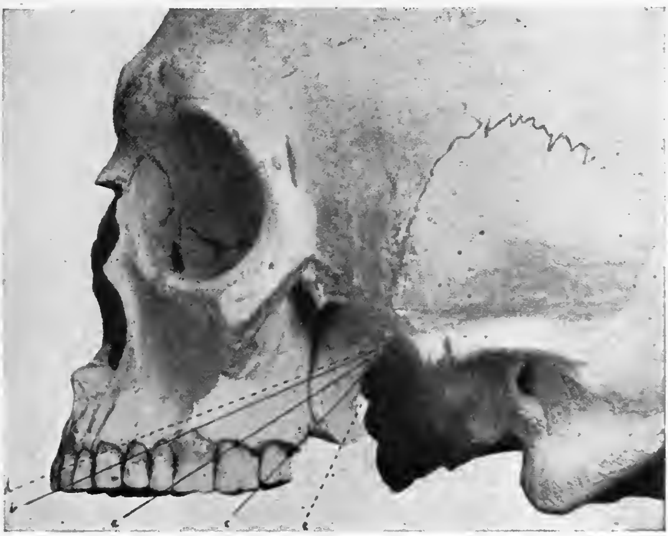

Fig. 202.—Projection upon the upper jaw of the different axes of entrance to the foramen ovale, showing their variability: *a*, Medium steep; *b*, flat; *c*, steep; *d*, overflat; *e*, oversteep. (Härtel.)

distance between the superior margin of the pyramid of the petrous portion of the temporal bone and the posterior inferior margin of the foramen ovale, and we find (Table II, No. 6) a minimum of 14 mm., a maximum of 23 mm., and an average of 19 mm. The minimum (*1.4*

Fig. 203.—Projection of an equally steep axis upon upper jaws of various height: *a*, *a'*, Short upper jaw, axis appears steep; *b*, *b'*, medium high upper jaw, axis appears medium steep; *c*, *c'*, high upper jaw, axis appears flat. (Härtel.)

cm.) is the standard; if we go deeper, we run the danger of puncturing through the chief trunk of the trigeminus through the cisternæ of

Fig. 204.—Position and size of area of skin anesthesia for injection of gasserian ganglion. (Härtel.)

the posterior cranial fossa (cisterna pontis). This has actually happened to us in the living subject, and emission of fluid resulted. One secures, if one immediately draws the needle back somewhat and then

Fig. 205.—Härtel route, showing axis of needle to pupil of eye when viewed from in front and to articular tubercle at base of zygoma when viewed from the side (photo from a cadaver. (Härtel.)

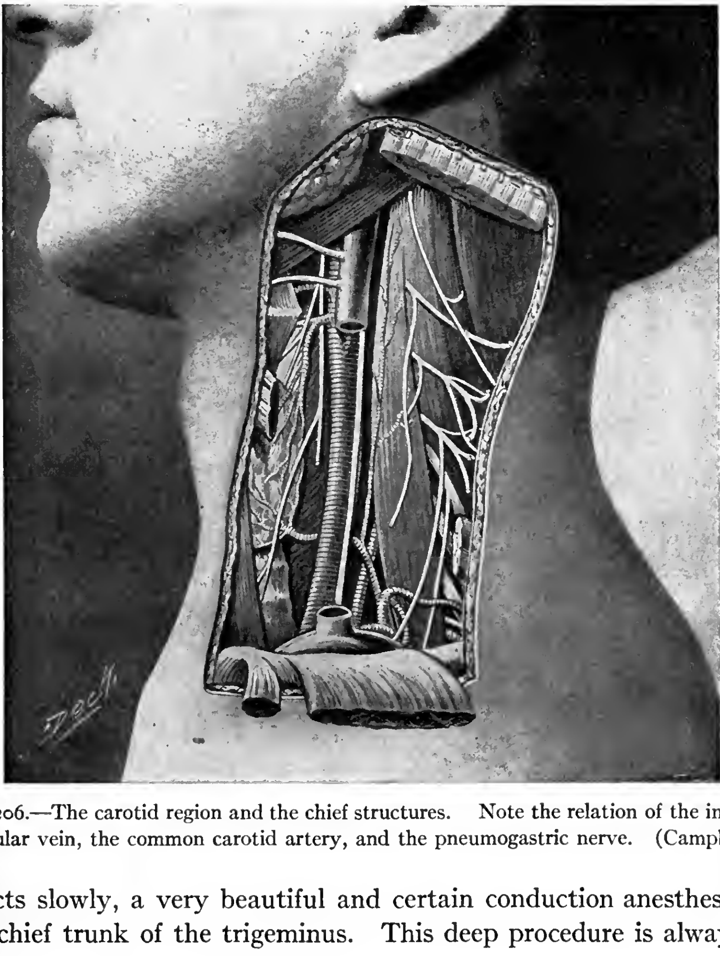

Fig. 206.—The carotid region and the chief structures. Note the relation of the internal jugular vein, the common carotid artery, and the pneumogastric nerve. (Campbell.)

injects slowly, a very beautiful and certain conduction anesthesia of the chief trunk of the trigeminus. This deep procedure is always to be warned against, for thereby one runs the danger of pricking the sinus petrosus superior, or of injecting the solution, instead of into the ganglion, into the posterior cranial fossa, which has collateral manifestations (vomiting) as a result.

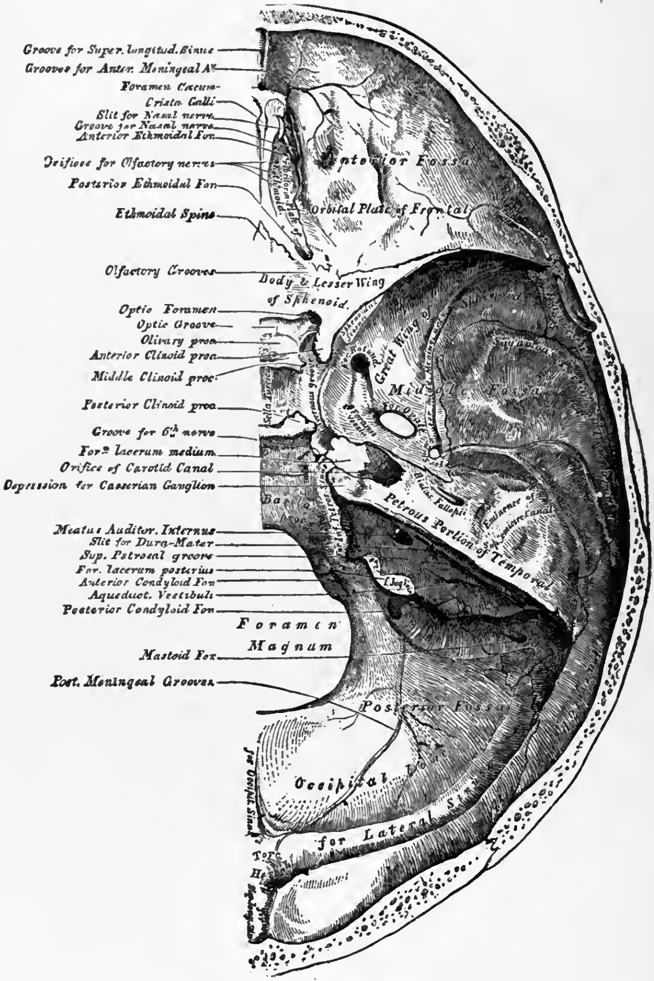

Fig. 207.—Base of the skull, inner or cerebral surface. (After Gray.)

"If we now follow the axis of the trigeminus already mentioned, then we find that it traverses the fossa infratemporalis, and passes on exactly in the middle line between the ascending branch of the lower jaw and the tuber maxillare. For choosing the puncture point it is important to know where the lateral projection of this axis on the upper jaw cuts the alveolar margin. This point is dependent on two different factors, namely: (1) On the more or less steep course of the axis of the trigeminus; (2) on the situation of the upper jaw.

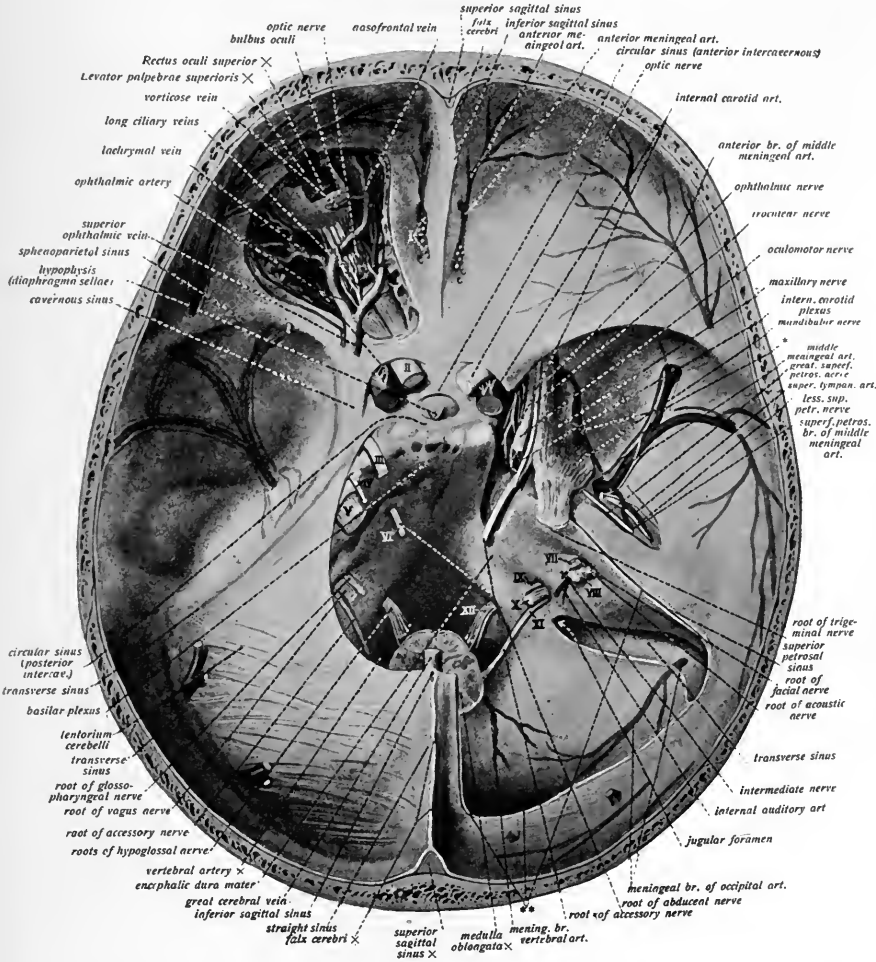

Fig. 208.—The dura mater with its arteries and sinuses, the veins of the orbit, and the course of the twelve pairs of cerebral nerves through the dura mater. The left orbit has been opened. Upon the right the tentorium cerebelli has been removed, the commencement of the transverse sinus opened, and the dura mater excised along the emerging nerves and the middle meningeal artery. × Meningeal nerve and anastomosis with the spinal nerve; *× = cut edge of tentorium. (Sobotta and McMurrich.)

"According to Fig. 202, the steeper the axis is the farther behind the upper jaw it strikes; on the other hand, according to Fig. 203, an axis with equally steep course will reach a more or less high built upper jaw farther forward or behind, and so appear more level or steeper.

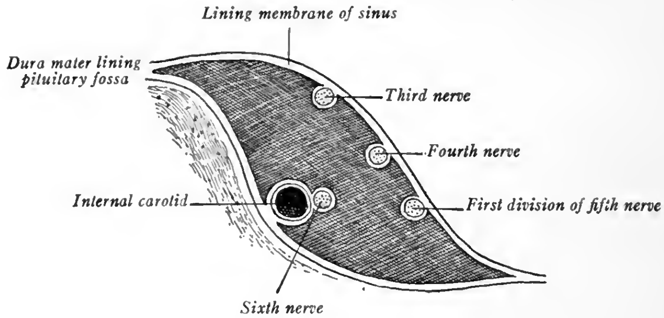

Fig. 209.—Showing the relative position of the structures in the right cavernous sinus, viewed from behind. (After Gray.)

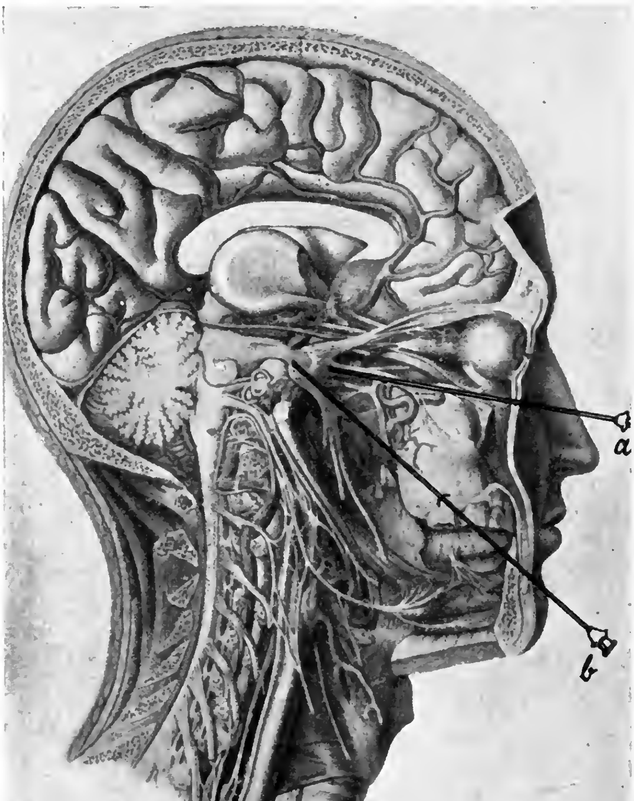

Fig. 210.—Nerves of the head (from Arnold) seen from the side: *a*. Needle directed along orbital route (Matas) into foramen rotundum; *b*, Härtel route to gasserian ganglion. (Härtel.)

Whatever the real basis of this relation may be in the individual case, in practice both amount to the same thing; namely, that we may not seek the puncture point in an exactly designated place, for example, at the height of a certain molar tooth, but that the puncture point varies within certain limits. We may not expect that we may penetrate forthwith into the skull by any one puncture point selected and reach our mark, but we must frequently make up our minds to repeated puncture. This changes the puncture point until it has reached the right axis, and now without resistance attains the cranial

Fig. 211.—Right pterygopalatine fossa, foramen rotundum and superior orbital fissure seen from behind. Needle *a* is passed from the pterygopalatine fossa out of the foramen rotundum. Needle *b* is pushed in a steeper direction through the inferior orbital fissure and impinges within the superior fissure. (Härtel.)

cavity, a situation that we have indicated above by the expression 'concentric puncture.'

"We have now examined the relation of the axis of the trigeminus to the upper jaw in different skulls, and designate as the 'middle part' an axis which strikes the upper alveolar margin at the height of the middle molar tooth (Fig. 202, *a*). 'Steep' means (*c*) cutting point of the axis with the posterior margin of the alveolar process, 'over steep' (*e*) still farther back; 'level' (*b*) means cutting point under the process of the malar bone at the height of the first molar tooth, 'over level' (*d*) farther in front of it. The values found are entered in Table II, No. 7. It follows from this that the 'middle part' axis is the most frequent, and *that in 90 per cent. of skulls the axis cuts the upper alveolar margin in the region of the three upper molar teeth* (Fig. 203, *b*, *a*, *c*).

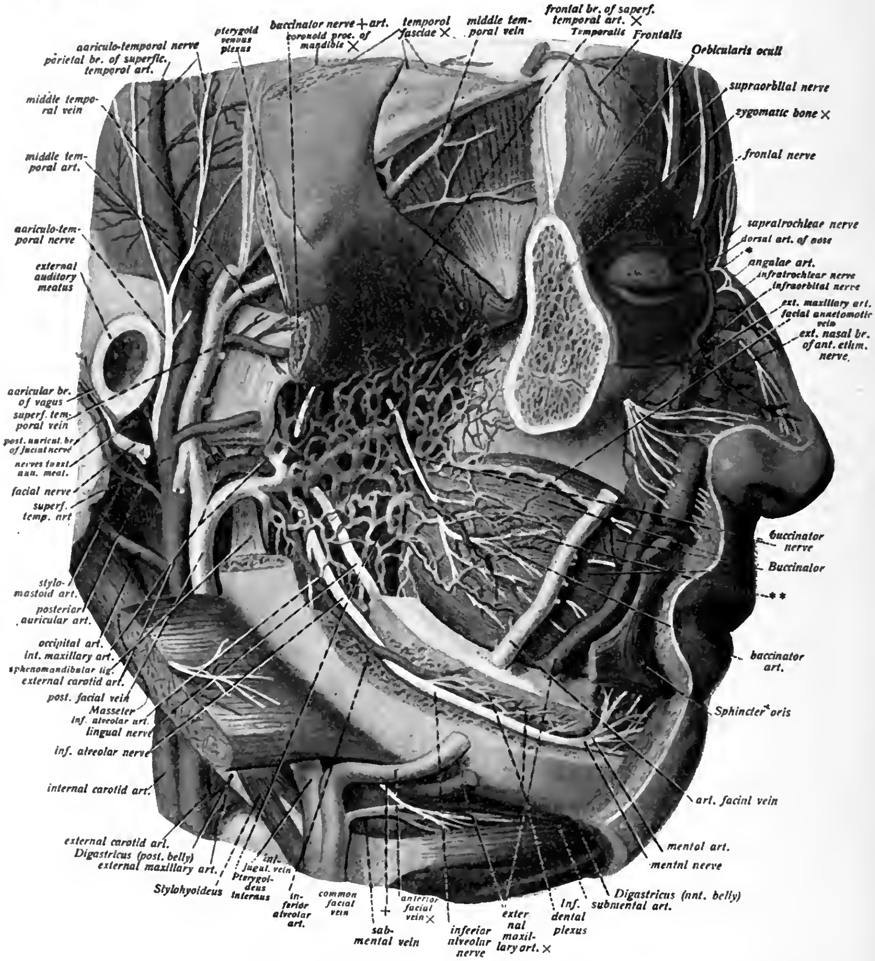

Fig. 212.—The nerves and vessels of the face (fourth layer, the deep facial veins). The zygomatic arch has been removed, the temporalis with the mandibular coronoid process reflected upward, the mandibular neck excised, the external ear cut off, and the entire mandibular canal opened up. * = Anastomosis between supratrochlear and infratrochlear nerves. ** = Branches of buccinator nerve passing to mucous membrane of the cheek. + = Mylohyoid nerve. + on the vein = divided communication with external jugular vein. (Sobotta and McMurrich.)

We will, consequently, accept as a standard puncture point that opposite the second upper molar tooth (of course, outside on the cheek), and if we do not come to the mark here we will vary the point on a line parallel to the alveolar margin, reaching back to the ascending

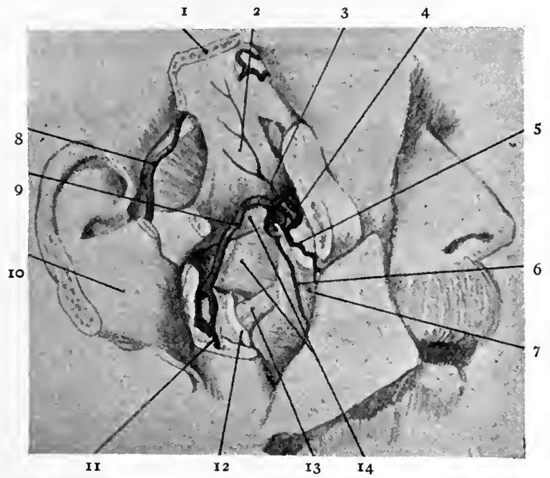

Fig. 213.—Normal course of the internal maxillary artery on the outer side of the ext. pterygoid muscle: 1, Coronoid process; 2, temporal muscle; 3, deep ant. branch temp. art.; 4, infra-orbital artery; 5, post. sup. alveolar art.; 6, buccinator art. and nerve; 7, buccinator muscle; 8, superficial temp. art.; 9, internal maxillary art.; 10, masseter muscle; 11, inferior alveolar art. and nerve; 12, lingual nerve; 13, int. pterygoid muscle; 14, ext. pterygoid muscle. (After Poirier.)

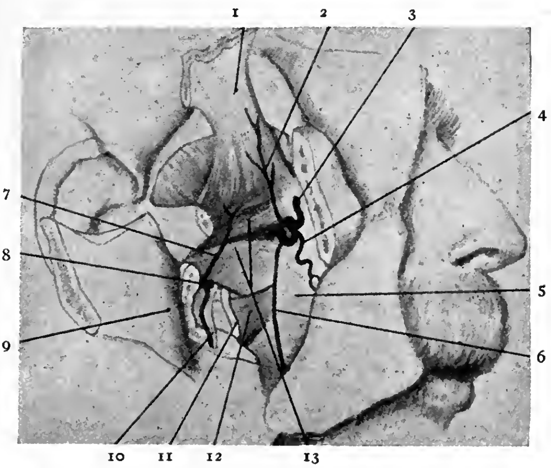

Fig. 214.—Atypical course of the internal maxillary on the inner side of the external pterygoid muscle: 1, Temporal muscle and coronoid process; 2, deep ant. temporal artery; 3, infra-orbital artery; 4, post. sup. alveolar artery; 5, buccinator muscle; 6, buccinator artery; 7, deep post. temporal artery; 8, internal maxillary artery; 9, masseter; 10, inf. alveolar artery and nerve; 11, lingual nerve; 12, int. pterygoid muscle; 13, ext. pterygoid muscle. (After Poirier.)

branch of the lower jaw and forward into the region of the upper premolar teeth (Fig. 204).

"Now that we have established a bone-way for the foramen ovale, we must consider the relations of the soft parts which our cannula has to pass through from the cheek to the ganglion Gasseri.

"We had chosen our puncture point in the lateral region of the cheek, opposite the alveolar margin of the second upper molar tooth. The point of the cannula penetrates the skin and finds itself in Bichat's fat of the cheek. The finger, placed in the mouth of the patient, feels the needle from the mucous membrane, and accompanies the advancing point of the same through the first strait between the margin of the lower jaw and the tuber maxillare. The finger maintains the

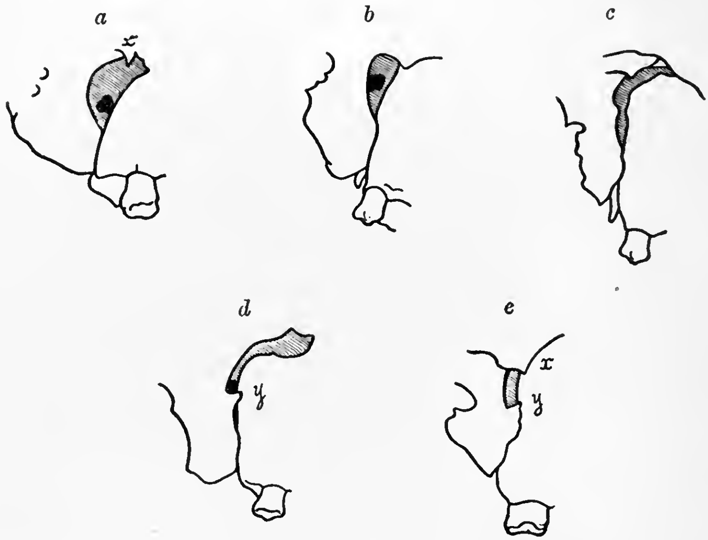

Fig. 215.—External lamina pterygoid process. Pterygopalatine fossa and maxillary tubercle. Right side of skull seen from the side: *a*, Wide fossa with spinous tubercle (*x*); *b*, medium wide; *c–e*, narrow fossa; *d*, anterior pterygoid spine (*y*); *e*, spinous tubercle (*x*), and anterior pterygoid spine (*y*). (Härtel.)

integrity of the mucous membrane of the vestibulum oris, this being accomplished by a curved motion of the needle around the buccinator muscle. The needle, therefore, goes between (medially) the buccinator muscle on the one side, and the masseter muscle, lower jaw, with processus coronoideus and temporal muscle (laterally) on the other side, through into the fossa infratemporalis, and now endeavors by perforation of the pterygoideus muscle externus, which fills the entire fossa, to reach the planum infratemporale, in connection with which, as we have seen above, finger-feeling can be auxiliary only in a portion of the cases. We need, therefore, other fixed points. Such a point is the *depth*. Before we stick the needle in we mark with the sliding catch a distance of 5 to 6 cm.; in case of forward curving of the cheek by a tumor, still more. We are thereby always informed as to the depth reached, and can thus protect ourselves from gross errors. In the second place we must now consider a *direction* discernible on inspection of the whole skull, and we have been able by careful observation and many examinations to establish as essential for the puncture of the foramen ovale the following fixed points:

Fig. 216.—Lateral route to foramen rotundum. (Braun.)

"(1) Viewed exactly from the front (for this determination of direction one must, like the designer, see with one eye only, and possibly with the aid of a second cannula held freely before one), the cannula introduced into the ganglion points to the pupil of the eye on the same side (Fig. 205). If we observe this rule, then we avoid deviating outwardly into the fossa temporalis, inwardly into the tube and pharynx region.

"(2) On exact lateral inspection the cannula points to the tuberculum articulare of the zygomatic arch (Fig. 205), If we do not observe this rule, then it may happen that we come too far forward into the fossa pterygopalatina, or too far back into the region of the foramen caroticum and of the foramen jugulare; the latter way, particularly—namely, the introduction of the needle into the medial part of the foramen jugulare instead of into the foramen ovale—we have several times taken wrongly on the cadaver, and the cannula appeared at the base of the skull, at the place of entry of the nervus vagus and glossopharyngeus into the dura.

Fig. 217.—Lateral injection of second division of fifth nerve in pterygopalatine fossa. (Härtel.)

"Viewed from below (with the skull inverted), the angle of the needle is seen in Fig. 219. Figure 220 is a sagittal section of the skull, and shows the axis of the needle seen from within. Figure 221 is a skiagraph of the needle transfixing the ganglion. In Fig. 222 is seen the angle and point of crossing within the skull of the axes of the needle if continued backward in bilateral puncture.

"The observance of the rule given above for the direction, as well as naturally the bone-feeling on the planum infratemporale, protects us certainly from this error. The pterygoid muscle is perforated near its origin on the pterygoid process and tuber maxillare; often the cannula goes through between the two heads of origin.

"Before we conduct the point of the needle from the fossa infratemporalis into the foramen ovale, we take the precaution of slipping back the sliding catch of the cannula $1\frac{1}{2}$ cm. from the skin-puncture place, in order thus to be aware of the depth of the further advance."

A summary of the essential points in making the Härtel puncture is given by Härtel as follows:

"(*a*) Puncture in the cheek at the height of the alveolar margin of the second upper molar tooth, establishing first on the cheek a wide

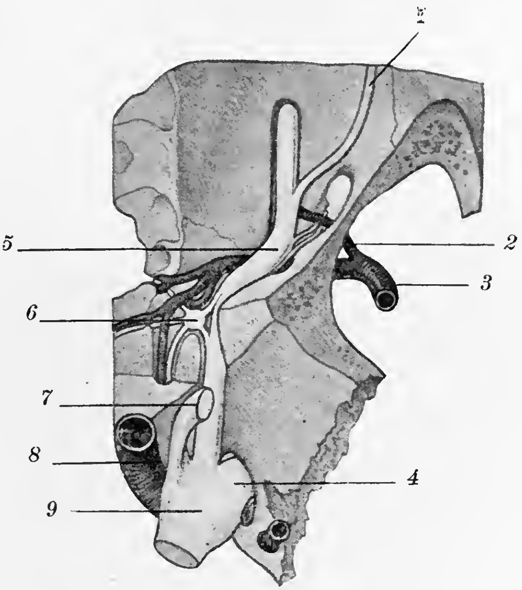

Fig. 218.—Pterygopalatine fossa and contents, showing the S form of the maxillary nerve and the position of the terminal branches of the internal maxillary artery beneath the nerve: 1, Zygomatic nerve; 2, infra-orbital artery; 3, int. maxillary artery; 4, mandibular nerve; 5, maxillary nerve; 6, sphenopalatine ganglion; 7, ophthalmic nerve; 8, int. carotid art.; 9, gasserian ganglion. (After Testut and Jacob.)

area of cutaneous anesthesia, which allows a variation of the puncture point toward the front or back according to the principle of the concentric puncture.

"(*b*) The cannula for puncture must be 0.8 mm. thin, 10 cm. long, and be provided with a flatly ground point. Before the puncture with the puncture-cannula, the anticipated puncture depth to the planum infratemporale (5 to 6 cm.) is marked on the same with the help of an aseptic ruler by the sliding catch used on the cannula.

"(*c*) Introduction of the cannula, accompanied by finger-feeling between the anterior margin of the ascending branch of the lower jaw and the tuber maxillare around the buccinator muscle to the fossa infratemporalis.

Fig. 219.—Shows direction of needle in transfixing gasserian ganglion by Härtel route, viewed from base of skull. (Original illustration from collection of Prof. Matas.)

"(*d*) Determination of the direction—seen from the front the cannula points exactly to the pupil of the eye on the same side; seen from the side, to the tuberculum articulare of the zygomatic arch.

Fig. 220.—Shows axis of needle in transfixing gasserian ganglion by Härtel route, seen from within on sagittal section of skull. (Original illustration from collection of Prof. Matas.)

"(*e*) The puncture of the foramen ovale takes place under continuing feeling with the hard and smooth surface of the planum infratemporale from the anterior exterior long side of the foramen.

"(*f*) After the foramen ovale is reached (relaxing of resistance, radiating pain in the area of distribution of the third branch) the sliding catch is shoved back 1½ cm. from the puncture point of the skin, and the cannula is introduced into the foramen ovale until pain is experienced also in the area of distribution of the second branch.

"(*g*) Attachment of the syringe containing 2 c.c. slow injection of the solution, which must not exceed 1 c.c.

"(*h*) Immediate testing of the anesthesia."

Within the **middle fossa of the skull** (Figs. 207, 208) the following points are of interest: In front is seen the foramen lacerum anterius, and immediately below this the foramen rotundum, with its axis directed downward, forward, and outward into the sphenomaxillary fossa. Posterior and external to the foramen rotundum is seen the foramen ovale.

The foramen spinosum lies slightly external and behind the plane of the foramen ovale and its artery (middle meningeal). As it leaves the foramen it curves outward hugging the bone; this vessel also is out of danger from the needle being advanced too far within the skull.

At the apex of the petrous portion of the temporal bone, where this bone is received into the angular interval, between the basilar process of the occipital and the posterior border of the great wing of the sphenoid, is seen the opening of the internal carotid artery and foramen lacerum medium.

The cavernous sinus courses along the inner margin of the middle fossa, with the internal carotid artery lying along its inner wall, both internal and above the foramen ovale. The position of the vessel at this point and its relation to the sinus and orbital nerves are shown in Fig. 209. Above and behind the foramen ovale is seen the depression for the gasserian ganglion. Above and behind this depression on the superior margin of the petrous portion of the temporal bone is seen the groove for the superior petrosal sinus.

The gasserian ganglion, slightly crescentic in shape, with its convexity forward, lies within the above depression, its upper surface intimately adherent to the dura mater. Beneath it pass its motor root and large superficial petrosal nerve; the large or sensory root runs forward toward the ganglion from its origin in the pons. Through an oval opening in the dura mater (the cavum Meckeli), and guarding this opening posteriorly into the cysterna pontis of the subarachnoid space, is a reticulated membrane—the porus trigeminus.

This communication of the ganglion with subarachnoid space through the cavum Meckeli is of considerable consequence in the deep injections of the ganglion, as spoken of later. The anatomy of these parts, as discussed by Härtel, is as follows:

"Let us now consider the **anatomy of the cavum Meckeli and of the ganglion Gasseri** (Figs. 168, 208, 210). The trunk of the nervus trigeminus rises in the region of the posterior cranial fossa out of the pons, next passes through the wide cavity of the cysterna pontis, which is filled with cerebrospinal fluid, and then enters between the sinus petrosus superior and the superior margin of the petrous portion of the temporal bone through a wide, oval gate of the dura mater (the porus trigemini), into the cavum Meckeli belonging to the middle cranial fossa. It has less the form of a compact nerve-trunk than that of a bundle of nerve-fibers, lying loosely together, which, as is well known, are covered only with the pia mater. In the cavum Meckeli the nerve forms the area triangularis, and radiates into the ganglion semilunare, which extends itself toward the front along the root of the great wing of the sphenoid, and sends off the three trunks of the trigeminus through the fissura orbitalis superior, the foramen rotundum, and ovale.

"The relation of the ganglion to the walls of the cavum Meckeli, which is formed out of a fold of the dura mater, is as follows: With the substratum, the dural membrane, that serves at the same time as the cranial periosteum, the ganglion is but loosely connected by means of loose connective tissue; with the superior dural wall on the contrary it is intimately united. The three trunks of the trigeminus leave the ganglion Gasseri as compact nerve-trunks closely adherent to the dura. Of course, the motor portion of the trigeminus does not participate in the formation of the ganglion. It takes its origin as the portio minor before the sensory portio major; it passes then on the inferior side of the ganglion, and joins itself to the third branch.

"From this situation of the nerves arises the fact that the resistance to a liquid injected with a syringe under pressure is least on the under side of the ganglion and at the place of the entrance of the main trunk of the trigeminus into the cavum Meckeli. Hence, there exists the possibility that the injected fluid may soak through the porous trigemini into the cysterna pontis. On sudden injection of staining solution in the cadaver this may be observed, and outside of the ganglion may be produced a staining of all the arachnoid spaces of the base of the brain. It appears to me that it may very well be possible that the *condition of sleep* observed clinically by us and by *Heymann*, in connection with an injection of a copious quantity of solution into the ganglion Gasseri, is to be attributed to this arachnoid infiltration.

"Of greatest importance for us, further, is the situation of the medial wall of the cavum Meckeli, which forms the dividing wall of the same from the sinus cavernosus. This medial wall is a thin, translucent, dural membrane. The first branch of the trigeminus, immediately after its emergence from the ganglion, turns into this dural membrane with a geniculate bend, and fuses with it so intimately that a macroscopic separation of the sinus wall from the nerve is not possible. If in anatomic books (Fig. 209) the nervus trigeminus I, oculomotorius, and abducens are represented as passing 'in the lateral wall' of the sinus, then this statement must be supplemented thus: that the relation of the two nerves of the muscles of the eye to the lateral wall is a much looser one than that of the first branch of the trigeminus. If one injects with a syringe into the ganglion Gasseri small quantities of solutions that are diffused with difficulty, such as ink or tincture of iodin, then one obtains a beautiful infiltration of the ganglion and of the chief trunk of the trigeminus, while the sinus cavernosus and the cisternæ of the arachnoid membrane remain free; on the other hand, aqueous solution of methylene-blue is diffused into the sinus as well as into the cisternæ. On the relation of the sinus cavernosus to the cavum Meckeli, just described, depends the appearance observed by us at first on too sudden injection of quantities of solution exceeding 1 c.c.; that is, an overlapping of the paralyzing effect of the novocain on the nerves of the muscles of the eye, which manifested itself either in transient dilation of the pupil concerned or in a likewise transient paralysis of the abducens."

The distance between the various points of interest within the skull, as measured by Härtel, are of interest.

From the superior margin of the pyramid of the petrous portion of the temporal bone to the posterior-inferior margin of the foramen ovale he gives a minimum of 14 mm., maximum of 23 mm., with an average of 19 mm. (See Table II, No. 6.)

The minimum of 1.4 cm. is the safe maximum depth to penetrate within the foramen; if a greater depth is reached, there is danger of puncturing the membranes and entering the cisterna pontis. This actually happened to Härtel, with the escape of cerebrospinal fluid; besides, there is danger of wounding the superior petrosal sinus or of injecting the solution beyond into the posterior fossa of the skull.

The shape and size of the foramen ovale vary considerably in different skulls, and even on the two sides of the same skull, to such an extent that a study of a large number of skulls is necessary to draw any positive conclusion. A composite of the whole, giving the average condition and variations from this average, must necessarily be less in a large number of cases than measurements or studies made upon any single skull.

The same may be said about the relative position of the foramen in relation to the surrounding parts; this variation of position, however, is less than that of the size and shape of the foramen.

The *sphenomaxillary* fossa is a small triangular space, situated beneath the apex of the orbit at the angle of junction of the sphenomaxillary and pterygomaxillary fissures. Its posterior wall is formed by the base of the pterygoid process and body of the sphenoid, which slightly overhang it in this position; its inner wall is formed by the vertical plate of the palate bone, which slightly overhangs it on the inner side; in front is the middle portion of the tuber maxillare.

Externally, it opens into the temporal and zygomatic fossa through the pterygomaxillary fissure.

Above the roof is partially deficient, where it communicates with the apex of the orbit beneath the sphenoid fissure.

Five foramina open within this fossa; on the posterior wall is the foramen rotundum; above, below, and internal to this the vidian, and still more inferiorly and internally, the pterygopalatine; on the inner wall is the sphenopalatine foramen, by which the fossa communicates with the nasal cavity. Below is the superior openings of the posterior palatine canal. This fossa contains, besides the superior maxillary nerve and its branches, Meckel's ganglion and the termination of the internal maxillary artery. It will be seen, from a study of the above and the use of a needle on the skull, that the transverse puncture made from below the zygomatic arch may, if the point of the needle is directed too high and advanced too far, enter the apex of the orbit and transfix the structures passing through the sphenoid fissure (Fig. 211), or may, if advanced sufficiently far, enter the orbital foramen; and, if directed more horizontally and advanced too far, may enter the nasal fossa through the sphenopalatine canal.

This last fossa may even be entered from above the zygoma, but from this angle it would be impossible to enter the orbit. For this reason some operators prefer the transverse route above the zygoma instead of below it.

INTERNAL MAXILLARY ARTERY (Fig. 212)

The larger of the two terminal branches of the external carotid is given off at about the level of the lower extermity of the lobule of the ear, at its origin embedded within the substance of the parotid gland. It first runs inward, at right angles to its point of origin, to the inner side of the neck of the condyle of the lower jaw, in this its maxillary portion lying between the ramus of the jaw and the internal lateral ligament. As it passes opposite the sigmoid notch it lies usually a little above its lower border, but usually about 1 cm. below the inferior border of the zygoma. In some few cases the artery may lie below the tendon of the external pterygoid, and, in crossing inward from this position, may be in danger of being wounded (Figs. 213, 214) when approaching the foramen ovale from below and in front, as in the Härtel route, or slightly more below the level of the lower border of the zygomatic process. Consequently, a needle entered at the lower border of the zygoma should be well above it, but if passed through the lower part of the sigmoid notch may come in contact with it.

As the artery passes forward and inward it lies parallel to the auriculotemporal nerve, above and in front of the inferior dental and along the lower border of the external pterygoid muscle. It then runs obliquely forward and upward, over the surface of this muscle (pterygoid portion). In its third or sphenomaxillary portion the artery runs transversely in a tortuous manner, and, while somewhat variable in its course, always lies below the superior maxillary nerve in the sphenomaxillary fossa, where it lies in close relation to Meckel's ganglion.

The only branch of this vessel of particular interest to us is the middle meningeal, which is given off opposite the sigmoid notch, and ascends almost vertically to the foramen spinosum in its course. It usually lies behind the transverse tract of the needle in a lateral puncture, but may occasionally lie more anteriorly. A small branch, the small meningeal, passes up through the foramen ovale, but this, with the internal maxillary vein, lies below and in front of the artery.

Other branches are either of small size or are situated outside of the course of the needle, and are of no particular concern to us here.

The best protection against the injury of a vessel here, as well as elsewhere, in making deep punctures is in the proper selection of the needle or cannula, combined with its skilful and careful use.

By the use of a small-calibered needle with flat point, and not a course needle with sharp, long point with cutting edges, the likelihood of a serious injury to a vessel is practically negligible, and amounts at most in cases in which it does occur to a small hematoma or slight ecchymosis at the point of puncture, which is probably from injury of a vein, the arteries having tougher walls and being more easily displaced.

On the lateral aspect of the skull in the transverse methods of approach to the foramen rotundum and sphenomaxillary fossa two routes are available: one above, the other below, the zygoma. The upper route rarely reaches the foramen rotundum, but enters the sphenomaxillary fossa just below the foramen. The best method of utilizing this route is to enter the needle high up on the cheek in the notch formed by the union of the zygomatic and frontal processes of the malar bone. From this point the needle is advanced transversely inward, when it impinges against the great wing of the sphenoid just above the pterygoid ridge. The point of the needle is now successively lowered until it slips beneath this ridge and enters the fossa. It is now advanced about 1 cm. further, and the injection made at a depth of about $4\frac{1}{2}$ to 5 cm. from the surface.

In entering this fossa, if the point of the needle is advanced too far forward it strikes upon the rough upper projection of the tuber maxillare, along which it must feel its way backward; if advanced too far backward it meets the external pterygoid plate near its base, and must be successively advanced forward until it slips over the sharp laterally projecting edge of this bone into the fossa beyond (Fig. 215).

If advanced too far within the fossa, it is possible to pass beyond and enter the nasal cavity through the sphenopalatine foramen, which lies about on a level with this line of puncture.

In entering the fossa from below the zygoma (Fig. 216) there are certain dangers to be avoided. The point of puncture lies below the notch on the malar (formed by the zygomatic and frontal processes) and about on a lateral plane with the posterior surface of the tuber maxillare. From this point the needle is advanced inward with an upward inclination, passing between the tuber maxillare in front and the pterygoid process behind, through the pterygomaxillary fissure into the fossa just beyond, to a depth not to exceed $4\frac{1}{2}$ to 5 cm.; the upward inclination of the needle is such that at this depth the point should be about $1\frac{1}{2}$ to 2 cm. above the point of puncture.

If the needle is advanced too far inward, and particularly if the point of entrance be slightly below the edge of the zygoma and the angle of the needle be too high, it is possible to pass beyond the sphenmaxillary fossa and transfix the structures, passing through the superior orbital fissure or even enter the orbital foramen.

As the axis of the foramen rotundum is at an angle with this and other transverse methods of puncture, it is only possible in about one-third of the cases to enter this opening; however, the fossa just in front of the forearm is readily reached and the nerve often transfixed at this point, or the solution deposited in direct contact with it.

A method erroneously attributed to Matas, while used at about the same time by him, is probably to be credited to Schlösser. This method has its puncture point slightly below and behind the malar prominence. From this point the needle, directed backward, upward, and inward, feels its way along the posterior surface of the tuber maxillare until it slips beyond its posterior projection through the pterygomaxillary fissure into the sphenomaxillary fossa at a depth of about 4½ to 5 cm. from the surface.

In discussing this fossa, the anatomic variations in its bony surroundings, and the methods of puncture Härtel states the following.

(In this discussion of the various methods of approach the Matas route is referred to as a transverse route beneath the zygoma. This route, while used by Prof. Matas probably independently and about the same time (1898) should, I believe, be credited to Schlösser. The original Matas route is the orbital puncture through the sphenomaxillary fissure.)

"Let us consider next the lateral entrance (Fig. 215). This has a sickle shape, which in its superior end continues into the inferior orbital fissure. The posterior margin of this sickle consists of a bone corner which is formed by the anterior boundary of the lamina externa of the pterygoid process, and above tapers into a ridge which separates the planum infratemporale from the planum orbitale of the great wing of the sphenoid bone, and is furnished with a process called tuberculum spinosum (Fig. 215, *a*, *x*). The anterior concave margin of the sickle is formed by the opposite surface of the tuber maxillare.

"According to the greater or less pneumatization of the antrum of Highmore, the tuber maxillare juts out behind more or less, so that the sickle form may vary from a small fissure ('type en cornue,' Fig. 215, *c–e*) to a half-circle ('type ovalaire,' *Chipault*, Fig. 215, *a–b*). The transverse diameter is correspondingly variable. It amounts (Table II, No. 9) in the minimum to 3 mm.; in the maximum, to 11 mm., and on the average, to 5.4 mm. A 'narrow fossa' with a width under 5 mm. we find in about 40 per cent. of the cases.

"Besides, there are the varieties of the posterior margin, which are dependent on the development of the masseters. The under part of the same, which belongs to the pterygoid process and almost always presents a very characteristic corner, which we wish to call Grenzleiste (marginal ridge), projects in special cases sharply and like a knife opposite the entrance of the fossa, and may bear a prong, which is called spina pterygoidea (Fig. 215, *d*, *e*, *y*). Just so, the superior part belonging to the great wing of the sphenoid bone may be either smooth or form an elevation, soon becoming pyramidal in shape or ridge-like, or running out into a point, the tuberculum spinosum already mentioned. Between these two spines a ligament may develop similar to the ligamentum pterygospinosum (Poirier), which has been described. The different types of the entrance of the fossa pterygopalatina are placed together in Fig. 215 and in Table II, No. 10. The relations of the entrance to the fossa are of importance for the ways of access of Matas (1) and Offerhaus (3). As far as the latter way is concerned, it is, in general, not practicable if the point of puncture above the zygomatic arch is chosen, for, according to Table II, No. 11, the needle introduced in this way only in a small portion of the cases (12 per cent.) reaches the superior part of the fossa which receives the nervus maxillaris; but also for the Matas-Braun way unfavorable varieties of the entrance present great difficulties.

"If we now consider the interior of the fossa, this is also subject to great changes. Of most importance to us is the posterior wall with the surroundings of the foramen rotundum, for a puncture of the nervus maxillaris can be successful in the whole region only if it reaches it shortly after its exit from the foramen rotundum, before it has given off its branches. This posterior wall can be likewise strongly changed only through the pneumatization of the bones forming it. Sometimes one finds the entire fossa walled up transversely or lengthwise with pneumatized walls, which belong to the sphenoid bone or else to the palatine bone.

"If we now next test the bony skull as to the possibility of puncturing the foramen rotundum directly by the Matas way (should be Schlösser—Author), then it is shown that only in 33 per cent. of the cases (Table II, No. 12) does the possibility exist of penetrating with the point of the cannula more or less deeply into the foramen, a possibility which by the orbital way (original Matas route—Author) —incidentally noted—is much greater (89 per cent.). Consequently, with the lateral puncture we cannot practically reckon on a direct injection of the foramen rotundum, but must content ourselves with washing the nervus maxillaris in the fossa.

"If we now seek fixed points for a successful puncture of the fossa sphenomaxillary, then here also the method of concentric puncture is of importance: for, on the one hand, we must shift the puncture point as much as possible to the front, in order to carry the needle to the posterior wall of the fossa; on the other hand, it may happen that, with a puncture point shifted too far to the front, the tuber maxillare obstructs the approach. Most frequently the puncture point by which it is possible to reach the exit of the foramen rotundum lies under the sutura zygomatico-malar, which is marked by a prominence, and in the living subject is usually palpable or somewhat behind this same suture. (See Table II, No. 13.)

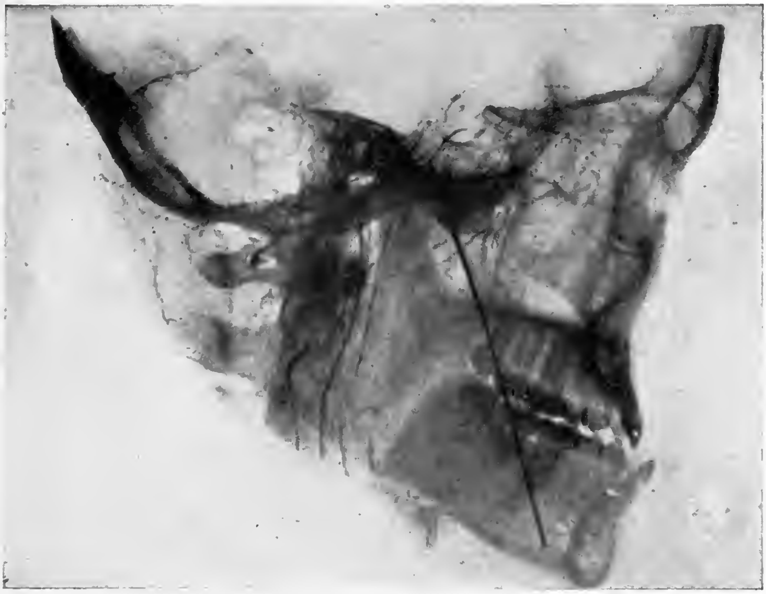

Fig. 221.—Skiagraph of needle transfixing gasserian ganglion by Härtel route; shows axis of needle in relation to teeth and bony parts of face and skull. Injected vessels are also seen. (Original illustration from collection of Prof. Matas.)

"Gliding backward on the tuber maxillare we come to the entrance of the fossa, and guide ourselves now to the opposite posterior wall, while we seek to come into the turning-corner of ridges bordering this wall, since with a higher puncture (Fig. 211) we are in danger of coming into the orbit, with a deeper one into the nasal cavity. Further, we must reflect that after passing the entrance we dare not go too deep—1 cm. at the most, which we can control by our sliding catch. The total depth amounts to 45 to 57 mm., on the average 50 mm. (See Table II, No. 14.)

"Favorable for the injection into the fossa is the circumstance that it is filled with loose masses of fat, which permit a good diffusion of the injected solution into the vicinity. The nervus maxillaris (Fig. 218) itself lies in the uppermost part of the fossa sphenomaxillary, and is fixed to its roof by connective tissue. In its course it takes an S-form, which in a sagittal direction comes out of the foramen rotundum; it bends laterally, in order to arrive at the sulcus infra-orbitalis of the upper jaw, when it takes the sagittal direction again. The orbital puncture follows the direction of this nerve-trunk itself, which in its manner presents a similar axial puncture."

Braun Method.—This is an effective and simple means of reaching the trunk of the third division at its exit from the skull, and fairly

Fig. 222.—Angle and point of crossing within the skull of the axes of the needle in the Härtel route, if continued backward in a bilateral puncture. (Original illustration from collection of Prof. Matas.)

as accurate as the Offerhaus, Härtel, or any other route for reaching the trunk of the nerve and much easier executed.

The needle is entered at about the midpoint of the zygoma on its undersurface, and directed transversely inward until it strikes upon the external plate of the pterygoid process near its base (Fig. 223). It will be seen, from a reference to the position of these parts, that the foramen ovale lies directly back of the base of this plate and on the same anteroposterior plane, consequently the depth to the external plate at its base is the depth to the foramen ovale, but on a slightly posterior plane, about 1 cm. Having now determined the depth from the surface necessary to penetrate, this is marked on the needle, which is partially withdrawn, and the point redirected slightly backward, in which direction it is advanced to the determined depth. When the nerve is reached this is recognized by the usual paresthesia along its branches.

The *method of Offerhaus* is a decidedly ingenious and valuable acquisition. To him is due the credit of attempting the first time to locate the relative positions of the foramina ovale and rotundum by anatomic measurements made on the base of the skull. This method aims

Fig. 223.—Lateral routes of injection for foramen ovale: 1, Offerhaus; 2, Braun. (Braun.)

to make the injections immediately beneath the foramina, reaching the nerves just as they leave the openings, at their approximately determined depth from the surface. This method, when applied with some judgment, making allowances for anatomic variations in individual cases by slightly manipulating the point of needle until it comes in contact with the nerve, which is recognized by the characteristic paresthesia along its branches, will be found to be a highly useful and valuable procedure.

In a study of 50 skulls Offerhaus found that the distance between the foramen ovale is approximately the distance from the two outer surfaces of the alveolar processes, opposite or just behind the last molar tooth, at the point where the processus pyramidalis ossis palatini joins the maxillary bones; this, then, is the distantia interalveolaris externa (D A. E.), and equals the distantia foramina ovale (D. F. O.) (Fig. 224).

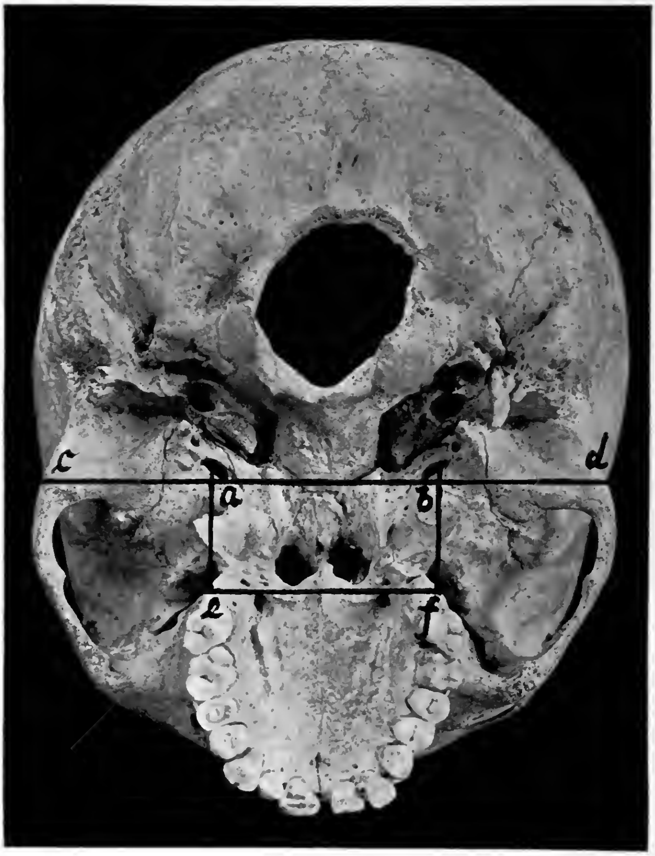

Fig. 224.—Offerhaus method for measuring base of skull to determine distance of foramen ovale from articular tubercle. (Braun.)

The distance between the foramina rotundum is the same as the distance between the alveolar processes of the maxilla on the inner side, behind or along the side of the last molar.

Distantia interalveolaris interna (D. A. I.).

The axis in which lie the foramina rotundum reaches the surface at the upper border of the zygomas at the point where the temporal portion merges with the molar; this is about the midpoint of the zygomatic arch, the linea interzygomatica.

The foramina rotunda lie about 2 to 4 mm. just above and behind this line. The axis in which lie the foramina ovale passes over the eminentia articularis and through the articular tubercles; occasionally the foramen lies 2 or 3 mm. back of this line, but as the axis of the nerve is downward and forward it usually passes through this axis. While the relative position and distances between these parts may vary slightly in different skulls, as well as on the two sides of the same skull, these measurements may be relied on as approximately correct, varying only within a few millimeters.

Fig. 225.—Method of using Offerhaus calipers. (Braun.)

In the clinical application of this method the distantia interalveolaris externa is measured with an ordinary pair of calipers or a compass; this is usually found to be about 5 cm., and equals (D. F. O.) distantia foramina ovalis; the distantia intertubercularis is next determined by specially constructed calipers (Fig. 225), though any instrument adapted to this purpose will do. On the Offerhaus calipers there is a movable part, which is attached to the point and projects outward to indicate the direct angle of puncture. These are usually placed on after the distance has been determined, which is shown by a scale to which the arms of the caliper are attached and along which they move. As the articular tubercles are usually easily felt, just in front of the temporomaxillary articulation at the root of the zygoma. this measurement is very simply made. In fleshy individuals a small allowance, about 1 cm., may have to be allowed for soft parts.

This distance is usually about 14 cm. We then subtract from this the distance between the foramina ovale, 5 cm., previously determined by measurement, between the alveolar processes, and divide by two. $\frac{14-5}{2}$ = 4.5 cm., the distance along the linea intertubercularis which the needle must travel to reach the nerve-trunk.

Occasionally, the ossification of the ligament pterygospinosum presents a bony barrier to the passage of the needle along the linea intertubercularis. When this exists there is usually an opening through this plate near the base of the skull, just to the side of the foramen ovale; this is best found by feeling with the needle along the smooth surface of the planum infratemporalis toward the foramen, and the opening through the obstructing plate is usually entered without much difficulty.

For injecting the second division the linea interzygomatic is determined by measuring with the large calipers the distance between the midpoints on the two zygomatic arches; from this is subtracted the distance between the inner surfaces of the alveolar processes at the last molar tooth, and this figure divided by two in the same way as for the preceding method.

This then gives us the depth to which the needle must travel to reach the second division of the fifth. Offerhaus advises that the needle be entered above the zygomatic arch for reaching the trunk of this nerve, but where it is desired to make the injection at the foramen rotundum the needle is entered below the zygoma, directed slightly upward. A very large coronoid process may check the passage of the needle here, in which case, if the mouth is opened wide, this descends out of the way.

The same difficulties may be encountered here in passing the needle within the sphenomaxillary fossa, as already mentioned in discussing those regions, and the same rule should be applied here to overcome these difficulties. Occasionally, this method may have to be abandoned in cases where the sphenomaxillary fissure is reduced to a mere slip, too narrow for the passage of the needle by the too close approach of the tuber maxillare to the pterygoid process. In this case the Matas route should then be tried.

Offerhaus recommended that 2 c.c. of from 0.50 to 0.75 per cent. cocain and adrenalin be used in making either injection. It would, however, seem best, in the writer's opinion, to use stronger solutions of novocain and adrenalin (2 c.c. of a 2 per cent. solution), as is suggested by most operators making these injections.

Offerhaus states that complete analgesia usually occurs in about fifteen minutes and lasts about one hour. This time could probably be lengthened by the use of stronger solutions, as suggested.

The utilization of these methods of measurement, as taught us by Offerhaus, may be applied to any other route of puncture applied

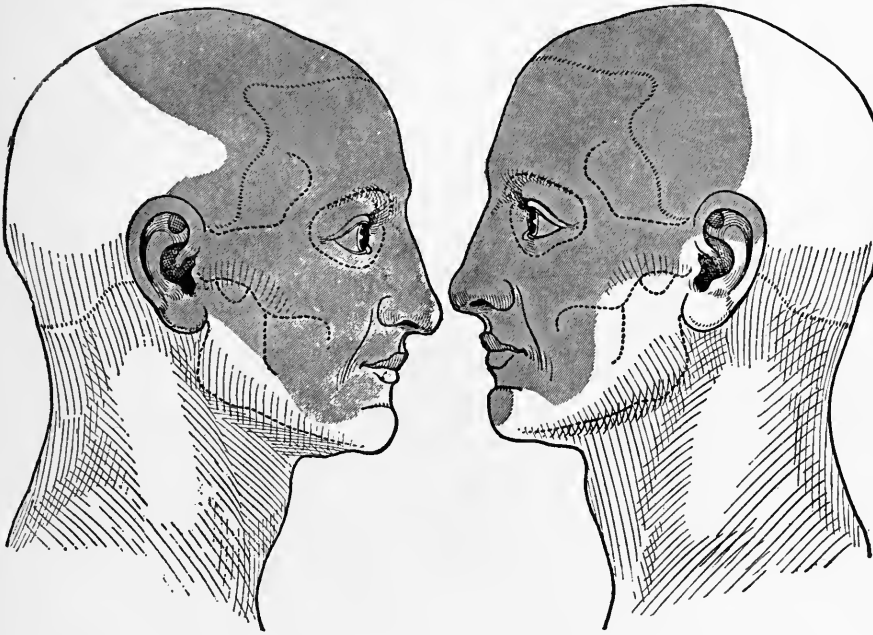

Fig. 226.—Novocain anesthesia of the right gasserian ganglion, tested immediately after injection. (Hartel.)

Fig. 227.—Anesthesia following alcohol injection in the left ganglion, tested immediately following injection. (Härtel.)

to the same region, and should serve as a valuable guide in determining the depth of penetration.

Härtel has done considerable work in clearing up certain inaccuracies and uncertainties which existed regarding the areas of distribution of the different branches of the fifth nerve. He shows these areas as taught in most of our text-books, and in Figs. 226–230 shows a number of anesthetized surfaces outlined immediately after unilateral ganglion injections. The tests were made with needles on patients sufficiently intelligent to make comparatively accurate observations; certain inaccuracies are, however, bound to occur, as marginal areas show diminished sensibility and adjacent surfaces are overlapped by the opposite nerve in a zigzag manner.

In the median line of the face the limits between the two sides were rather sharply defined, as variations were not so numerous as had previously been supposed; still this overlapping may take place sufficiently in spots to make it always advisable to anesthetize both sides in operations approaching the median line.

On the skull, in the midline, the area of anesthesia extended well up toward the vertex capitis, but laterally in the region of the auricle

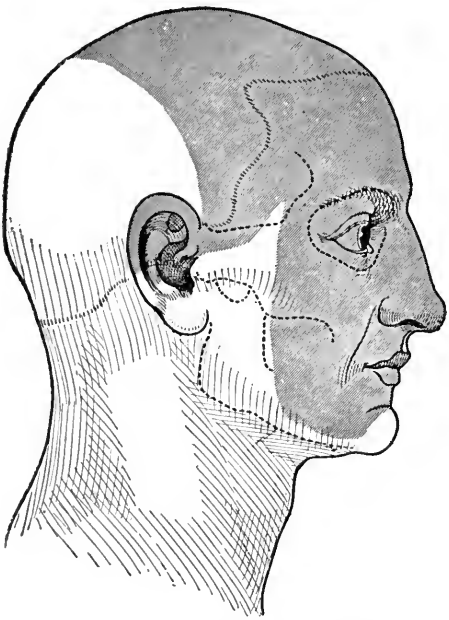

Fig. 228.—Novocain anesthesia of right gasserian ganglion, tested immediately after the injection. (Härtel.)

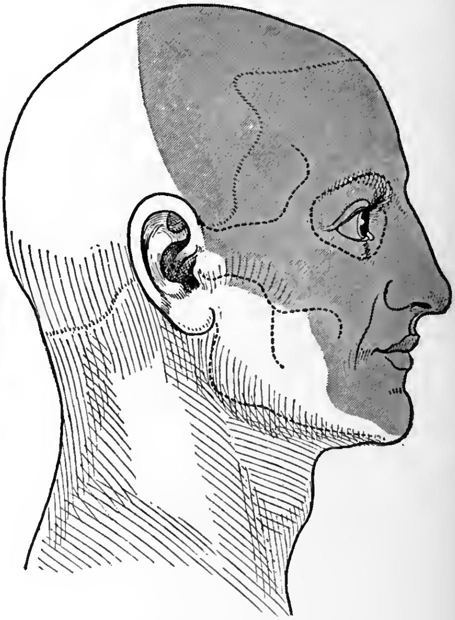

Fig. 229.—Novocain anesthesia of right gasserian ganglion, tested immediately after the injection. (Härtel.)

some variations were met with. He calls attention to this extended area of anesthesia as offering favorable opportunities by this method for trephining, etc., upon the sinciput.

"In the face the area of distribution of the cervical nerves (nervus auricularis magnus, cutaneous colli) projects from below laterally more or less extensively into the trigeminus region, so that we never can reckon on pure trigeminus anesthesia in the region of the auricle, lateral temples, cheeks on the sides, the parotid gland, at the angle of the jaw and chin, and hence must always prefer infiltration to ganglion injection.

"Relative to the innervation of the face, observations which we have made after alcohol injection as to the capacity for regeneration of the sensibility are of interest. Figure 230 shows the area of diffusion of the analgesia twelve days after the alcohol injection into the ganglion Gasseri; Fig. 231, the same twenty-five days after. We see clearly how, especially in the frontal regions of the margins, collateral tracts of sensibility are developed. In the same category the observation belongs that after ganglion injection the anesthesia died out earliest in those regions whose nerves were treated earlier with

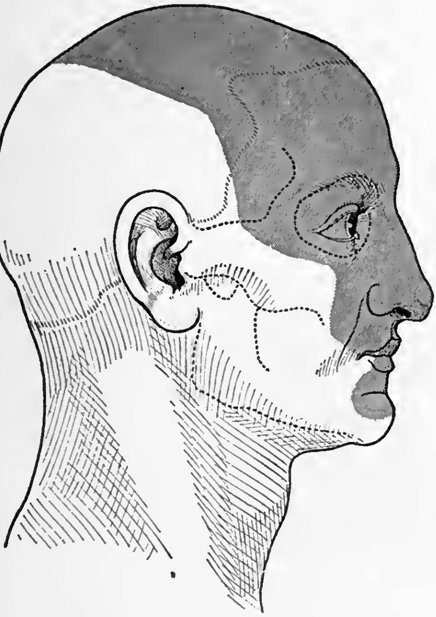

Fig. 230.—Anesthesia twelve days after alcohol injection of right gasserian ganglion. (Härtel.)

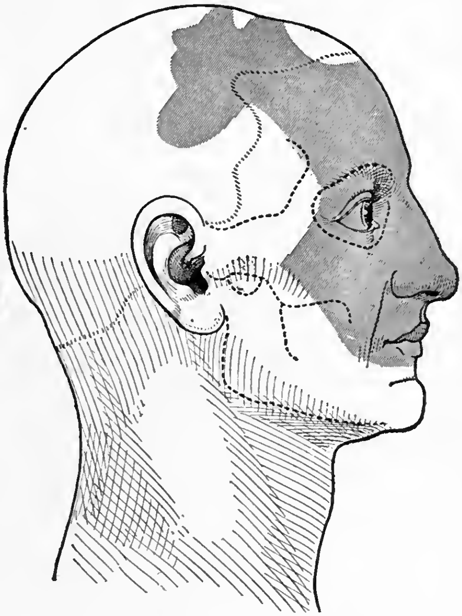

Fig. 231.—Same as Fig. 230, twenty-five days after injection. (Härtel.)

peripheral alcohol injection. If we compare our areas of anesthesia with the anesthesias found by Krause, after the extirpation of the ganglion Gasseri, then we find that ours are more extended and approach more closely to the statements of the anatomists. This is attributable to the fact that our tests were undertaken immediately after the injection, while Krause, for independent reasons, first undertook the tests of sensibility eighteen days after the operation.

"2. *Deep Sensibility*.—By ganglion injection the collective bones and soft parts of the face become anesthetic, as far as they belong to the area of distribution of the trigeminus. If the operation approaches the median line, bilateral anesthesia is to be preferred. Resections of the upper jaw, operations on the bones of the nose and orbit, are thoroughly feasible under this anesthesia.

"The mucous membranes of the eye and nose are certainly without feeling, as well as the conjunctiva and cornea. The corneal reflex dies out, also the sneezing reflexes of the nasal mucous membranes, but on the contrary the vomiting reflex of the pharynx does not. The accessory cavities of the nose are likewise anesthetic. Radical operations of empyemas of the antrum of Highmore are feasible with unilateral ganglion anesthesia. For the ethmoid cavity double anesthesia is always to be recommended (Fig. 193). Observations concerning the sphenoid sinus and the hypophysis are not available.

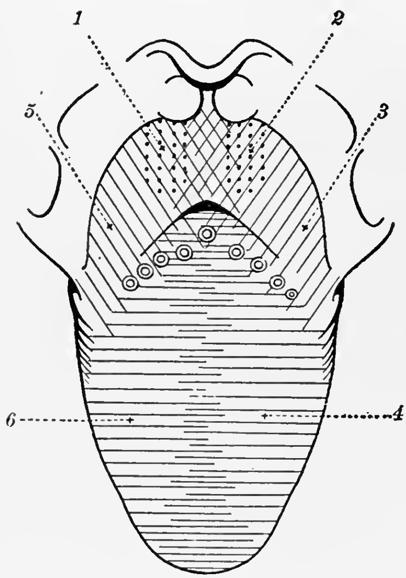

Fig. 232.—Sensory innervation of the tongue: 1 and 2, Vagus nerve (dotted); 3 and 5, glossopharyngeus (oblique lines); 4 and 6, lingual nerve (horizontal lines). (After Zander and Spalteholz.)

"In the oral cavity complete anesthesia of the teeth, the jaws, and the hard palate are to be reckoned on, but the soft palate is not always entirely without feeling. Likewise the anesthesia of the *tongue*, at least in the posterior part, is very uncertain after double ganglion injection. If we observe the diagram of the sensibility of the tongue (Fig. 232), then we see that only the anterior part belongs to the trigeminus, the lateral parts to the glosspharyngeus, the base to the vagus. According to our experiments, the trigeminus region of the tongue is to be restricted still more. Perhaps sensory fibers are received through the chorda tympani, which communicate with the facialis, thence to the trigeminus, and are conveyed to the glossopharyngeus. Therefore, for tongue operations conduction anesthesia in the lingula appears to us to be more certain than at the base of the skull or in the foramen ovale. Accordingly, for the operation for carcinoma of the tongue, as we shall see later, ganglion anesthesia has little significance; here with our earlier procedure we obtained the same, if not better, results.

"In the case of large operations in the nasopharynx, on the contrary, I might not dispense with ganglion anesthesia on account of the division of the second branch (compare Table I), yet here also, as in all marginal areas, it is to be combined with copious infiltration.

"The *area of the application* of the conduction anesthesia of the ganglion Gasseri is, therefore, as follows:

"(1) Operations on the anterior skull, the orbit, the malar bone, the upper jaw, the nasal cavity, the oral cavity, and the pharynx, sometimes combined with adrenalin infiltration for the purpose of the production of bloodlessness and with novocain infiltration of the uncertain marginal regions (region of the skin of the cervical nerves, region of the glossopharyngeus), as well as the cocainizing of the mucous membrane not in the area of distribution of the trigeminus.

"(2) Plastic operations on the face.

"(3) Operations on the branches of the trigeminus and on the ganglion Gasseri. The so far favorable results of alcohol injection, in cases of trigeminus neuralgia, make it altogether probable that the operations on the trunks may be discontinued in the future, that the extirpation of the ganglion Gasseri may still be necessary only in very rare instances.

"The *duration of the novocain anesthesia* of the ganglion Gasseri amounts on the average to one and one-half hours; this is true for the Braun tablets dissolved in cold normal salt solution. Attempts to boil up the solution once more with the addition of hydrochloric acid resulted in a very transient anesthesia of short duration."

In discussing the clinical application of his method, Härtel states the following:

CONDUCTION ANESTHESIA AND INJECTION TREATMENT OF THE GANGLION GASSERI

"The technic of the puncture of the ganglion Gasseri has been exactly described in the first part of the work. The instrumentarium consists of: (*a*) a nickel-plated steel cannula, 10 cm. long, 0.8 mm. thick, furnished with a flatly ground point and a sliding catch; (*b*) a fine needle for the skin-anesthesia; (*c*) a Record syringe, and (*d*) a metal ruler by means of which the desired depth is fixed on the needle with the sliding catch (Windler, Berlin) (Fig. 233).

"For the performing of the puncture the patient is laid down on the operating-table, with the upper part of the trunk raised somewhat and the head lifted up by a pillow. After disinfection of the cheek with alcohol or tincture of iodin, the skin-anesthesia is produced, then with the long needle, on which the anticipated depth of the planum infratemporalis (5 to 6 cm.) is marked by the sliding catch, the puncture is performed with the observance of all the rules given. (See the Summary.) The index-finger of the left hand is put into the mouth, in order, in the vestibulum oris, to guide the point of the needle submucously between the ascending branch of the lower jaw and the tuber maxillare. At this time the mouth of the patient is closed. We refer once more to the importance of the rules for direction given above (Fig. 205). If they are not regarded, and, for example, the point of the needle seen from in front points too far toward the median line, then, instead of getting into the foramen ovale, we get into the tube and the solution runs into the pharynx.

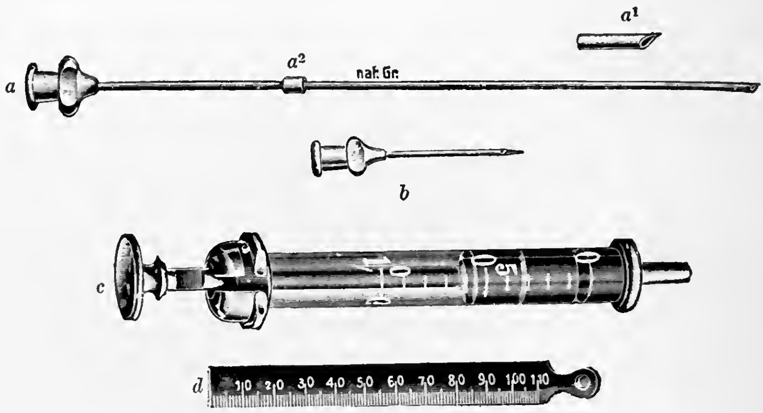

Fig. 233.—Instrumentarium for injection of gasserian ganglion (Windler, Berlin): *a*, Needle, 10 cm. long, 0.8 mm. thick. Nickeled steel with short sharp point a^1 and movable gauge a^2; *b*, fine needle for skin anesthesia; *c*, 2 c.c. record syringe; *d*, metal centimeter measure (reduced). (Härtel.)

"The ease or difficulty of performing the puncture is entirely dependent on the anatomic relationships of the foramen ovale concerned. If difficulties appear, then they always recur in the same patient, while the puncture once performed smoothly always succeeds a second time. As the foramina ovalia are usually different on the two sides, even in the same individual, it may happen that the puncture is difficult on one side and easy on the other.

"If one makes a good anesthesia of the skin, then the penetration of the soft parts of the cheek and of the zygomatic fossa is completely painless. Even the striking of the needle against the planum infratemporale causes no pain. On the contrary, the soft parts, situated medially from the foramen ovale in the vicinity of the tube and of the pharynx, are extremely sensitive. With inexact localization of the pain on the part of the patient, this sensitiveness may simulate for us the reaching of the nerve and lead to false passages. The touching of the third branch, for the most part, incites distinctive sensations in the area of distribution of this nerve (lower teeth, tongue, also the region of the ear; compare Table I), which are stated partly only as paresthesia, partly as distinct pains. If this pain produces annoyance, then a novocain injection already undertaken may greatly relieve its further advance. After introduction of the needle into the foramen ovale, feeling is experienced in the area of distribution of the second branch (upper teeth, upper lip, palate, etc.). But there are many patients who are not in condition to give any definite localization of the pain, so that one is guided only by the anatomic landmarks by contact with the bone and the determination of direction.

"The needle is shoved forward to a depth of 1½ cm. into the foramen ovale. No further bone resistance should occur, otherwise we are not in the correct axis, and must repeat the puncture in somewhat altered direction. If we should get emission of fluid, then we must draw the needle back a little. The *injection* takes place quite gradually drop by drop. The pressure to be used with it is reasonably strong. On stronger resistance one should guard himself against forcing the solution forward in an explosive manner, but should move the needle forward or back somewhat and then try to inject.

"Immediately after the injection of the first decigramme of the solution the puncture pain subsides. The injection of alcohol is felt as a burning and glowing in the entire half of the head. We found the injection of alcohol was almost painless if one or several days previously a novocain injection had been made, and we, therefore, recommend in all cases of injection treatment of neuralgia of the trigeminus the antecedent undertaking of the less painful novocain injection.

"The dose amounts to ½ to 1½ c.c. of a 2 per cent. novocain-suprarenin solution (Braun's Höchster tablets) for the local anesthesia, ½ c.c. of 80 per cent. alcohol for the treatment of neuralgia. For anesthesia in every case one injects, to begin with, ½ c.c. of a 2 per cent. novocain solution in order to test the anesthetic efficacy of the solution. For small operations this dose is sufficient; for greater interferences of longer duration the higher dose is necessary.

"We judge the success of the puncture from the anesthesia that takes place, which, as a rule, is present momentarily after the injection. Only in a few cases does it appear later (up to five minutes). If then no anesthesia has resulted, the puncture is to be pronounced a failure and to be repeated.

"Up to the present time the conduction anesthesia of the ganglion Gasseri has been used in 16 operations. In 9 cases the ganglia of both sides were anesthetized. The operations performed were the following: resection of the upper jaw, 6; extirpation of the tongue, 2; orbital tumor, 1; extraction of foreign body in the orbit, 1; sarcoma of the nasopharynx, 2; plastic operation on the masseter, 1; minor jaw operations, 3. Further, for the purpose of the treatment of neuralgia, 27 injections of novocain or alcohol into the ganglion Gasseri were undertaken on 14 patients. If we reckon singly those cases in which the foramen ovale of the same side was punctured several times (repetition of injections for neuralgias), then there were 39 cases of puncture of the ganglion Gasseri; among these the puncture succeeded *easily* after one or two attempts in 28 cases; *with difficulty*, so that the puncture succeeded only after several efforts, in 7 cases. In 4 cases, after several injections, no certain anesthesia appeared in the trigeminus region of the side concerned, so that here it remains questionable whether the ganglion Gasseri had been reached. These last 4 cases are those of 3 patients with neuralgia of the trigeminus and 1 patient with carcinoma of the tongue, in whom, on injection of both sides, the left side did not become completely anesthetized.

"Anesthesia occasioned by the injection of novocain or alcohol into the ganglion Gasseri is extended to the entire area of distribution of the trigeminus. As this area is still by no means to be looked upon as completely known, and besides is subject to variability, the ganglion injections are fitted to make important contributions to the study of the *sensibility of the trigeminus*. Until now the extent of the sensibility of this region was determined, either through anatomic preparations of the finest nerve-endings (Zander, Frohse) or by examinations on patients, from whom the ganglion Gasseri was removed by operation (F. Krause). By ganglion anesthesia these methods should be supplemented valuably and conveniently. A complete elaboration of this subject is undertaken in conjunction with a neurologist, Doctor Simons (Oppenheim clinic).

SUMMARY

"(1) The method of intracranial conduction anesthesia of the ganglion Gasseri insures the possibility of making the entire half of the head innervated by the trigeminus completely anesthetic by means of the injection at one point of small quantities of novocain-suprarenin solution, and likewise, by means of bilateral injection, the united areas of each trigeminus. The anesthesia takes place at once and continues on an average one and one-half hours. In a majority of chiefly very extended operations on the facial portion of the skull the method was used with the best results, partly alone, partly in conjunction with infiltration of the marginal areas.

"(2) Uncomfortable collateral effects of the injection (sleeping condition, vomiting, pains in the head, etc.) appeared only in isolated cases, in consequence of the use of a large dose and of careless injection technic, and are avoidable by correct dosage and exact observance of the technical rules set forth by the author.

"(3) By the possibility of the direct puncture of the ganglion Gasseri the injection-treatment of trigeminus neuralgia receives a supplement of value, which in severe cases permits the avoidance of the operation for the extirpation of the ganglion. According to experiences up to this time, novocain injection into the ganglion gives good results. The injection of alcohol into the ganglion is physiologically similar in its action to extirpation of the ganglion, so far as can now be determined. As, however, the danger of the formation of neuroparalytic corneal ulcers is not to be avoided with certainty, the alcohol injection of the ganglion Gasseri, like the Krause operation, is to be reserved for the most severe and desperate cases only; for the other cases the method to be chosen remains the injection into the nerve-trunks, which is to be made as far as possible an endoneural one, according to the exact anatomic and technical directions given by the author.

"(4) In a number of cases the author has succeeded in puncturing the foramen rotundum directly from a puncture point situated on the inferior orbital margin, and in obtaining an immediate complete anesthesia in the region of the second branch of the trigeminus by injecting a small quantity of novocain-suprarenin solution. He has tested this anesthesia in a series of operations, and recommends this puncture especially for those cases in which for anatomic or pathologic reasons the other ways to the second branch are inaccessible.

"(5) Concerning the methods of the conduction anesthesia of the branches of the trigeminus practiced until now chiefly by Braun and Offerhaus, anatomic studies and clinical experiences are reported. The good applicability and extraordinary practical significance of these conduction anesthesias are demonstrated in the majority of the operative reports of the 'Klinik.'"

Regarding the after-effects of an injection of the gasserian ganglion, Härtel has already accumulated sufficient clinical material from which to make reliable observations.

In 5 cases there was dilatation of the pupil which lasted for about one-quarter of an hour, and once after an alcohol injection there was a transient contraction of the pupil. Twice after the injection of novocain there was a paralysis of the abducens, which disappeared in a short time. This, as Härtel states, is no doubt the result of a diffusion of the solution into the lateral wall of the sinus cavernosa and reaching these nerves in this position. (See Figs. 208, 209.)

Following these experiences smaller caliber syringes were used, which permitted slower injections; since this change these disturbances had not been reported. Occasionally a transitory paralysis of

Fig. 234.—Result of removal of one-half of inferior maxilla under regional anesthesia for malignancy. (Case of Prof. Matas.)

the masseters occurred, which, however, was not annoying and, on double injections, a dropping of the jaw occurred, but there was no masseter disturbances following alcohol injections.

In his early experience certain disturbances of a general nature occurred, but, upon the change of technic and slower injection of a quantity not to exceed $1\frac{1}{2}$ cm., these disturbances did not recur.

Härtel insists that all injections of alcohol or novocain must be slowly made, with the patient recumbent; if alcohol, this position is maintained for at least one hour afterward, and if for any reason the head is elevated it must be raised by assistance and not by the patient. An explanation of disturbances, which occurred in patients who set up, is probably to be found in the fact that the solution may be sucked out of the cavum Meckeli, through the porus trigemini, into the subarachnoid space of the posterior cranial fossa, and there came in contact with the vagus producing vomiting, etc.

In 3 cases following novocain injections herpes appeared at the corner of the mouth; this, however, was without other disturbance, and disappeared after a few days. In 1 case of alcohol injection in a woman who had previously suffered from diabetes, but was free from sugar at the time, the herpes was of greater extent and reached to the cheek and eyelids; in this case there was also desiccation of the anesthetic cornea. From this experience, Härtel concludes that pre-

Fig. 235.—Front and side view, showing result of removal of one-half of inferior maxilla for malignancy. (Case of Prof. Matas.)

caution should be exercised in injecting diabetic patients, and that after alcohol injections the same precautions should be taken for protection of the cornea as after extirpation of the ganglion; this is also a strong point in proving that alcohol injections have a decided destructive influence upon the ganglion and simulate very closely the same results obtained following its removal. In 5 cases following novocain injections there was pain in the head for several days following, which Härtel attributes to an aseptic meningitis, and in 1 case reported by Härtel there was a septic meningitis; the termination of this case is, however, not given. This result, he believes, due to the use of a solution made from tablets, and concludes that only those solutions prepared in ampules should be used. This, however, appears to me as hardly the explanation, as a tablet solution can be rendered as absolutely sterile as when prepared in any other way. This is of interest in connection with the fact that more recently, in the English literature, appeared a report of extensive sloughing occurring following the use of an old but re-sterilized solution of novocain, which result was repeated when again tested on the arm of the operator.

As the ganglion injection is a practically new departure, it is to be expected that difficulties and unpleasant results may occasionally be encountered, and further emphasizes the fact that these injections are not to be indiscriminately used for all purposes, but only under definite indications, and when compared with the results obtained from operations upon the ganglion for neuralgia these unpleasant sequelæ, with a possible occasional serious complication, will bear the most favorable comparison and should be regarded as minor considerations.

It is to be expected, also, that as experience increases and technic improves that many of the unpleasant disturbances may be avoided.

In this connection the injection of the ganglion is not unlike the early history of spinal analgesia—both are made in dangerous ground (the fifth very strongly resembles a spinal nerve.) It is to be expected that further experience will teach us how to avoid unpleasant results.

As a final word of advice for making deep injections into the trunks of the fifth nerve or at their foramina of exit, aside from the information contained in the preceding pages, it will be found of great help, as suggested by Braun, to have near by a skull set in the same position as the patient's head to further guide one in the accurate passage of the needle.

CHAPTER XXIII

THE ORGANS OF SPECIAL SENSE WITH DENTAL ANESTHESIA

THE EYE

COCAIN was first used as an anesthetic in the eye, brought forward by Koller in his epoch-making announcement in 1884, and although many other agents have since been introduced, each having claims in one or the other direction, still cocain remains the anesthetic of choice in this particular field, and will be the agent considered here in discussing the various ophthalmologic operations.

For a consideration of the different drugs as substitutes for cocain and their particular advantages, see chapter on Local Anesthetics. A few brief remarks regarding the use of cocain in a general way will first be made.

The prolonged or repeated use of cocain in the eye as a means of controlling pain is objectionable on two grounds: First, the haziness produced in the superficial cells of the cornea by its continued action, made worse when combined with the use of coagulating antiseptics, such as bichlorid of mercury (see chapter on Cocain); and, secondly, in chronic conditions requiring its repeated use, particularly when placed in the hands of the patient, may lead to the formation of a habit. The first objection raised against it in the early history of its use has been largely overcome by a better knowledge of its action gained by experience leading to its more judicious and skilful use.

The slight cloudiness which is seen to follow the repeated application of cocain to the cornea was first observed by Koller; this, however, clears up after a short time, but is most marked and persistent when bichlorid of mercury is used as a cleansing and antiseptic wash in the strengths ordinarily employed (1 : 4000–6000).

Koller undertook experiments upon rabbits to determine the cause of this action ("Ref. Hand Book Med. Sci.," 1901, vol. iii, p. 156). Cocain was instilled into one eye and the lids closed and held together with forceps; the other eye, into which no cocain had been instilled, was held open with an eye speculum. After some time it was observed that the eye held open showed drying and loss of superficial epithelium, while the cocainized eye showed very little change; from this it was concluded that the hazy changes seen to occur were not due solely to the action of the anesthetic. His views on this point were further substantiated by other observers.

It is highly useful in any examination of the eye, where pain, photophobia, and lacrimation would otherwise render an examination extremely difficult, if not impossible, as in cases of conjunctival or corneal troubles, superficially situated foreign bodies, injury from chemical irritants, etc. When used for this and other purposes it is better to make several applications of weak solutions, 0.50 to 1 per cent., than to use stronger, 4 to 5 per cent. solutions, and, where stronger solutions are necessary for operative purposes, it is better to precede their use by the application of a few drops of a weak solution, as the contact of strong solutions produce a burning irritating pain of some seconds duration before anesthesia sets in. Its use for pain which might possibly be of glaucomatous origin should be carefully avoided, as it has repeatedly been proved to hasten the development of a threatened glaucomatous attack. An objection raised by some operators against cocain in cataract operation is that it renders the eye so hypertonic as to make the expression of the cataract more difficult; of recent years, however, this objection has been overcome by more skilful methods, and, on the contrary, its use has many advantages, the dilation of the pupil making iridectomy unnecessary by avoiding prolapse of the iris. The use of cocain and other local anesthetics in all ophthalmologic operations has gradually extended, until now the use of general anesthesia has been reduced to a minimum and by some is almost entirely discarded.

In all operations upon the lids a triangular or crescentic line of infiltration made subcutaneously with 0.25 to 0.50 per cent. solutions, with or without adrenalin, as indicated, will block off the operative area and secure a perfect anesthesia (Fig. 236).

In chalazion a light infiltration made deep under the subcutaneous tissues just under the growth, combined with one or two applications of a 2 to 5 per cent. solution over the region, will suffice to render the field anesthetic.

While all operations upon the conjunctiva and cornea may be made perfectly painless by instillations, in such operations in which the iris is to be handled or cut, this is not always successful by instillations alone, and when used it is necessary to use strong solutions, 4 to 5 per cent., and begin about twenty to thirty minutes before the time for operation, instilling a few drops every five minutes, allowing it ample time to be absorbed and affect the deeper parts. During this time it is necessary to keep the eye closed to prevent evaporation and drying of the cornea. The difficulty of rendering the iris absolutely anesthetic by this method led surgeons in the earlier use of cocain to inject some of the solutions into the anterior chamber after the corneal section, a method which has now been almost entirely superseded by the subconjunctival injection. This method was practiced by Koller as far back as 1885, and is carried out as follows: After several instillations into the conjunctival sac to render this and the cornea anesthetic, a speculum is inserted, and the conjunctiva seized by means of a mouse-tooth forceps; three points of injunction are usually selected, one just below the cornea and one on each side just below the middle line; it

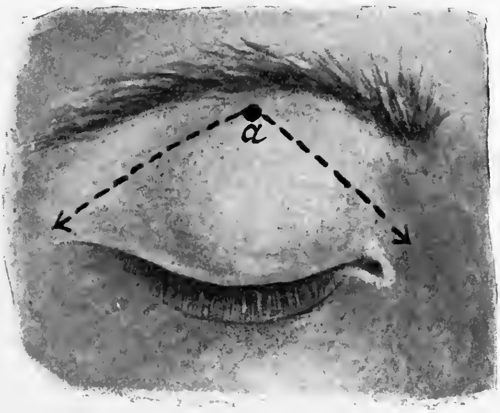

Fig. 236.—Method of anesthesia of upper eyelid. (Braun.)

is necessary that these sites be so chosen that the resulting edema will not interfere with the operation. At each point 2 drops of a 5 per cent. solution are injected, care being taken that the needle does not penetrate into the subconjunctival layers, which would result in too much edema. After these injections the eye is closed for five minutes, by which time some of the edema subsides and the solution has been given time to act and the iris is thoroughly anesthetic, when the operation may be undertaken.

For the removal of cataract several instillations at intervals of a few minutes of a 5 per cent. solution, keeping the eye closed during the interval, will usually suffice; but when it is necessary to handle or operate upon the iris, these instillations should be supplemented by subconjunctival injections of 2 to 5 per cent. solutions.

For operations upon other parts, tendons or muscles, after the preliminary superficial anesthesia, the conjunctiva is seized with forceps just over the point of operation, and the point of the needle is inserted as deeply as possible into Tenon's capsules and 2 or 3 drops injected at the point of the intended operation.

The eye is now closed, and after a delay of five to ten minutes the tendons can be painlessly divided; in cases where it is necessary to advance the tendons this is not entirely free from pain, as the necessary pulling on the central and deeper parts of the muscle cause pain, as these have not been reached by the anesthetic solution.

In operations upon glaucoma, acute and chronic, Koller recommends 5 per cent. solutions of cocain containing 2 per cent. pilocarpin, and states that after an experience with this method of over ten years he has not met with any bad effects which could be attributed to the injection, and the results obtained compare favorably with those obtained by any other method.

Professor Koller, in speaking of the action of cocain as a mydriatic, as well as its use in certain inflammatory conditions, states the following:

"The pupil-dilating property of cocain is of great value in ophthalmoscopy. While the dilatation is sufficient in the dark chamber to allow a satisfactory examination it does not have the blinding effect of belladonna, the pupil all the time responding to light.

"This is due to the fact that cocain dilates the pupil by constricting the blood-vessels of the iris, but leaves the sphincter intact; besides, the accommodation is hardly interfered with.

"The pupil-dilating power of cocain, if combined with that of atropin, is invaluable in cases of iritis.

"The mydriatic effect of this combination is stronger than that of any other drug or any combination of drugs; it counteracts both forces that contract the pupil, the sphincter and the blood-vessels. (Hyperemia of the iris tends to contract the pupil by stretching the tortuous course of the iris arteries, while the blood-vessels, when empty, return to their tortuous course and so dilate the pupil.)

"The anemia of the blood-vessels is a strong check to the inflammation, the pain ceasing mostly after a few instillations and the duration of treatment being greatly shortened. The writer uses a mixture of equal parts of a 1 per cent. solution of sulphate of atropin and a 5 per cent. solution of hypochlorate of cocain; at first he instils every ten minutes until the pupil is dilated (three to four instillations are necessary), then only three times a day.

"The combination of the two drugs is also efficient in cases of cyclitis."

For enucleation it is necessary to carry the injection deep down around the origin of each recti muscle. The superficial parts are first anesthetized in the usual manner by instillations and subconjunctival injections, combining adrenalin with the latter as well as with the deeper injections around the recti muscles, using not over 1 or 2 drops of 1 : 1000 adrenalin at each point of injection, making use of a 2 to 5 per cent. solution of cocain. After the anesthesia of the superficial parts the conjunctiva is divided and the orbit opened; the needle is then passed deep down to the origin of each recti and 2 or 3 drops deposited at each point; when this has been completed at all four points, and a delay of a few minutes allowed for thorough saturation of the tissues, the anesthesia should be complete and the operation proceeded with.

The advantages of combining adrenalin with the cocain here is decided in lessening the amount of hemorrhage which is otherwise frequently profuse, as well as prolonging and lessening the possibilities of toxic symptoms arising through absorption. Operators differ in their views regarding the advisability of the use of adrenalin in other operations, but most all agree that it is of advantage in such operations as enucleation, tenotomy, and advancement of the tendons, where it both intensifies and prolongs the anesthesia. The injection of the solution into the insertion of the tendons is not desirable as it causes too much swelling, but during the operation pledgets of cotton wet with cocain and adrenalin can be laid upon the field.

In operations for pterygium adrenalin appears to be contra-indicated, as its blanching effect renders the outline of the growth less distinct.

In the removal of foreign bodies adrenalin would seem contra-indicated, except where the hemorrhage is severe, as slight hemorrhage may prove of benefit by washing infectious material out of the wound, which might otherwise enter the deeper tissues; on the same grounds cocain, on account of the ischemia it produces, might prove objectionable and be replaced here by some other agent which does not cause such vasoconstriction.

As a general thing, adrenalin should be very cautiously used about the eye; its too free use, or too strong solution, may give rise to an aching pain or produce disturbances in the cornea. When used by instillation it should not exceed a few drops of a 1 : 10,000 to 15,000 solution.

In all operations upon the eye with cocain care should be exercised, as idiocyncrasies are frequently encountered and may give rise to unpleasant and often toxic symptoms.

For a diagram of the nerves of the eye, see Fig. 167, and for a further description of the anatomy of these parts, see chapter on the Head. In addition to the above two special methods of anesthesia are frequently employed for enucleation, the methods of Löwenstein and Siegrist.

Löwenstein anesthetizes the ciliary ganglion and retrobulbar structures by a retrobulbar infiltration. After first anesthetizing the conjunctiva by infiltration, a point on the outer orbital margin is selected and a long, fine needle entered at this point and passed obliquely inward and backward behind the bulb (see "Anatomy of the Orbit" in chapter on the Head), injecting the solution as the needle is advanced until a depth of about $4\frac{1}{2}$ cm. has been reached. Care is exercised not to puncture the bulb by displacing it inward with the finger and by a lever-like motion of the needle to determine that it is free in the retrobulbar space; at this point from 1 to 2 c.c. of a 1 per cent. cocain solution is injected.

In the method of Siegrist the same purpose is accomplished by using curved needles, which are passed through the conjunctiva from four puncture points around the margin of the orbit and passed around the bulb into the retrobulbar tissues.

THE EAR

From a study of the nerve supply of the auricle it will be seen that a horseshoe-shaped injection, embracing the ear from below, made subcutaneously and carried down beneath the attachment of the deep fascia to the bone, will reach and block the entire nerve supply to these external parts, or the procedure, as illustrated in Fig. 237, may be adopted.

Where the operative field involves the external parts of the auditory canal supplied by the auricular branch of the pneumogastric an injection should be made deep at the root of the ear, on its posterior aspect, where this branch of the pneumogastric passes upward and forward through the auricular fissure between the mastoid process and the auditory canal.

This simple procedure will permit of any operation on the external parts. Solution No. 1 will be found sufficiently strong for this purpose; the addition of adrenalin will render the field completely ischemic. In exceptional conditions of great vascularity a procedure, used by Prof. Matas and reported in the following case, will be found of great value:

"The utility of Corning's principle of incarceration was most forcibly impressed upon my mind in 1890 in operating upon an extremely vascular nevoid angioma of the entire auricle.

"In this case the ear presented elephantine proportions, and pulsated with the arterial and venous blood by enormously dilated blood-vessels; one of the caverns ruptured by ulceration and the patient nearly succumbed after a frightful hemorrhage. The external carotid was ligated, but this was followed by only temporary improvement. A few weeks afterward the ear was cocainized, resected, and bared completely of its tegumentary covering, including the afferent blood-vessels, which were all secured and ligated by a very simple procedure. This consisted in the injection of a 4 per cent. solution of cocain (0.5 o of 1 per cent. would have been sufficient) into the peri-auricular tissues at the root of the ear, until a complete circle of cocain solution had been formed around it. Four hair-lip pins were then introduced at equidistant points, so as to transfix sections of the circle. These were used as binding posts to hold a thin rubber band, which was wound around each pin, and the rubber was stretched tightly around the pedicle. The pulsations in the ear ceased immediately, and, with the arrested circulation, a complete anesthesia of the auricle followed. which permitted the operation to be performed throughout without pain or hemorrhage."

Fig. 237.—Points of injection for anesthetizing external ear. (Braun.)

Fig. 238.—Van Eicken's method of injection for anesthetizing external auditory canal. (Braun.)

For the anesthesia of the external auditory canal and tympanum, many operators in this field have worked out various plans by which operations on these parts may be painlessly performed.

Von Eicken suggests the following:

For external parts he begins by spraying with ethyl chlorid, and then follows with an injection of cocain and adrenalin solution in the posterior fold of the pavilion, under the cartilage of the floor of the canal. The needle is directed upward and backward to reach the point of emergence of the auricular branch of the pneumogastric, which is the sensory nerve of the posterior part; without completely withdrawing the needle, the point is then forced toward the anterior and deeper part of the canal to attain the auriculotemporal filaments (Fig. 238).

Complete anesthesia of the external canal is thus obtained in one or two minutes. The tympanum is next anesthetized by injecting the solution into the skin of the deeper part of the canal.

While the above may prove successful, it has not appeared to us that the use of ethyl chlorid about the external auditory canal was very satisfactory, as its application here has seemed unpleasant to the patient.

The following plan by Tiefenthal appeals to us more, and is equally simple; a combination of the two, by injecting the auditory branch of the pneumogastric as recommended above, followed by anesthesia of the drum as practiced by Tiefenthal, may prove more satisfactory.

Tiefenthal recommends that 4 drops of a 20 per cent. solution of cocain with 1 drop of adrenalin (1 : 1000) be placed in contact with the drum membrane for fifteen minutes. This produces a slight reduction of sensibility, but insufficient for paracentesis. Then, with a small syringe having a fine, angular needle, he injects through the lower part of the membrane 2 to 4 drops of a 5 or 10 per cent. solution of cocain with adrenalin. After a few seconds the membrane appears whitish gray from the anemia of the tympanic cavity, the anesthesia is complete, and paracentesis may be performed without pain or hemorrhage.

Professor Neumann, who has done much work with local anesthesia on the ear, secures anesthesia in much the same way. The operative possibilities are not, however, limited to these simple procedures, mastoid operations being performed with equal success. For this purpose it is necessary to have a strong syringe. Neumann used a metal syringe with specially modified needle, but any strong syringe and needle will do. He recommends a 1 per cent. eucain solution, with 5 drops of tonogen (an Austrian preparation of adrenalin) to each cubic centimeter for infiltration of the soft parts. The deeper infiltration about the periosteum is done with a 1 per cent. solution of cocain and 5 drops of tonogen to each cubic centimeter. The solutions are warmed before injection to about 45° C. to facilitate their diffusion.

The entire region over the mastoid is now thoroughly injected subcutaneously with the eucain solution, from the base to the apex and forward to the ear (Fig. 239); some of the solution is then injected subperiosteally; the ear is now drawn forward, and the anterior wall of the mastoid process injected subperiosteally down to the bony termination of the auditory canal (Fig. 240).

Through a speculum, which is now inserted into the ear, 1 c.c. of the cocain solution is injected into the superior wall of the auditory canal, at the point of junction of the bony and cartilaginous portions,

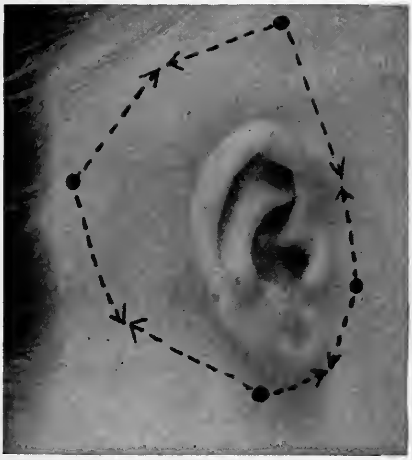

Fig. 239.—Points of injection for surrounding operative field with zone of anesthesia for mastoid operation. (Braun.)

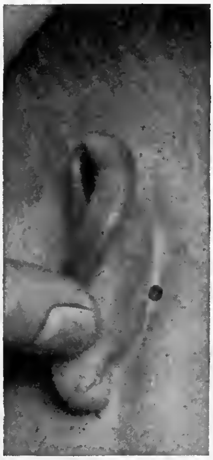

Fig. 240.—Point for deep injection behind ear. (Braun.)

another syringeful into the inferior wall, and slightly less into the anterior and posterior walls. These injections must be made beneath the periosteum, and in such a manner that they produce a distinct bulging or protrusion, which disappears as absorption takes place. A small pledget of cotton, saturated with 20 per cent. cocain solution, is now inserted into the tympanic cavity through the perforation in the tympanic membrane (which always exists in these cases). This is not removed until the antrum is opened during the progress of the operation.

After a delay of about fifteen minutes the operation may be begun. It is recommended that in cutting the bone only a very sharp chisel should be used, which is held as flat as possible and the bone shaved off in this manner, and never holding the chisel perpendicular, which would produce too much concussion and would be very trying to a conscious patient. If preferred, a burrow or other drilling instruments may also be used. While the above description is for the regular mastoid operations, it is by no means limited to this class of cases, but may be used equally as well in acute mastoiditis.

NOSE AND THROAT

The present-day operator little conceives of the difficulties experienced in certain departments of surgery in the days before the introduction of cocain and its congenors, even after we had the many benefits conferred by general anesthesia. As illustrative of these conditions, and the efforts many were making toward finding suitable local anesthetics, I quote the following by Dr. Wm. C. Glasgow, of St. Louis, read before the American Laryngological Society at New York, 1879. The same difficulties were experienced in all fields of work where local anesthetics are now so freely used.

"The need of an agent by which the excessive sensibility and the spasmodic contractions of the larynx caused by the introduction of instruments can be controlled has been fully experienced by every laryngeal surgeon.

"The common method of deadening sensibility by the repeated introduction of the sound is tedious both to operator and patient. Some cases can be readily operated upon with slight preparation, but still we find others where the most persistent education gives little result.

"The use of bromids, potassium, sodium, and ammonium, when applied locally and taken internally, produce a certain effect in diminishing the sensibility, but their use is unsatisfactory when the production of anesthesia of the larynx is desired. The same may be said of ice and the various astringents, as, for example, tannin. The morphin and chloroform solution of Professor Bernatzic, given by Turch and as used by Bruns and Schroetter, does certainly produce the desired result, but as the constitutional effects of morphin are marked long before the anesthesia of the larynx is sufficient it cannot be regarded as a safe remedy or one that can come into general use.

"In 1871, fresh from the instruction of the Vienna school, I used this solution for the first and I trust for the last time. The patient was a young girl, with papillomata of the larynx. I applied the solution of Bernatzic after the manner taught by Schroetter. The constitutional symptoms preceded the local anesthesia fully one and one-half hours, and they became so grave during the operation that it had to be suspended and the most energetic measures employed to combat the toxic efforts of the drug. The local anesthesia, however, was complete.

"I have seen the morphin solution repeatedly used with great success in the Vienna clinic, and it may be possible that my patient was peculiarly susceptible to the drug; still, the method is subject to too many risks ever to become popular.

"During the past winter I have been experimenting with two remedies, both of which produce, in a measure, not only the desired anesthesia, but also relief from pain. I refer to hydrate of chloral and carbolic acid. Both remedies have been extensively used in throat practice, but, as far as I am aware, they have never been suggested or used for the purpose of producing anesthesia of the larynx, etc."

The above gives a brief idea of earlier difficulties encountered and the efforts made by the pioneer operators in their search for a satisfactory local anesthetic; up to the very time of the discovery of cocain this search had gone ceaselessly on; the literature of the precocain period is full of similar reports, and many different measures utilized to produce the, until then, unsatisfactory local analgesia.

It is particularly to the surgeon specialist, and especially in ophthalmology and nose and throat surgery, that local anesthesia has proved a great boon to the operator, reducing to simple office procedures many operations which formerly required a sojourn in an institution and a general anesthetic for their performance. Also, for the use of such instruments as sounds and dilators, much tedious and trying practicing of the patient is now done away with where the parts can be readily anesthetized. The examination of sensitive and inflamed parts can also be carried out without the discomfort to the patient formerly necessary. Notwithstanding the many advances in local anesthesia during the last few years, and the newer and safer agents introduced, cocain still remains the anesthetic of choice among the great majority of operators in these special fields. This is no doubt due to the fact that cocain, being the first agent introduced, the methods of application necessary to its success have been studied and perfected, until now it is hard to displace it from its firmly established position. However, we are firmly convinced that the time and trouble required to understand the slight differences necessary in the technic of the use of some of the safer agents, particularly novocain, to insure the same degree of anesthesia will be more than amply repaid by the occurrence of fewer sequelæ and toxic symptoms. For this reason, we especially urge the reader to consider carefully the description of these different agents described in the chapter on Local Anesthesia, and that part of the chapter on Technic dealing with the action of concentrated and weak solutions as it is particularly applicable to nose and throat surgery. In our discussions here we will follow the trend of the present time and describe the operative procedures under cocain.

It is not alone in operative work that local anesthesia may prove of value in this field, as it may be used to advantage in a certain limited number of cases in a diagnostic way; in reflex neurosis, starting from the nose, the exact location of the trouble can often be definitely determined, as an application of cocain to the starting-point relieves the reflex (asthma, etc.).

There are three methods of applying cocain to these parts in common use—by sprays, swabs, and infiltration (cataphoresis rarely). In using a spray it is advisable, as a rule, to use only weak solutions (2 per cent.) in graduated bottles, so that the exact quantity used may be definitely known to avoid the possibility of poisoning, having the patient to expectorate any accumulations in the mouth or pharynx instead of swallowing them. Weak solutions, applied repeatedly at intervals of a few minutes, will accomplish as much as stronger ones and eliminate dangerous possibilities; the first application, by constricting the blood-vessels, produces a certain degree of ischemia when subsequent applications upon the ischemic area act more profoundly and absorption is greatly lessened. For application with a swab stronger solutions are advisable, 5, 10, or 15 per cent., although many operators use highly concentrated solutions up to 50 per cent., as will be spoken of later.

For application to the larynx it is usually advisable to use solutions of at least 20 per cent. For infiltration it is usually necessary to use from 0.50 to 2 per cent. solutions.

Adrenalin plays an active part in nearly all these applications, but it should be cautiously used, as it is an agent capable of producing considerable disturbance, and many symptoms erroneously attributed to the anesthetic are in reality due to the adrenalin. In this respect, it may be said that it often produces a peculiar tight feeling or pain in the head when too freely or injudiciously used.

The advisability of administering to all patients about to undergo an operation of any severity upon these parts some preliminary sedative a short while before, the same as is advocated for any general surgical procedure under purely local means, has been discussed by rhinologists. The objections found with the usual morphin and scopolamin is that most of these patients are operated in the sitting position, and while the medication accomplished the desired end in relieving anxiety and uneasiness, it often makes the patient so drowsy that they nod about and are unsteady in the chair. Leshure makes use of the following, which is given by mouth about one-half hour before operation—morphin, $\frac{1}{4}$ gr.; hyoscin hydrobromatic, $\frac{1}{100}$ gr.; and strychnin sulphate, $\frac{1}{30}$ gr., which is practically equivalent to our morphin and scopolamin, with the addition of the strychnin.

Miller recommends the following—sodium, potassium, and ammonium bromid, āā 10 gr.; spiritus ammoniæ aromaticus, 1 dram; aqua q. s.; this is given a short while before operation.

If nausea occurs during the progress of the operation it is usually relieved by the inhalation of ammonia, and with any evidence of faintness the head should at once be lowered.

In operations upon the anterior end of the nose in such procedures as the removal of dislocated septal cartilages infiltration is usually necessary, using 0.50 to 1 per cent. solutions of cocain with adrenalin, injecting the solution beneath the skin and mucous membrane surrounding the field sufficient to produce a moderate degree of edema, and allowing a few minutes to elapse before beginning the operation.

A somewhat similar technic can be followed in dissecting out portions of the lateral cartilages, when these encroach upon the breathing space; the injection is made beneath the skin and mucous membrane, particular attention being paid to the region of the nasopalatine nerves, for if these are not rendered anesthetic pain will be complained of in the front teeth when those nerves are reached.

In the anesthetization of those parts of the nasal tract, septum, and turbinates, which are usually accomplished by swabbing the operative area, many operators of extensive experience and undoubted ability prefer to make use of very strong solutions, sometimes reaching 50 per cent. and stronger, rather than follow the example of the general surgeon, whose aim is constantly to reduce the concentration of the solutions used to the minimum effective strengths. It would seem to us advisable to use repeated applications of weaker solutions rather than such concentrated strengths, but the use of the strengths in this especial field is not without a rational basis founded upon physiologic laws, as is discussed in the chapter on Principles of Technic. The merit of the procedure is further borne out by the constantly accumulating clinical evidence and the skill and ability of those making use of these practices. Some operators, when operating upon these parts by means of the swab, prepare their solution by placing a few grains of pure cocain crystals in a dish or suitable receptacle and moistening them with just enough adrenalin (1 : 1000) to render them soluble, claiming better results from this solution, which gives an anesthesia of from three-quarters to one hour duration.

In operations upon the septum and turbinates two methods of inducing anesthesia are in vogue: By packing the nasal cavity with pledgets of cotton, wet in the anesthetic solution, and allowing them to remain for about twenty minutes; this may be supplemented later, if found necessary, by a light application with the swab. The objection of this method of packing is that large quantities of cocain are likely to be absorbed, as the packs come in contact with the entire nasal fossa and their presence stimulates the flow of mucus, which washes the cocain down into other parts where absorption takes place. A much safer and better method is to anesthetize the field by the use of swabs, and here much skill can be shown in their use; in beginning the application of a swab upon sensitive parts it can always be preceded by the use of the spray; after the swab has been applied, allow it to remain in position a few moments; as the anesthetic is taken up it diffuses in all directions, which can be recognized by the blanching effect upon the tissues; the application is then reapplied within the margin of this area in much the same way as a skilful surgeon will infiltrate the skin; in this way the patient is not conscious of pain or other discomfort during the anesthetizing process.

Special attention should be paid to any irregularities, such as spurs and deviations, to insure reaching all overhanging or posterior surfaces, by bending the applicators in suitable directions. An applicator once used should not again be placed in the solution, as mucus and other secretions carried in with it dilute the solution.

The utilization of regional methods of anesthesia has a limited application within the nose, by swabbing the solution in concentrated form over the trunks of the nerves at their points of emergence upon the nasal septum. Some few operators recommend injecting the solution at these points, and while this may in rare instances be necessary, as in the case of extensive scar formation or other conditions, the majority of operators find the swab sufficient, as the solution readily penetrates the overlying mucous membrane and reaches in effective strength the underlying nerves. (See discussion of the use of concentrated solutions upon mucous surfaces in chapter on Principles of Technic.)

By a study of the accompanying illustrations, showing the course and distribution of the nerve supply, a knowledge of regional methods here is readily obtained (Figs. 241, 242, 243, 244).

The presence of scar tissue occasionally found in the septal mucosa, the result of previous disease (small-pox, etc.) or injury, may render the production of perfect anesthesia by means of applicators impossible. In such cases resort must be had to infiltration; this however, is rarely necessary.

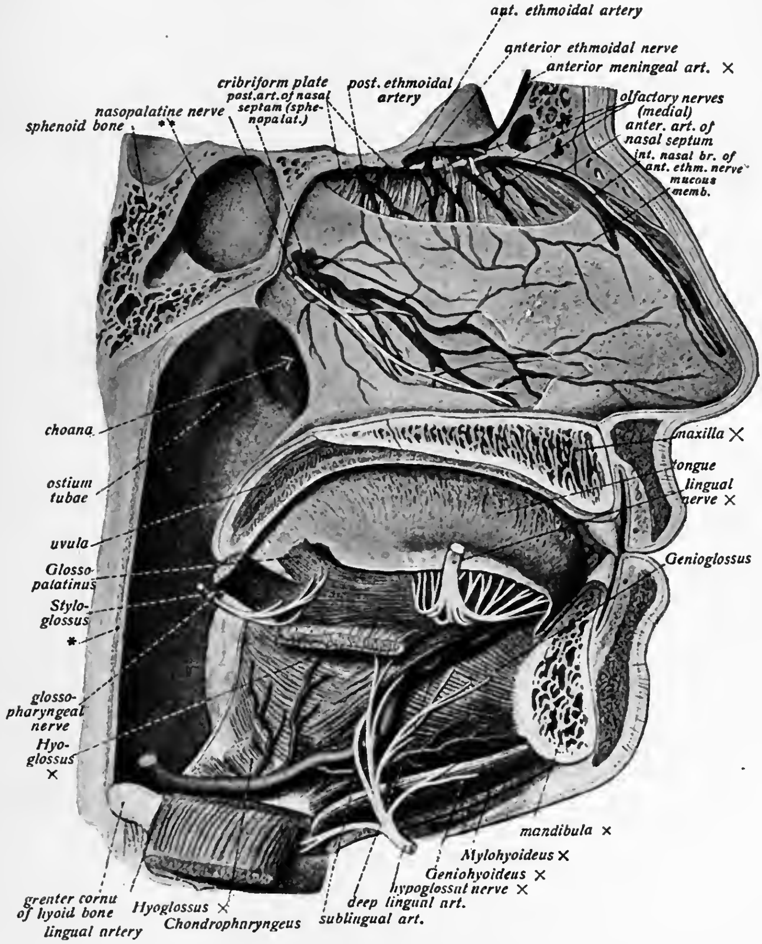

Fig. 241.—The nerves and arteries of the nasal septum and of the tongue. * = divided posterior pharyngeal wall. ** = sphenoidal sinus. (Sobotta and McMurrich.)

When using infiltration, Killian recommends a regional anesthesia blocking the septal nerves. He makes the injection at two points—(1) just anterior to the tuberculum septi in an upward direction, and (2) at a point just below the middle of the lower border of the middle turbinate (Fig. 245).

The Inferior Turbinate.—This is anesthetized in much the same way as the septum, except that greater difficulties are usually encountered, particularly when it is large, overhanging, and encroaching upon the surrounding parts; however, the application of the cocain-adrenalin solution soon produces a certain amount of shrinkage, making the

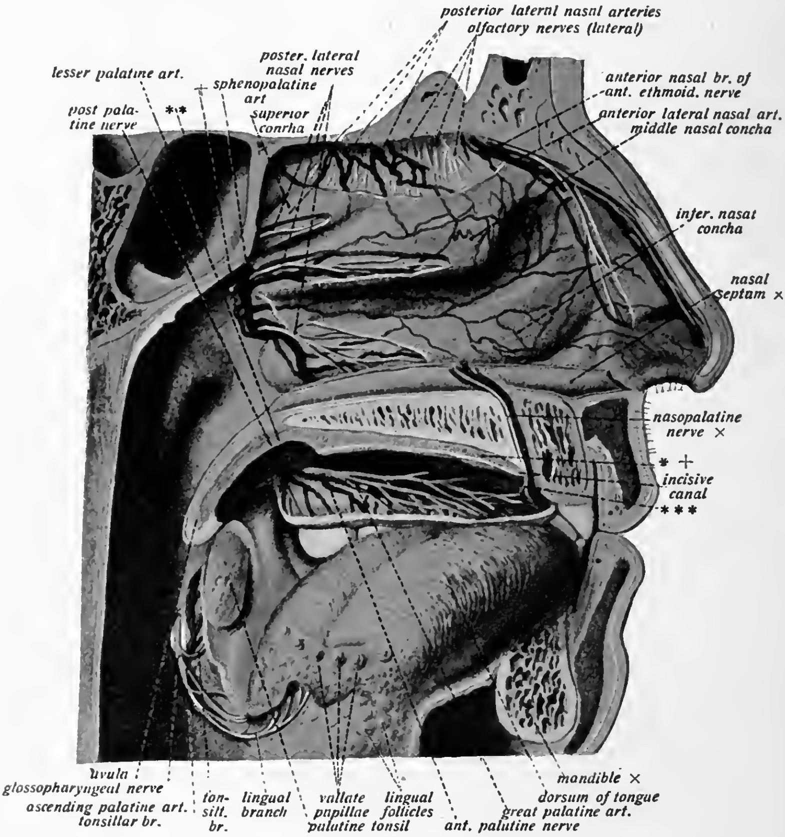

Fig. 242.—The nerves and arteries of the outer nasal wall and of the palate. The tongue has been drawn out, all of the nasal septum except its lower portion removed, and the mucous membrane of the faucial isthmus divided along the glossopharyngeal nerve and the ascending palatine artery. ** = Sphenoidal sinus. * = Divided branches to nasal septum. *** = Anastomosis between nasopalatine and anterior palatine nerves. * + = mucous membrane of hard palate. (Sobotta and McMurrich.)

concealed parts more accessible. At times it is necessary to reach the posterior parts by using a curved applicator passed from behind through the nasopharynx. Rarely is it found necessary to use infiltration, and when this is done great care should be exercised as the absorptive power of this tissue is tremendous.

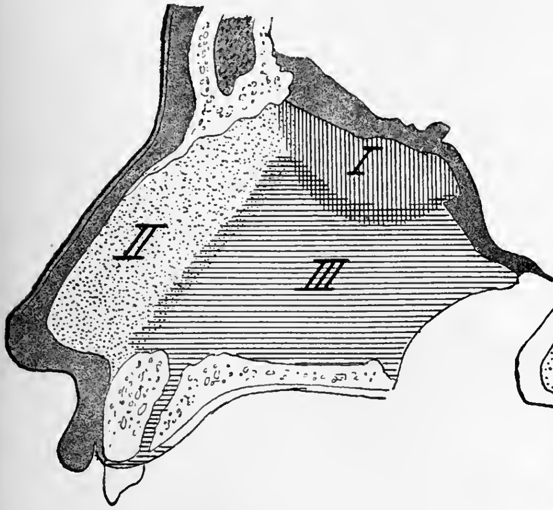

Fig. 243.—Innervation of nasal septum. (Braun.)

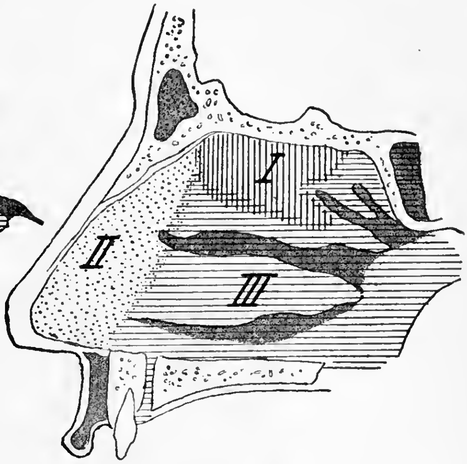

Fig. 244.—Innervation of lateral nasal wall: *I*, Olfactory nerve; *II*, nasal nerve; *III*, nasopalatine nerve. (Braun.)

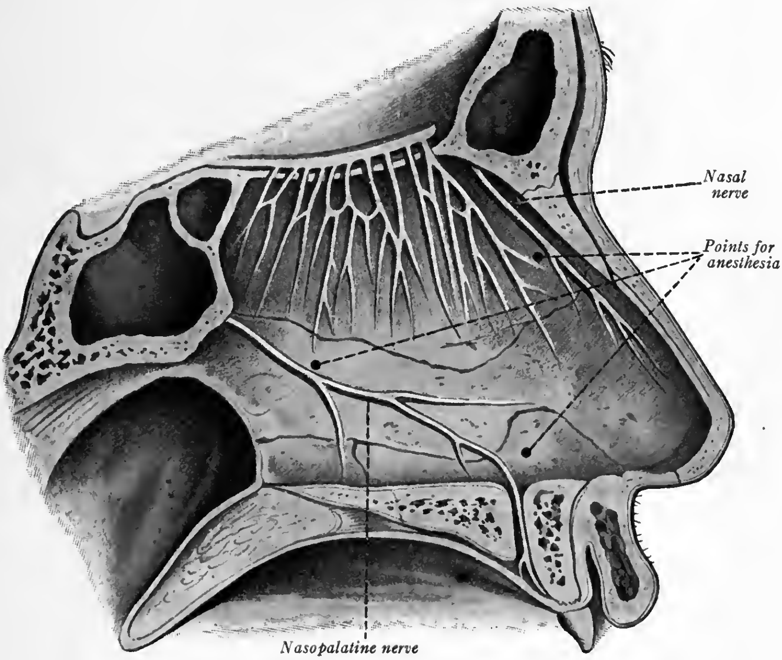

Fig. 245.—Points of anesthesia for Killian regional method. (Braun.)

The *middle turbinate* is usually much simpler, and is treated in much the same manner.

The *nasofrontal duct and antrum of Highmore* are operated upon in the same manner by securing anesthesia by the use of swabs over the surfaces to be operated upon.

The *uvula* presents no difficulties, and is easily anesthetized by a few applications with the swab or it can be infiltrated.

The *lingual tonsil* presents some difficulties, and should be anesthetized with great care, particularly if the cautery is to be used; as cocain is destroyed by heat, it is necessary to have the anesthesia penetrate well beyond the influence of the cautery, passing the swabs well down to its base between the folds of the lymphoid tissue.

The *nasopharynx* is ordinarily rather difficult of operation under local anesthesia, largely due to its being rather difficultly accessible, and to its being covered in these cases with tenacious mucus which protects the underlying membrane. However, certain operations can be very satisfactorily performed. The anesthesia is accomplished by swabs passed back through the nose on each side and up through the mouth; during this procedure care should be exercised not to overlook the posterior border of the septum.

The ordinary curet is unsatisfactory for operations under local anesthesia, as the blade wounds the deeper structures, which have been only imperfectly anesthetized; instead resort should be had to such instruments as the Schultz adenotome, which are so constructed as to protect the deeper parts.

The Faucial Tonsil.—This structure, on account of its ready accessibility, is ordinarily quite easily enucleated under local anesthesia, different operators using different methods of anesthesia and various anesthetic solutions; recently some have advocated quinin and urea, on account of the absence of after-pain under its use and the diminished tendency to postoperative hemorrhage.

From our personal experience with this agent we would not care to recommend it as it is at present used. (See chapter on Quinin and Urea.) The anesthetizing process is begun by brushing the tonsil, its anterior and posterior pillars, and supratonsillar fossa with a swab wet in a strong 10 to 20 per cent. solution of cocain and adrenalin. A 1 to 2 per cent. solution of cocain, containing 1 : 10,000 adrenalin, is then injected into the anterior and posterior pillars, carrying some of the solution down under the base of the tonsil. When carefully injected it is not necessary to use more than 40 to 60 minims, which should result in a perfect anesthesia in a few minutes. As the tonsil is being separated from the pillars and its bed, if any pain is complained of, swabbing over the area will control it.

Hemorrhage is usually very slight, owing to the use of adrenalin, but if any occurs it must be perfectly controlled before leaving the case, as it may increase as the effects of the adrenalin pass of:

Larynx and Trachea.—Any applications to the larynx is best preceded by a preliminary spraying with a 2 to 5 per cent. solution, having the patient inhale at the time, preferably using graduated bottles.

The superficial anesthesia secured in this way will permit of the easy use of the swab later, which is used with a 20 per cent. solution.

Figs. 246, 247.—Outline of points of injection for anesthesia of frontal sinus: 1, Penckart point of injection for nasal nerve; 2, point of injection on side of cheek for reaching sphenomaxillary fossa. (Braun.)

To anesthetize the trachea a 5 to 10 per cent. solution is usually necessary, which is sprayed in at the moment of inspiration, having the patient to expectorate any which may accumulate in the pharynx.

In all operations upon the above-mentioned parts, where the procedure is at all protracted, the operator is warned of returning sensibility by the return of vascularity and oozing of the parts, which always precedes the return of sensation and affords time for the application of additional anesthetic.

In very extensive operations within the nasal cavities considerable advantages may often be offered by blocking the superior maxillary nerve where it leaves the foramen rotundum, as described in the chapter on the Head. This could be supplemented by the use of adrenalin locally to control the hemorrhage, or, under extreme conditions, ligating the external carotid artery.

Under certain conditions it may be advisable to use combined methods of anesthesia, which are discussed under this heading.

For operations upon the frontal sinus the field is embraced in an area of infiltration, as shown in Figs. 246, 247, carrying the infiltration deep down to the periosteum, at the orbital margin, to reach the supra-orbital and supratrochlear nerves at this point; following this very light infiltration is necessary laterally and above, but may often be found unnecessary. Anesthesia of the mucous lining of the sinus is controlled by a median orbital injection made at point 1, for the technic of which see chapter on the Head.

DENTAL ANESTHESIA

Here all methods of anesthesia find a field of application, from ethyl chlorid and topical applications down to the more extensive operations performed under regional anesthesia. Ethyl chlorid is used in the opening of abscesses and other simple incisions, and is sometimes employed for extractions. For this purpose the ordinary container may be used, which sprays one side of the gum at a time, or a specially devised instrument, with a forked-shaped or two-pronged tip, which directs the spray to both sides at the same time.

For the purposes of infiltration about four agents are now employed—namely, cocain, β-eucain, alypin, and novocain—together with a large number of proprietary mixtures, which contain mixtures of the above agents with other ingredients in different proportions, most of them containing adrenalin.

Thymol is one of those agents, and seems preferred by the great majority of dentists, as this agent combines antiseptic and anesthetic qualities; in dilutions of 1 : 2000 it prevents the developments of bacteria, and in more concentrated solution, 1 : 200 it is destructive to most organisms. Dentists frequently make use of this quality as well as its anesthetic effect by applying solutions to sensitive pulp cavities; this anesthetic property is quite decided. Experiments upon animals show that 1 : 1000 solutions will paralyze the cutaneous nerve-endings of frogs immersed in it for a short time. As recommended by Fischer, the proportion in anesthetic mixtures should be about 1 : 5000. He prefers the following formula, which he recommends for infiltration purposes:

Novocain	1.5
NaCl	0.92
Thymol	0.025
Distilled water	100.0

For all practical purposes our solution No. 2 (1 and 2 per cent. novocain), with 5 drops of adrenalin to the ounce, will be found amply sufficient, much cheaper, and more satisfactory than the many proprietaries now on the market, or the solution recommended by Fischer

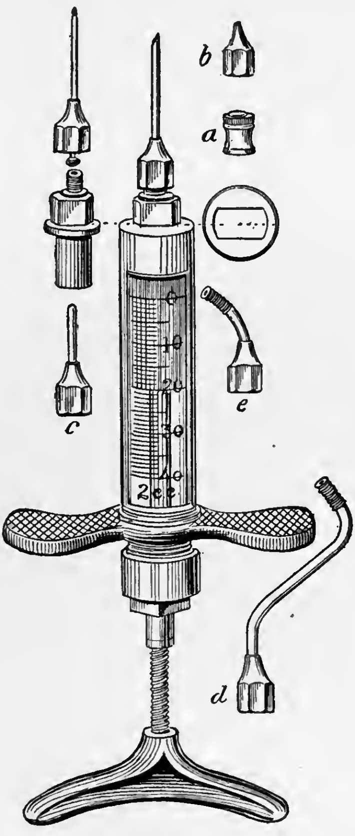

Fig. 248.—Injection syringe of glass and metal, designed by Dr. Guido Fischer. (See Fig. 249 for explanation of lettering.)

may be used. For injection into the gums specially constructed syringes with short, stout needles, often directed at an angle, are necessary, as the ordinary syringe and needle will not stand the pressure needed to infiltrate such dense tissue. The syringe and needles shown in Figs. 248 and 249 have, after a thorough experience, been found to fill all requirements, and have been adopted by Fischer.

The dental nerves and their areas of distribution are seen in Figs. 144, 160, 161, 162, and 163, and a more thorough description is given in the chapter on the Head.

It should be remembered that dental anesthesia, when applied to the roots of the teeth, is practically always a paraneural injection, and may require ten or fifteen minutes to become effective. These

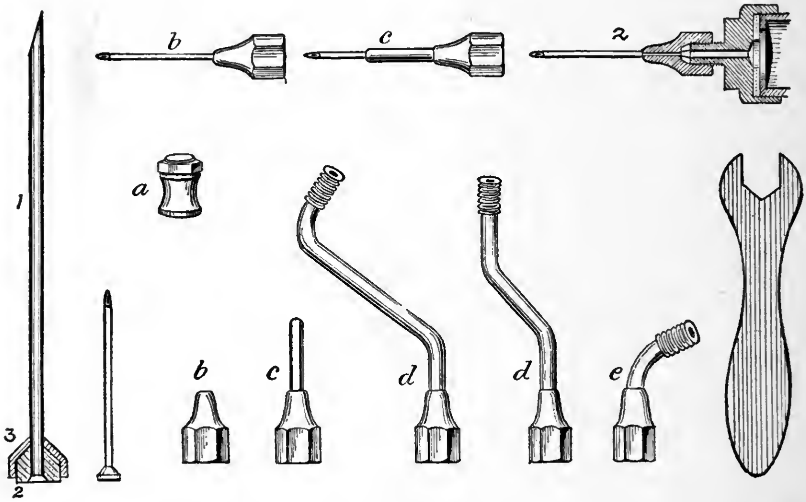

Fig. 249.—Needles, awls, and wrench for injection syringe, designed by Dr. Guido Fischer. At the left is a considerably enlarged reproduction of the new needle, showing the details of construction as follows: 1, The hollow needle, either of seamless steel, pure nickel, gold, or iridio-platinum; 2, body of soft metal for firmly tightening the needle upon the orifice of the syringe; 3, conical shell of hard metal, open below, from which the soft metal cone protrudes. This arrangement remedies the deficiencies of the old styles of needles in which the unprotected soft metal cone could not stand much use, became flattened easily, and jammed in the hub so firmly that both hub and needle had to be replaced, which was rather expensive if gold or iridio-platinum needles were used. The new needles are attached to the syringe absolutely tightly by inserting the needle in one of the hubs (*b* or *c*) and screwing it firmly on the orifice of the syringe. In order to enable practitioners with sensitive fingers easily to manipulate the hubs, which heretofore were milled, the hubs *b* and *c*, also the middle pieces *d* and *e*, are made with hexagonal connections, so that they can be conveniently and firmly tightened by a slight turn of the wrench. No force should be used, otherwise the soft metal cone of the needle becomes unnecessarily worn. (Fischer.)

injections should be made subperiosteally rather than under the mucous membrane, and under considerable pressure, as this solution must force its way through bony tissue to reach the nerve-fibers at the root of the tooth.

Before making the injection the surface is cleansed and touched with iodin. The needle should be entered at a right angle to the mucous surface, injecting as the needle is advanced, and slowly pushed through to the periosteum, which is penetrated, and the needle advanced a short distance along the bone and well up toward the root of

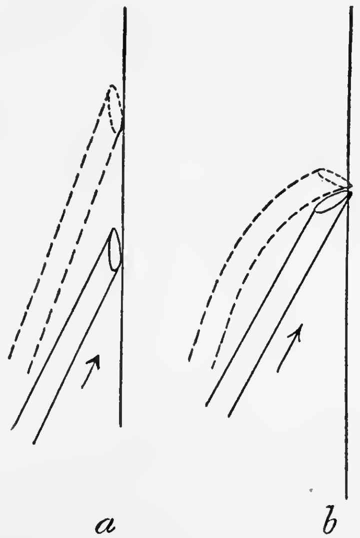

Fig. 250.—Position of needle in mucous anesthesia, aperture of needle pointing toward the bone: *a*, Correct position; *b*, incorrect position. The point of the needle is forced into the periosteum and to the bone. (After Seidel.)

the tooth; the opening in the needle point should always be directed toward the bony surface (Figs. 250, 251, 252, 253), the remainder of the solution now slowly injected, the needle withdrawn, and the

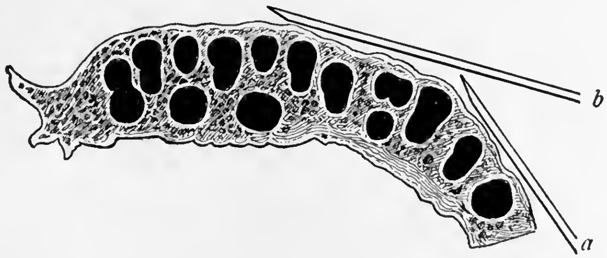

Fig. 251.—Position of needle for horizontal injections in several upper teeth: *a*, Labial injection; *b*, buccal injection. (After Fischer.)

finger pressed upon the point of injection for a few seconds. In those parts of the mouth in which the needle cannot be advanced at a right angle it must be done obliquely, but should be made as nearly at right angles as possible.

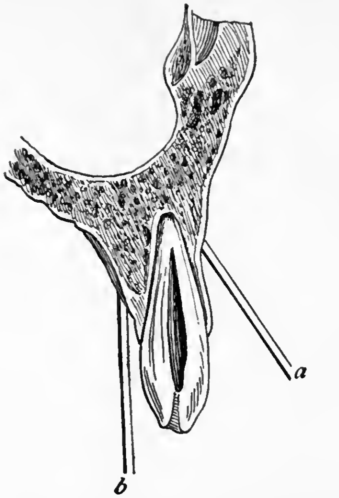

Fig. 252.—Position of needle for injection in upper canine: *a*, Labial injection; *b*, palatal injection. (After Fischer.)

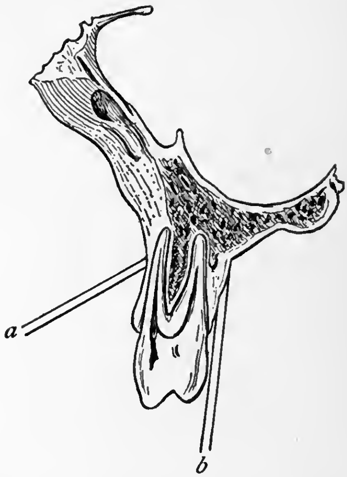

Fig. 253.—Position of needle for mucous anesthesia in upper first bicuspid. Above is seen the infra-orbital foramen: *a*, Buccal injection; *b*, palatal injection.

Fig. 254.—Injection in palatal mucous membrane at lateral incisor region. Syringe is held like penholder. (After Fischer.)

Repeated punctures by the needle are to be avoided when possible, as two or more teeth can be injected by using a long needle and advancing it in such a position that the area of injection can be made to embrace several teeth (Fig. 251).

For injections upon the palatine surface the needle is made to enter more nearly in the axis of the tooth (Figs. 252, 254), inserted back from the gum margin, and advanced to a subperiosteal position over the root apex. In dealing with the upper molars, instead of making the injection as above, an injection can be made into the posterior palatine canal (regional anesthesia), this injection sufficing for all three molars, as follows:

On the lateroposterior surface of the tuber maxillare of the superior maxilla are seen a varying number of foramina, the openings of the

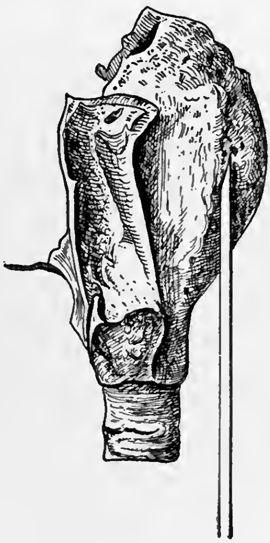

Fig. 255.—Position of needle for injection at maxillary tuberosity. (After Fischer.)

posterior superior dental canals through which the sensory nerve-filaments pass to the three upper molars; before entering these canals the nerves run downward and forward for a short distance in the submucous tissue in close proximity to the parent trunk. (See Figs. 144–160.)

To inject these nerves in this position the mouth is held half-open, the cheek drawn outward and upward, and the zygomatic process reached with the finger; the needle is entered high up in the mucous membrane about over the second molar, with its point directed upward, backward, and inward, the syringe being held well away from the bone; the solution is injected as the needle is advanced, with the point hugging as closely as possible the convex surface of the tuberosity (Fig. 255) until its posterior surface is reached. From ½ to 1 dram of a 1 to 2 per cent. solution of a novocain-adrenalin solution is distributed along the track of the needle. Ten or fifteen minutes may be required to attain the maximum anesthetic effect.

The lingual portion of the inferior maxilla is injected in a similar manner, but where several teeth are to be anesthetized it will be found best to block the inferior dental nerve at its entrance into the dental canal, as described in the chapter on the Head.

When this form of anesthesia is resorted to an additional injection will be necessary for the molars on their buccal surface, as this tissue is supplied by the buccinator nerve. (See Fig. 162.)

A review of the appended table (pp. 606–608), taken from Fischer, will be found useful, as indicating the points and methods of injection in simple and complicated cases as well as the amount of anesthetic solution to be used.

Some years ago a pressure method of anesthesia for the painless extirpation of pulps was introduced. The exact origin of this method seems hard to trace; it was, however, early reported on by Dr. Kells, of New Orleans, and H. H. Hill, of St. Louis (1899). For its success it is necessary that the pulp be exposed, the essential feature being the driving of the anesthetic under pressure into the root canal of the tooth. It is carried out as follows: A small piece of cotton (or spunk, as originally recommended) is moistened with alcohol, and then touched with the local anesthetic, preferred in powdered form, so that a few small crystals adhere to the cotton; this is placed in contact with the exposed pulp; the rest of the cavity is then filled with ordinary red rubber (unvulcanized); light pressure is then applied with a ball burnisher as large as can be fitted to the cavity; as the pain ceases the pressure is increased until considerable force is exerted, which is continued for a few minutes; this has the effect of driving the anesthetic into the pulp canal. When the exposure of the pulp is minute after the first application, the opening is enlarged and the process repeated. When this has been properly carried out it should permit the painless use of the broach.

It is said that when arsenic has been previously used the resulting anesthesia is not usually as pronounced.

Cataphoresis has been used in dental surgery, but is not very popular and requires much time. Other electric devices have been used, but do not properly come within the scope of this book.

For regional methods of anesthesia applicable to more extensive dental operations reference should be had to the chapter on the Head, which describes the technic necessary for regional anesthesia of the upper and lower jaws, the illustrations being particularly useful.

"Additional explanation of tables: The period of waiting in Cases 1 to 10 is about ten minutes; after injection in the inferior dental foramen as in Nos. 11 to 16, twenty minutes. In Nos. 13 to 16 no injection lingually is required. All combinations of anesthesia of several teeth on one side can easily be calculated by applying to the first and last tooth of the series to be anesthetized the technic specially indicated for the same in the tables.

"If, for example, the right half of the upper jaw, from the canine to the third molar, is to be anesthetized, an injection is made in the canine fossa at the root apex of the canine; the needle is then advanced along the periosteum to the root apex of the second bicuspid, injecting altogether 2 c.c.; then 1 c.c. is injected at the maxillary tuberosity, about 10 drops in the posterior palatine foramen, and about 0.25 c.c. palatally, between the canine and first bicuspid."

TABLE A (Copied from Fischer).

Teeth—I. Upper.	Technic of injection employed.		Mountings of syringe.	Quantity of solution.	
	(a) In simple cases.	(b) In cases complicated by periostitis, parulis, etc.		In labial or buccal injections.	In palatal or lingual injections.
1. Central incisors.	Needle inserted at root center of lateral, and directed to root apex of central.	Needle inserted at root centers of canine and central of opposite side, whose root apices are infiltrated with solution.	Hubs B or C. Needle No. 17a.	In cases. (a) 0.5 c.c. (b) 1.0 c.c.	Of class. (a) 0.1 c.c. (b) 0.3 c.c.
	Palatally, injection at central.	Palatally, injections at lateral and central of opposite side, or conductive anesthesia from infra-orbital foramen, and mucous anesthesia at central of opposite side, palatally.	For conductive anesthesia, needle No. 17c.		
2. Lateral incisors.	Needle inserted at root center of canine, and directed to root apex of lateral.	Needle inserted back of root apex of canine, where solution is deposited; same procedure at root apex of central.	As in 1.	(a) 0.5 c.c. (b) 1.0 c.c.	(a) 0.1 c.c. (b) 0.3 c.c.
	Palatally, injection of lateral.	Palatally, injection at lateral, or at central and canine.			
3. Canines.	Needle inserted back of root apex of canine, where some solution is deposited, and directed toward canine.	Conductive anesthesia from infra-orbital foramen.	(a) As in 1. (b) Long needle No. 17c.	(a) 0.1 c.c. (b) 0.5 c.c.	(a) 0.5 c.c. (b) 0.5 c.c.
	Palatally, injection at the canine.	Palatally, injection at canine, or first bicuspid and lateral.			
4. First bicuspid.	Needle inserted in center of canine, and directed to root apex of first bicuspid.	Conductive anesthesia from infra-orbital foramen, or injections at root apices of canine and second bicuspid.	(a) As in 1. (b) As in 3.	(a) 1.0 c.c. (b) 1.5 c.c.	(a) 0.5 c.c. (b) 0.5 c.c.
	Palatally, injection at first bicuspid.	Palatally, injection of first bicuspid, or second bicuspid and canine.			
5. Second bicuspid.	Needle inserted in center of first bicuspid and directed to root apex of second bicuspid.	Conductive anesthesia from infra-orbital foramen, and injection at maxillary tuberosity.	(a) As in 1. (b) As in 3.	(a) 1.5 c.c. (b) 2.0 c.c.	(a) 0.50 c.c. (b) 0.25 c.c.
	Palatally, injection at second bicuspid.	Palatally, injection at second bicuspid and posterior palatine foramen.			

6. First molars.	Injection at maxillary tuberosity and root center of first molar. Palatally, injection at posterior palatine foramen.	Injection at maxillary tuberosity and infra-orbital foramen. Palatally, injection at posterior palatine foramen.	(*a*) and (*b*) Hub B and needle No. 17c; if desirable in injection at maxillary tuberosity, middle piece D.	(*a*) 1.5 c.c. (*b*) About 10 drops.	(*a*) 0.25 c.c. (*b*) About 10 drops.
7. Second molars.	Injection at maxillary tuberosity and root center of second molar. Palatally, injection at posterior palatine foramen.	Injection at maxillary tuberosity and infra-orbital foramen. Palatally, injection at posterior palatine foramen.	As in 6.	As in 6.	As in 6.
8. Third molars.	Injection at maxillary tuberosity and root center of third molar. Palatally, injection at posterior palatine foramen.	Injection at maxillary tuberosity. Palatally, injection at posterior palatine foramen.	As in 6.	As in 6.	As in 6.

TABLE B (Copied from Fischer).

Teeth—Lower.	Technic of injection employed.		Mountings of syringe.	Quantity of solution.	
	(*a*) In simple cases.	(*b*) In cases complicated by periostitis, parulis, etc.		In labial or buccal injections.	In palatal or lingual injections.
9. Central incisors.	Needle inserted at root of center lateral, and directed to root apex of central. Lingually, injection at central.	Needle inserted at reflection of mucous membrane below central, and directed to mental fossa, where solution is deposited. Lingually, injection at lateral.	(*a*) Hub B and needle No. 17a. (*b*) Hub C and needle No. 17c. Palatally, always middle piece E and needle No. 17a.	(*a*) 0.6 c.c. (*b*) 1.0 c.c.	(*a*) 0.25 c.c. (*b*) 0.25 c.c.
10. Lateral incisors.	Needle inserted at root of center canine, and directed to lateral. Lingually, injection at lateral.	Needle inserted at reflection of mucous membrane below canine, and directed to mental fossa, where solution is deposited. Lingually, injection at canine.	(*a*) As in 9. (*b*) As in 9.	(*a*) 0.6 c.c. (*b*) 1.0 c.c.	(*a*) 0.25 c.c. (*b*) 0.25 c.c.

TABLE B (Copied from Fischer)—(*Continued*).

Teeth—Lower.	Technic of injection employed.		Mountings of syringe.	Quantity of solution.	
	(*a*) In simple cases.	(*b*) In cases complicated by periostitis, parulis, etc.		In labial or buccal injections.	In palatal or lingual injections.
11. Canines.	Needle inserted at reflection of mucous membrane below canine, and directed to mental fossa, where solution is deposited. Lingually, injection at canine of first bicuspid, or conductive anesthesia from mandibular foramen.	Needle inserted at reflection of mucous membrane below canine, and directed to mental fossa, where solution is deposited. Conductive anesthesia from mandibular foramen. Lingually, injection at first bicuspid.	(*a*) and (*b*) Hub C and needle No. 17c. Lingually, Hub E and needle No. 17a.	(*a*) 1.0 c.c. (*b*) 2.0 c.c.	(*a*) 0.25 c.c. (*b*) 0.25 c.c.
12. First bicuspid.	Needle inserted in gingival papilla of canine, and directed horizontally to first bicuspid. Lingually, injection at first bicuspid, or conductive anesthesia from mandibular foramen.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of first bicuspid. Lingually, injection at second bicuspid.	(*a*) Hub B and needle No. 17a. (*b*) Hub B or C and needle No. 17c. Lingually, middle piece E and needle No. 17a.	(*a*) 1.0 c.c. (*b*) 2.5 c.c.	(*a*) 0.25 c.c. (*b*) 0.25 c.c.
13. Second bicuspid.	Conductive anesthesia from mandibular foramen, and injection buccally at second bicuspid.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of first bicuspid.	(*a*) and (*b*) Hub C and needle No. 17c.	(*a*) 1.5 c.c. (*b*) 2.5 c.c.	
14. First molars.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of first molar.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of second bicuspid.	(*a*) and (*b*) Hub C and needle No. 17c.	(*a*) 2.5 c.c. (*b*) 2.5 c.c.	
15. Second molars.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of second molar.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of first molar.	(*a*) and (*b*) Hub C and needle No. 17c.	(*a*) 2.5 c.c. (*b*) 2.5 c.c.	
16. Third molars.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of third molar.	Conductive anesthesia from mandibular foramen, and injection buccally in papilla of second molar.	(*a*) and (*b*) Hub C and needle No. 17c.	(*a*) 2.5 c.c. (*b*) 2.5 c.c.	

TABLE I (COPIED FROM HÄRTEL)

SENSORY INNERVATION OF THE HEAD AND NECK WITH MUCOUS MEMBRANES AND MENINGES

Compiled from "Anatomies"

Cranial or spinal nerve.	Nerve.	Principal branches.	Territory of distribution.
A. SENSORY INNERVATION OF THE SKIN			
I. *Trigeminus Distribution*			
V_1 Ophthalmic nerve	Lacrimal		Skin on outer angles of lids.
	Frontal	Supra-orbital	Upper lid, forehead, and vertex of head.
		Supratrochlear	Skin on inner angles of lids.
	Nasociliary	Ant. ethmoid (nasal nerve)	Tip of nose.
		Infratrochlear	Skin on inner angles of lids.
V_2 Maxillary nerve	Temporomalar	Temporal	Anterior part of temple.
		Malar	Malar region.
	Infra-orbital		Side of nose. Lower lid. Anterior part of cheek. Upper lip.
	Buccinator		Skin at angle of mouth.
V_3 Mandibular nerve	Auriculotemporal		Anterior part of ear. Temple. Cheek.
	Inf. dental	Mental	Lower lip. Chin.

Spinal nerve and scheme of ramification.	Nerve.	Principal branches.	Territory of distribution.
II. *Anterior Branches of the Spinal Nerves (Area Cutanea Anterior)*			
(C_1)			
C_2	Occipitalis minor		Posterolateral region of head.
	Auricularis magnus		Ear, temple, and side of face.
C_3	Superficialis colli		Anterior region of the neck.
C_4	Supraclavicular		Upper part of thorax and shoulder.

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TABLE I (*Continued*)

Spinal nerve and scheme of ramification.	Nerve.	Principal branches.	Territory of distribution.
	III. *Dorsal Branches of the Spinal Nerves (Area Cutanea Posterior)*		
(C_1)			
C_2	Lateral branches	Occipitalis major and tertius	Median posterior region of head.
C_3	" "		Posterior region of neck.
C_4	" "		
C_5	" "		
C_6	" "		
C_7	" "		
C_8	" "		

Cranial nerve.	Nerve.	Principal branches.	Territory of distribution.
	B. Sensory Innervation of the Mucous Membrane		
	I. *Conjunctiva and Bulbus Oculi*		
V_1 Ophthalmic	Lacrimal		Outer part upper and lower lids (Zander).
	Frontal	Supra-orbital, Supratrochlear	Inner part upper lid.
	Nasociliary	Infratrochlear	Inner part lower lid and tear sac.
		Ganglionic and ciliary	Cornea, conjunctiva, bulb.
V_2 Maxillary	Infra-orbital	Palpebral	Lower and part of upper lid (Zander).
	Temporomalar		Lateral part lower lid.
	II. *Nose and Accessory Sinuses.*		
	a. Nasal Fossa		
V_1 Ophthalmic	Nasociliary	Ant. ethmoid (ant. nasal)	Anterior upper part nasal fossa.
V_2 Maxillary	Sphenopalatine, Sphenopalatine ganglion.	Post. nasal (sup. and inf.)	Remainder of nasal fossa.

b. Accessory Sinuses

V_1 Ophthalmic	Nasociliary	Post. ethmoid	Sphenoid sinus. Posterior ethmoid cells.
		Ant. ethmoid	Anterior ethmoid cells. Frontal sinus.
V_2 Maxillary	Sphenopalatine	Nasal branches (Testut)	Antrum of Highmore.
	Infra-orbital	Alveolar superior (post. med. and ant.)	

III. *Mouth*

V_2 Maxillary	Infra-orbital	Sup. alveolar	Upper teeth and gums on buccal side.
		Sup. labial branches	Mucous membrane of the upper lip.
	Sphenopalatine ganglion	Nasopalatine	Palatine tooth, periosteum, gums.
		Palatine	Hard and soft palate.
V_3 Mandibular	Inf. alveolar	Dental	Lower teeth and gums.
		Mental	Mucous membrane, lower lip.
	Lingual	Sublingual	Lingual gum anterior teeth (Bünte and Moral).
		Lingual branches	Tongue to foramen cecum.
		Isthmi fauc. branches	Part of tonsil.
	Buccinator		Mucous membrane, cheek.

IV. *Pharynx and Larynx*

V_2 Maxillary	Sphenopalatine ganglion	Pharyngeal (Boek)	Region Eustachian tube.
V_3 Mandibular	Lingual	Branches to isthmi fauc.	Part of tonsil.
IX Glossopharyngeal		Pharyngeal tonsil, lingual branches	Pharynx (vagus). Tonsil, pillars of tonsil. Base of tongue behind foramen cecum.
X Vagus		Pharyngeal	Pharynx.
	Superior laryngeal	Internal	Base of tongue near epiglottis. Entrance of larynx to rima glottis.
		External	Mucous membrane of larynx below rima glotis and ventricle of Morgagni (Testut).

TABLE I (*Continued*)

Cranial or spinal nerve.	Nerve.	Sensory nerve ending.	Territory of distribution.
		V. *Mucous Membrane of Ear*	
V_2 Maxillary	Sphenopalatine ganglion	Pharyngeal	Tube (glossopharyngeal).
V_3 Mandibular	Auriculotemporal		External auditory passage, outer surface of tympanum (vagus and second cervical).
	Spinal recurrent		Mastoid cells (glossopharyngeal).
IX Glossopharyngeal	Tympanic		Tube. Tympanic cavity. Inner surface of tympanum. Mastoid cells.
X Vagus	Auricularis		External auditory passage. Outer surface tympanum (trigem. and sec. cervical).
C_2 Anterior branch	Auricularis magnus		External auditory passage (trigeminus and vagus).

Cranial nerve.	Nerve.	Terminal nerve.	Territory of distribution.
		C. SENSORY INNERVATION OF DURA MATER	
V	Ophthalmic	Tentorial (origin within the skull).	Tentorium cerebelli.
V	Maxillary	Middle meningeal (origin within the skull).	Dura, anterior and middle cranial fossa.
V	Mandibular	Spinosus (origin without the skull).	Dura, middle cranial fossa (sphenoid sinuses and mastoid cells).
X Vagus		Meningeal (origin without the skull from the jugular ganglion).	Dura, posterior cranial fossa around jugular foramen.
XII Hypoglossal		Occipital (origin in hypoglossal canal; sensory branch originates probably from the lingual V_3).	Dura, posterior cranial fossa around foramen magnum.

TABLE II (Copied from Härtel)

COMPILATION OF INVESTIGATIONS ON SKULL

No.	Subject of investigation.	Result of investigation.	Number of skulls examined.	Number of individual measurements.
	The total number of skulls examined was 69, of which 15 were complete, 4 half skulls; the remainder were bases with or without vertex and inferior maxilla.		69	
	Ten isolated sphenoid bones were examined, as well as a number of other isolated bones.		10	
1	Length of foramen ovale.	Minimum . . . . 5 mm. Maximum . . . . 11 " Average . . . . 6.9 "	62	116
2	Width of foramen ovale.	Minimum . . . . 2 mm. Maximum . . . . 7½ " Average . . . . 3.7 "	62	114
3	Varieties of foramen ovale. (See Observation to No. 10.)	A width of 3 mm., unfavorable for the injection, occurred 11 times, 8%. Impossible for injection, due to bony variations (ossified lig. pterygospinosus bridging the foramen), occurred once. The smallest foramen measured 5×2; the largest, 11×5 mm. Circular or oblique forms were observed 4 times. Ossification of the lig. pterygospinosum 9 times in 5 skulls. Union of foramen ovale and for. spinosum 4 times in 3 skulls. Union of for. ovale with for. lacerum 3 times on 3 skulls.	71	134
4	Distance of for. spinosum, caroticum, and jugulare from posterior edge of for. ovale.	For. spin., minimum . . . . 0 mm. Maximum . . . . 6 " Average . . . . 2.3 "	15	24
		For. carot., minimum . . . . 8 mm. Maximum . . . . 17 " Average . . . . 12.7 "	18	31
		For. jug., minimum . . . . 15 mm. Maximum . . . . 28 " Average . . . . 20 "	18	31

TABLE II (*Continued*)

No.	Subject of investigation.	Result of investigation.	Number of skulls examined.	Number of individual measurements.
5	Relation of pterygoid process to for. ovale: a = width of upper part lamina externa; b = distance of anterior edge for. ovale from ant. edge lamina externa; $y = b - a$ indicates the dangerous interval along which the needle passes between the pterygoid process and the for. ovale.	(*a*) Minimum ... 6 mm. Maximum ... 16 " Average ... 12.3 " (*b*) Minimum ... 9 mm. Maximum ... 18 " Average ... 14.2 " (*y*) Minimum ... −2 mm. Maximum ... +8 " Average ... +2 "	18	35
	The smaller the y, the surer the injection.	Negative value for y was found 10 times, value greater than 4 mm. twice.		
6	Distance of for. ovale (lower edge) from upper edge of pyramid of petrous bone to impressio trigemini (= intracranial distance of route to gasserian ganglion).	Minimum ... 14 mm. Maximum ... 23 " Average ... 19 "	58	110
7	Projection of "trigeminal axis" on the alveolar process of upper jaw. "Overflat" means cutting the alveolar process in front of the zygomatic process; "flat," under the zygomatic process; "medium," between the zygomatic process and post. edge of alveolar process; "steep," on the posterior edge; "oversteep," beyond the post. edge of alveolar process.	Inclination of the axis overflat 7 times = 6.1%. Inclination of the axis flat 32 times = 28%. Inclination of the axis medium steep 44 times = 38.6%. Inclination of the axis steep 27 times = 23.8%. Inclination of the axis oversteep 4 times = 3.5%. In about 90% the axis to the ganglion meets the upper jaw in the region of the third molar tooth.	61	114
8	Distance of the ant. edge of ramus of lower jaw to tuber-maxillare.	Minimum ... 8 mm. Maximum ... 18½ " Average ... 12.8 "	18	38
	The distance was less than 12 mm. 9 times = 23.7%; 12 mm. and over 29 times = 76.3%, or in about one-fourth of the cases is it impossible to feel the planum infratemporale from the mouth.			
9	Width fossa pterygopalatine (greatest diameter of entrance).	Minimum ... 3 mm. Maximum ... 11 " Average ... 5.4 " Narrow fossa with a width of <5 mm. was found in about 40% of cases.	39	75

10	Varieties of fossa pterygopalatine. Observation: since the statistics in large part deal with selected material, the figures of the frequency of varieties must be accepted with caution.	Tuberculum sphenoidale strongly developed (pyramidal, flat, and pointed forms), 62 times. Strongly developed marginal ridge (anterior edge lamina externa pterygoid proc.), 36 times; ant. pterygoid spine, 9 times. Fossa developed by the sharply projecting pneumatized walls of neighboring sinuses (especially proc. orbitalis os. palatini), 9 times.	60	116
11	Where a horizontally introduced needle, above zygomatic arch, meets the fossa pterygopalatine (Offerhaus method). The more pronounced the Crista infratemporalis and the tuberculum sphenoidale, the deeper will be the fossa.	(*a*) In upper part fossa 10 times, 12%. (*b*) In for. sphenopalatine 46 times, 55%. (*c*) Below for. sphenopalatine 20 times, 24%. (*d*) Introduction of needle by this route impossible 8 times, 9%.	46	84
12	Injection of for. rotundum from the fossa pterygopalatina by the Braun method.	Injection possible 38 times, 33%. Injection impossible* 77 times, 67%. * The fossa in these cases was reached and the point of the needle was near the for. rotundum.	62	115
13	Position of injection to reach the fossa pterygopalatina by this method. (The more pronounced the tubermaxillare, the further behind should the needle be entered.)	Point of injection in front of sutura zygomatico maxillaris, 15 skulls, 10%. Under the suture, 26 skulls, 52%. $\frac{1}{4}$ to $1\frac{1}{2}$ cm. behind the suture in 19 skulls, 38%.	50	
14	Distance of for. rotundum from lower border of zygoma at zygomaticomaxillaris suture (Braun method).	Minimum .... 45 mm. Maximum .... 57 " Average .... 50 "	8	15
15	Condition of route to for. ethmoid post. (Inner smooth plane of orbit.)	Route smooth, 42 skulls, 80%. Route slightly concave, 6 skulls, 12%. Route slightly convex, 4 skulls, 8%.	52	
16	Condition of lateral smooth plane of orbit (route to ophthalmic and lacrimal nerve).	(*a*) Smooth or slightly concave (0.2 mm.), 18 skulls, 13%. (*b*) Concave (3.4 mm.), 38 skulls, 60%. (*c*) Strongly concave (5 mm.), 6 skulls, 10%.		
	The concavity was in about half the cases (35) equal above and below, in $\frac{1}{4}$ above (13) and under (14) very pronounced; in 2 cases there existed a biconcave surface through protrusions of the great wing of the sphenoid.			
17	Condition of inferior smooth plane of orbit (route for orbital injection of maxillary nerve).	Smooth in 6 skulls, 50%. Concave (3 mm.), 3 skulls, 25%. Strongly concave, 3 skulls, 25%.	12	
18	Resistance encountered by needle behind post. ethmoid for. in median orbital injection (marked development of sphenoid sinus).	Needle met resistance in 12 skulls, 50%. No resistance in 12 skulls, 50%.	24	

TABLE II (*Continued*)

No.	Subject of investigation.	Result of investigation.	Number of skulls examined.	Number of individual measurements.
19	Distance of ant. ethmoid foramina from inner edge of orbit at height of injection.	Minimum . . . . . 15 mm. Maximum . . . . . 22 " Average . . . . . 18.5 "	13	26
20	Distance of post. ethmoid for. from similar point.	Minimum . . . . . 29 mm. Maximum . . . . . 42 " Average . . . . . 34.0 "	61	119
21	Distance of optic foramen from similar point.	Minimum . . . . . 33 mm.* Maximum . . . . . 47 " Average . . . . . 40.8 " * The minimum, 33 mm., was observed only once; the next highest minimum was 37.	28	56
22	Resistance encountered by needle in lateral orbital injection on orbital roof (narrow superior fissure), no resistance (wide sup. fis.).	Met resistance 105 times, 86%. No resistance 17 times, 14%.	63	122
23	Distance of outer edge of fis. orbitalis sup. from outer edge of orbit at height of frontomalar suture.	Minimum . . . . . 27 mm. Maximum . . . . . 40 " Average . . . . . 33.5 "	59	112
24	Injection of for. rotundum by orbital route (possible with wide fissure, impossible with narrow or tortuous fissure).	(*a*) Possible 112 times, 89%. (*b*) Impossible 14 times, 11%.	68	126
25	Distance of for. rotundum from outer lower edge of orbital margin.	Minimum . . . . . 39 mm. Maximum . . . . . 51 " Average . . . . . 45.4 "	63	118

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