LOCAL ANESTHESIA

ITS

SCIENTIFIC BASIS AND PRACTICAL USE

BY

PROF. DR. HEINRICH BRAUN

OBERMEDIZINALRAT AND DIRECTOR OF THE KGL. HOSPITAL AT ZWICKAU, GERMANY

TRANSLATED AND EDITED BY

PERCY SHIELDS, M.D., A.C.S.

CINCINNATI, OHIO

FROM THE THIRD REVISED GERMAN EDITION

WITH 215 ILLUSTRATIONS IN BLACK AND COLORS

LEA & FEBIGER

PHILADELPHIA AND NEW YORK

PREFACE TO THE FIRST ENGLISH FROM THE THIRD GERMAN EDITION.

THE writer of this work, Professor Braun, has justly been called "the father of local anesthesia." My object in placing his work at the command of the English-speaking surgical profession is to systematize the vague, erratic, and unsatisfactory efforts which have been made in this field for many years, by offering a logical procedure based upon scientific facts and having an exact and undeviating technique.

Considering the brilliant results that are being obtained especially in Germany with infiltration and conduction anesthesia, it is with much pride that we can number among our American confrères, men who were pioneers in this particular form of anesthesia. Matas, Cushing, Corning, Crile and others attempted conduction anesthesia shortly after the introduction of cocaine in 1884. Their methods, however, held but a minor place in surgery until the introduction of the suprarenal preparations and the less toxic substitutes for cocain. It was only after the discovery of the active salts of the suprarenal gland by Takamine in 1901 that the progress of local anesthesia became assured, for without its use anesthesia sufficient for surgical purposes was impossible.

In this translation I have attempted to adhere as closely to the text as the differences in the two languages would permit, for which reason I hope I may be pardoned for the occasional repetitions which Prof. Braun uses in his work to impress certain important facts. Because of the merit of this German text-book it is a pleasure to stand sponsor for the English translation. I am indebted to Prof. Braun for according me the privilege of translating his work, which represents years of patient toil in the perfection of technique, as it exists today.

The profession must and will accept a method of anesthesia which has no mortality, and will use it in many cases which are today being operated upon under general anesthesia. Without casting any reflection upon the men who have devoted their time and energy to the development and improvement of the technique of general anesthesia, it cannot be gainsaid that the latter will always carry with it a definite mortality. Leaving the many other advantages of local anesthesia out of consideration, the absence of mortality and injury to the tissues should give it a permanent place in surgery.

I am indebted to Dr. Bertha Lietze for her efficient help in this translation.

P. S.

CINCINNATI, OHIO, 1914.

AUTHOR'S PREFACE TO THE THIRD EDITION.

The extensive use of local anesthesia in general surgery has heretofore been possible only to those who have made a study of the literature and who have learned by practice and experience the methods and their limitations. The various surgical text-books give but a very superficial knowledge of local anesthesia, whereas the special monographs, as a rule, overestimate the value of one particular method. Many monographs have appeared in recent years which have simplified the technique. They have shown that the indiscriminate use of any particular method is not permissible, that nearly every operation, every tissue, in fact every part of the body, requires a particular technique for anesthesia, and that operations can only be carried out under this method after a most careful study of the innervation of the operative field.

It seems, therefore, timely that we should collect what knowledge we have at present of local anesthesia. As is well known, I have for years worked toward this end. On the one hand I have enlarged upon my numerous contributions in reference to the results of my experience with the scientific basis of local anesthesia, and on the other hand I have eliminated the unimportant facts from the contents of this book. I have attempted to demonstrate objectively the development of the various local anesthetic methods so that the student will be able to make practical use of local anesthesia without the necessity of investigating a very extensive literature. This has been accomplished by a description of many operations performed under local anesthesia, with the aid of numerous illustrations, a number of which are photographs taken during these operations for the purpose of demonstrating the possibilities of local anesthesia and the value of a better understanding of the technique. This portion of the book is naturally of a subjective character, as it has only been possible for me to describe operations under local anesthesia after obtaining a knowledge of all methods and experiments carried out over a period of years.

The technique, as is well known, has been markedly influenced by the introduction of suprarenin. The photographs and sketches have been made by me in large part.

For a clear understanding of local anesthesia, a knowledge of its use in the special branches, such as ophthalmology, otology, rhinology, gynecology, and urology, is necessary. These departments havė made such progress that we, as surgcons, cannot overlook them. My experience in the fields of surgery and the specialties has been rather extensive. Thus I may be able to suggest some things even to the specialist. Nevertheless, in writing this portion of the book I have been aided by specialists in their respective fields, but I am particularly indebted in this direction to Prof. Dr. Schwarz and Dr. Viereck for their help. I also considered a description of medullary anesthesia as necessary, inasmuch as it forms a part of local anesthesia, and within certain limits is of much practical value.

PROF. DR. H. BRAUN.

CONTENTS.

LOCAL ANESTHESIA.

CHAPTER I.

HISTORY OF LOCAL ANESTHESIA UP TO THE DISCOVERY OF COCAIN.

The most important step in the development of modern surgery, following the antiseptic or rather aseptic treatment of wounds, has been the possibility of operating without pain. The danger and pain, together with most uncertain final results following the slightest surgical procedure, were the heavy responsibilities imposed upon the science of surgery in early days. The attempt to improve upon the treatment of wounds was like groping in the dark, as long as the cause of wound infection and the methods of overcoming it were unknown. The ways of relieving the patient from surgical pain were far more clearly defined. The desire to relieve pain is as old as the history of man, but its consummation extended over many centuries, during which endless efforts were made to relieve the suffering of mankind, as was so forcibly expressed in the words of Hippocrates: "Divinum est opus sedare dolorem." Attempts to reach this goal continued for almost two thousand years after Hippocrates, as may be judged from the countless errors made in the effort to relieve pain, which just before the discovery of anesthesia caused Velpeau to give expression to his thoughts in the disconsolate words, "Eviter la douleur dans les opérations, est une chimère, qui n'est pas permise de poursuivre."

We learn from tradition of the attempts of the Egyptians, Chinese, Greek, and Roman physicians, also medicine men of Africa (Felkin), to induce sleep artificially. They knew of the stupefying effects of the narcotic juices of plants and used them in the form of drinks to relieve the pain of patients undergoing surgical operations. Alcohol was also used for many years for this purpose.

During the Middle Ages narcotic inhalations were used in the effort to produce general anesthesia. Sponges soaked in the juices of the miracle-producing mandrake root, hemlock, henbane, and poppy, so-called sleep sponges, were used to convey the essence of various plant juices to the patient to induce sleep. These were the only means at the disposal of the surgeons in this early period. The older methods of narcosis were too dangerous when effective, and were ineffective when free from danger. There is no doubt that life is endangered if a patient is so benumbed with alcohol, opium, cannabis indica, etc., that the sense of pain during operation is lost. On the other hand, we know that a semiconscious patient does not withstand operation so well as one fully conscious, and resists the efforts of the surgeon more than the latter. For this reason narcosis by this method was rarely used, and toward the end of the Middle Ages was entirely given up by the surgeons.

By means of various precautionary methods, some fantastic, some useful, attempts were made to lessen the pain and shorten the duration of the operation which must now be looked upon as a step in the advancement of knowledge. We learn that greased and warm instruments should lessen pain in cutting through tissues, in fact the same virtues were ascribed to gold and silver instruments. Skill and speed on the part of the operator materially shortened the suffering of the patient, and was made possible by the development of operative technique and improvement in the surgical armamentarium.

Consequent upon these additions to surgical knowledge it is interesting to note that Lisfranc advised, whenever possible, to cut the nerves supplying the operative field with the first incision. The history of general anesthesia began with the discovery of modern inhalation anesthetics, as nitrous oxide, ether, chloroform, and ethyl bromide; the general use of these agents, however, did not take place until some years later.

Efforts to relieve pain by local anesthetic agents were attempted at the same time that experiments were being made with general anesthesia. According to the statements of writers of ancient and medieval times, Egypt possessed two such agents. The one taken from the holy animal of the land consisted of the fat of the crocodile, or the dried and powdered skin of the same animal. This was to be laid on the skin of the patient and was supposed to induce anesthesia. We will make no mistake in classing this with the religious and mystic ceremonies underlying suggestive therapy of the old as well as present times. The other supposed Egyptian agent is the oft-mentioned stone of Memphis, which, according to Plinius, produced local anesthesia if rubbed on the skin with vinegar. During the Middle Ages this method was wrongfully considered a means of inducing general anesthesia. From present sources of information we are unable to state what virtues may be attributed to this stone. Littré has suggested that this stone was a variety of marble which, when used as before mentioned, evolved carbon dioxide. Opposed to this theory is the fact that carbon dioxide has no influence on the intact skin. Huseman holds in reference to the traditional statements of Pliny and Dioskorides that it is doubtful if a "Lapis Memphitis" was actually used for purposes of local anesthesia in ancient times, as the translation of the old Egyptian medical works do not mention definitely anything regarding this stone.

A method of much historic value devised in ancient times for the production of local anesthesia was the compression of nerve trunks. This accomplished its purpose without doubt to a certain degree, and one was actually able by this means to perform practically the only operations that could be done upon the extremities, namely, amputations, with little if any pain, even if the pain occasioned by the operation was only exchanged for the pain caused by the compression. This form of anesthesia is being constantly brought up anew after all other methods are abandoned or forgotten, only to be again given up on account of its serious after-effects. The observation that patients with neuralgia and other painful affections instinctively tried to lessen their pain by pressure upon the affected parts, also that paralysis occasionally followed accidental pressure on the nerve trunks; and, again, the binding of a limb to prevent hemorrhage during amputations, causing disturbances of sensation, were possibly the reasons for popularizing this method. According to the investigations of Corradis, the binding of an extremity with a band for the purpose of producing local anesthesia was in use since the classical times. The Arabian physicians likewise used a method of ligating a limb with the aid of a stick, not only to prevent the loss of blood but also to reduce pain. In the sixteenth century Ambroise Paré used this method for a like purpose. In 1676 Schumann described the amputation of a leg of a woman under local anesthesia, praising the "ligatura fortis" both for its blood-stilling and pain-reducing qualities. While the medical onlookers observed the amputated foot, and the wound surgeon busied himself tying up the part, the woman asked: "Is the foot already off?" She was happily assured that all was over.

Van Swieten and Theden advocated interrupted compression of the entire surface of the limb by means of strong bandages. Juvet again advocated the circumscribed ligation of a limb above the field of operation, and held this method to be sufficient in preventing all sensation. On account of many failures and the opposing statements from authoritative sources this method again fell into discredit. DeSault said that in his time (beginning of last century) this method was in general use, but he gave it up as the ligation of an extremity carried with it the danger of gangrene, if tied sufficiently tight to produce anesthesia. Thirty years later, in spite of these statements, Liégard again used this procedure and described several toe operations performed without pain after tying off the leg just above the ankles. Velpeau also recommended this method, having gained his experience in operating on the great toe. This method seems never to have been given recognition in Germany. In England, J. Moore in 1784 attempted to bring about pressure paralysis of the sensory nerves by other means. He constructed an apparatus with two pads, one to compress the sciatic nerve, the other the anterior crural. He describes a leg amputation which was carried out in this way without pain, after the apparatus had been in place for one and one-half hours, during which time the patient received one grain of morphine. Hunter, who witnessed this operation, recommended Moore's method, also B. Bell, who in fact stated that it was the only remedy suitable for the lessening of operative pain. Other surgeons had no success with this method. Malgaigne tried brisement forcé on the knee-joint with the help of Moore's apparatus, but it was found necessary to interrupt the operation as anesthesia was not obtained. This apparatus was found to be defective, as it caused very severe pain and intense venous congestion in the limb to which it was applied. A sufficient compression of the crural nerve was impossible for anatomical reasons, therefore Moore's method was soon forgotten and replaced by the simpler method of ligation. In the early seventies of the last century compression or ligation anesthesia was again tried by surgeons of all lands from both a theoretical and practical stand-point, following the introduction by Esmarch of his rubber bandages in bloodless surgery, and even in more recent times was again advocated.

Long after compression another remedy, also physiological, for the local relief of pain, was used for surgical purposes, namely, cold. This was first introduced about the middle of the sixteenth century by Thomas Bartholinus, who learned of the pain-stilling quality of cold from his teacher, Marco Aurelio Severino, the Neapolitan anatomist and surgeon.[1]

His recommendations were later forgotten, three hundred years passing before the chilling of the tissues was again used in surgery, notwithstanding repeated observations made with this agent. J. Hunter found by animal experimentation that the ears of rabbits became insensible when surrounded by a freezing mixture. Larrey, chief surgeon to Napoleon's army, relates that the wounded in the battle of Eylau (February 7–8, 1807) requiring amputation had absolutely no sensation in their limbs, the operation being performed with the temperature 19° below zero. Another French military surgeon, Moricheau-Beaupré, who served under Napoleon during the Russian campaign, remarked about the sedative action of cold, but mentioned no specific instance in which cold was used as an anesthetic. The chilling of the tissues for inducing anesthesia was described by Arnott (1848), Guérard, Richet (1854), and introduced practically by Richardson. It is useful today in minor surgery and is a helping agent with other anesthetics.

Investigating the experiments as carried out during ancient times, it should be noted that various chemical agents, drugs, and plant remedies were used in producing a local

[1] Thomas Bartholinus states: Antiquam cauterio ulcera in membris exciteutur, nix affricata induit stuporem. Id me docuit Marcus Aurelius Severinus in Gymnasio Neapolitano olim preceptor meus et hospes, Chirurgorum hoc saeculo princeps. Rectissime autem nivem in vasculum materiæ convenientis capax, sed oblonga ad extremum et myrtiformi specie, conjectam, sine rei ullius interventu applicavit. A gangrenæ metu securos non jussit, medicamento sub angustis parallelis lineis applicato, sensu vero post horæ quadrantem sopito, secare locum indolentem licebit. (Cited by Kappeler).

analgesia. At the end of the eleventh book of the Iliad it is related how Patroclus cut an arrow from the back of the wounded Euripiles:

"And there Patroclus laid him down and cut
The rankling arrow from his thigh, and shed
Warm water on the wound to cleanse away
The purple blood, and last applied a root
Of bitter flavor to assuage the smart,
Bruising it first in his palms: the pangs
Ceased; the wound dried; the blood no longer flowed."

The universal attempts to induce local anesthesia were continued by virtue of a theory which existed until recent times, that sleep-producing drugs would produce their peculiar effects when applied locally. In ancient times mandragora, hyoscyamus, aconite, and juice of the poppy seed and Indian hemp were in almost universal use by the Hindus, Egyptians, Greeks and Romans in the preparation of pain-quieting applications, plasters, salves, washes, etc. These were probably used more by the magicians and quacks than by the physicians, and were also used less as a prophylactic against operative pain than for the relief of painful afflictions. The old Egyptian physicians knew (Prosper Alpin) that mixtures of benumbing substances could produce local anesthesia for surgical purposes. It is indeed interesting to note that the Chinese even in recent times (Porter Smith), after the discovery of chloroform and the knowledge of its use, applied such artemisian mixtures for local anesthesia as the datura tatula, cannabis indica, atropa, and mandragora, drugs described in Pen-t'san-Kong-muh by Li-shi-chin in 1597, the date of the earliest materia medica. The leaves of these mixtures were made into balls with calamus leaves, placed on the painful areas or operative field and burned. This artemisia was so highly prized by the Chinese that with the defeat of their fellow tribesmen, the south Asiatics in Borneo, they were compelled to pay tribute in artemisian camphor (Koehler).

In the middle ages we again meet with the local use of narcotic drugs for the relief of pain in surgical operations. The local use of these drugs originated in the medical school of Salerno, which was the first to use narcotic inhalations for similar purposes. Ægidius von Corbeil, a well-known professor at Salerno, states that about the middle of the twelfth century, by the use of cataplasms of poppy, henbane, and mandrake root applied to the skin the field of operation could be rendered insensitive.[1]

It is hard to believe that by these means a sufficient amount of the previously mentioned drugs could be absorbed from the unbroken skin to produce a useful anesthesia. This method was not more generally accepted than the oldest anesthetic procedures. In more recent times (1850) we have evidence of similar experiments

[1] De Renzi, Coll, Salernit., cited by Husemann: Est quoque notandum, quod papaver, jusquiamus mandragora plurinum somnum provocant, unde pro sua nimia humiditate, si ex his fiat cataplasms et ponatur loco de quo debet fieri incisio, vel cyrurgia, omnino removebit sensibilitatem.

by Bouisson, who describes an operation for unguis incarnatus, which he was able to perform without pain, after bandaging the toe for several days with applications containing opium. The same idea that remedies which were useful in the artificial production of sleep must be likewise of use for local anesthesia if applied to the skin is once again noted after the introduction of ether and chloroform anesthesia. This was most strikingly stated by Richardson, who claimed that general and local anesthesia were identical processes brought about by the dehydration of the tissues. Expression was again given to these views in a quotation by Arans: "Que toutes les substances volatiles, auxquelles on a reconnu jusqu'à ce jour des propriétés anesthésiques générales, possèdent également des propriétés anesthésiques locales, ou en application intérieur, ou sur la peau."

Parisot demonstrated that a saturation of the skin can readily be brought about by the application of chloroform, which gave rise to the opinion that local anesthesia could be more readily produced with the volatile inhalation anesthetic agents. The truth of the statements has been partially verified. Some of these substances when used in a gaseous or fluid state on the skin produce, after more or less severe irritation or destruction of tissue, superficial and fleeting disturbances of sensation even when the effect of cold from evaporation is prevented. Simpson, Nunnelly, Aran, and later Kappeler, knowing the intense irritating properties of chloroform, were nevertheless convinced of its efficiency as a local anesthetic. Extensive experiments by Wittmeyer demonstrated conclusively that local anesthesia could be produced with Liquor Hollandicus (Ethylenechloride) and ether hydrochloricus chloratus (a mixture of tri- and tetra-chlorethylchloride). Experiments along these same lines had already been carried out by Wutzer, Aran, and Nunnelly. Other inhalation anesthetics like ether sulphuricus and amylen were ineffective when applied to the skin. Corning, in later experiments, was unable to produce local anesthesia under any circumstances with chloroform, while Bumm, after trying the preparations recommended by Wittmeyer, found the relief from pain so fleeting and incomplete that the anesthesia was insufficient for the most superficial or shortest surgical operation. These experiments were barren of practical and useful results and have for us about the same historic interest as the cataplasms of the professor of Salerno.

We might next consider other agents which were used experimentally in an effort to discover practical methods for inducing local anesthesia, the value of which are doubtful except in the minds of the originators. An experiment with one of these reputed agents has been described by Simpson and Nunnelly, who stated that prussic acid was the best local anesthetic, a belief shared by many others, notwithstanding the fact that no one carried out an experiment to prove the truth of this assertion. Simpson finally tried the method by placing his finger in a glass containing prussic acid, but on account of alarming toxic symptoms was compelled to discontinue the experiment. Percival in 1772 discovered that under certain conditions CO_2 could be used as a local anesthetic. Later Ewart and others advised the use of carbonic acid in the form of a spray in cases of painful ulcers. In 1774 Ingenhous and Beddoes demonstrated experimentally the sedative effect of carbonic acid on parts of the body from which the epidermis had been artificially removed. Broca and Skinner tried this method with success in painful affections of the bladder, and Simpson, Follin, Scanzoni, Maisonneuve, Monod, and Demarquay in diseases of the female genitalia and various other surgical conditions. All observers agreed that carbonic acid applied to the intact skin produced no anesthetic effect, for which reason it was very seldom used in operative work.

Guerin advised the burning of a small strip of skin with Vienna paste around the field of operation; strange as it may seem, this method was advocated not during the Middle Ages but in the year 1883.

The results of the superficial application of volatile liquids to the skin for the purpose of inducing anesthesia were up to this time very unsatisfactory and impractical. Richardson now advocated the use of the electric current in aiding the absorbtion of these agents to which anesthetic properties had been ascribed. In short, from numerous observations it was thought that the galvanic and faradic currents were alone capable of producing local anesthesia. On the advice of Francis, a dentist from Philadelphia, Suerssen and many others carried out experiments for the painless extraction of teeth, using electric currents. Foussagrives, Bygrave, Friedrich and Knorr used this method for similar purposes in performing minor operations. Their results were lauded with enthusiasm, notwithstanding the fact that Nussbaum, von Bruns, Bumm and others had proved the absolute uselessness of the method. We know today without doubt that neither the induced nor constant current has any effect in the production of local anesthesia which would be of use in minor surgical work. Bumm has said: "The very conflicting statements of various authors would be difficult to explain, were it not for the fact that one must always remember the self-delusion of the operator on the one hand and the varying or even untruthful statements as to subjective feeling on the part of the patient on the other." This statement is certainly true, for everywhere in the history of local anesthesia the role of suggestion and auto-suggestion is found playing a large part. No matter how imperfect a method of local anesthesia may be, it will still have its adherents. The same state of affairs is occasionally found today.

Richardson's "Voltaic Anesthesia" consisted in the application of the positive electrode of the galvanic current to the skin, the sponge of the electrode being wet with the solutions of the tincture of aconite, extract of aconite, and chloroform. He conceived the idea that the circulation in the part to be anesthetized would be increased in rapidity from the irritation of the galvanic current, and would therefore be better fitted for the absorption of the narcotic drug with consequent anesthesia. The control experiments of Wallers proved that the slight insensibility of the skin produced by this means, even with the accompanying severe irritation, was due to the drug itself and was in no wise dependent upon the electric current. Much later (1886) Adamkiewicz tried to aid the absorption of chloroform by the skin with the cataphoric action of the electric current. Paschkis and Wagner, and later J. Hoffmann, demonstrated that cataphoresis did not occur with the electric current used in connection with the non-conductor chloroform. In regard to the newer and more fruitful efforts with cataphoresis. See Chapter IX.

Anesthesia of mucous membranes by means of local applications seems to have been little, if at all, attempted in former medical times, although more should have been expected from these tissues on account of their greater permeability than from the intact skin. Carbonic acid had been used for purposes of local anesthesia as previously mentioned, and seems to have been applied to the mucous membranes of the mouth, pharynx, bladder. and female genital organs. In more recent times Brown-Séquard mentioned that the larynx could be made absolutely insensitive by allowing a stream of carbonic acid gas to play against the back part of the throat for a few minutes. Gellé used with success applications of CO_2 gas to the external ear for relieving earache. Attempts at producing local anesthesia of mucous membranes by the vapor of ether or chloroform have been occasionally noted in the literature, but the extensive use of this method never found general acceptance. The discovery of the laryngoscope in 1857, and with it the development of laryngology, brought about a most urgent need for a means of anesthetizing the mucous membrane of the larynx. In the year 1862 Lewin made the statement that a drug for producing local anesthesia of the larynx did not exist. Huette and Czermak recommended potassium bromide for the larynx, but their results could not be verified by Lewin, Scheff, and others. The results of Tuerck, Bruns and Schroetter, and later Scheff, in anesthetizing the larynx by applications of chloroform, concentrated solutions of morphine with the addition of vinegar, alcohol, etc., could likwise not be substantiated. These applications produced in only a small percentage of cases a tolerance of the laryngeal mucous membrane to pain, and were not without danger owing to the severe irritation of chloroform. In the use of morphine in such large doses, according to Harris three-fifths of a grain, the possibility of poisoning was always present. Schroetter in his early experience with this method had one death from morphine poisoning. Scheff also warns against the repeated painting of the larynx with chloroform and morphine. Tobold never had satisfactory results with the Tuerck method, and it may be said that in all cases where a satisfactory anesthesia of the larynx was obtained, the result was due to the systemic effect of the morphine.

This method finally became obsolete following the extensive experiments of Zawerthal on dogs, and further confirmed by a large clinical experience.

The discovery by Alexander Wood, of Edinburgh, in 1853, of hypodermic injections by means of a hollow needle, is an important historical fact in connection with our subject. His discovery was most important from the fact that drugs could be introduced directly into the circulation. It also gave us a new method of introducing different solutions of drugs into the tissues so as to come into more intimate contact with the nerve supply and there exert their chemical or physical action, something heretofore impossible. Wood started out with this in mind, using as his first injection solutions of morphine and tincture of opium; this he injected in the neighborhood of nerve trunks for the purpose of utilizing the local anesthetic properties of the drug for the relief of neuralgic pain. Morphine and opium were chosen for the purpose owing to the prevailing idea that sleep-producing drugs exerted their action at the site of injection. The injection of solutions of morphine to obtain local anesthesia in minor operations was used with partial success in the following year for the removal of toe-nails, cauterization of wounds, and ulcers. In some cases results were no doubt due to the systemic effect of the morphine, as in a case of Jarotzky and Zulzer, where the strapping of a testicle with adhesive plaster was done without pain; likewise Walker was able to employ taxis in a case of strangulated hernia, and succeeded in reducing it without pain, following the injection of 1 grain (0.06) of morphine. Eulenburg injected $\frac{1}{8}$ grain of morphine in each side of the exit of the superior laryngeal nerve, through the thyrohyoid membrane, and was enabled in this way to produce an absolute anesthesia of the larynx. Much later (1880) this same procedure was described by Rossbach, but control experiments by others were without results. Tobold, according to Eulenburg, found that sensation of the upper part of the larynx was diminished by these injections, but anesthesia sufficient for operation could not be produced. Chloroform injections were used for purposes of local anesthesia by C. H. Hunter, but were given up because the pains from the injections was far more severe than those from the operation. Pelikan and Koehler, the latter with great reserve, however, advocated the use of the glucoside saponin subcutaneously for the production of local anesthesia, but the severe pain due to this irritating drug, as observed by Eulenburg, Keppler, and Kappeler, prohibited its further use. The use of physiological solutions of proper temperature injected into the tissues for the purpose of dehydrating them, and causing them to swell, belongs to more recent times and will be described later.

It will be seen from the preceding historical sketch how earnest were the constant efforts made during the past for a useful local anesthetic. After the introduction of general anesthesia these efforts were, if anything, carried on with greater zeal. In preanesthetic days surgical operations were always associated with pain in the minds of both physician and patient, but with the advent of anesthesia these conditions changed. Patients now demanded that operations be carried out without pain under general anesthesia, although the method was hazardous. On account of this danger the desire still prevailed to find a method of painless operating without the drawbacks of general anesthesia. The approach to our subject takes us back again to the history of ancient times where the means to the end had already been indicated. In every possible manner, both physiological and chemical, attempts were made to influence sensation in the nerve trunks or their endings for the production of local anesthesia, by the use of cold, compression, and drugs of all kinds. Drugs were applied to the skin and mucous membranes, their absorption being aided by the electric current, or they were injected; yet the only method of use handed down to modern times was the application of cold. The efforts to discover an efficient chemical anesthetic, which was the punctum saliens, failed completely, and until the discovery of such drugs, local anesthesia was without tangible form. The new era, therefore, began in 1884 with the introduction of cocaine, which in its physiological reactions differed from all heretofore known substances. The history of local anesthesia was in the following years synonymous with cocaine anesthesia and will be considered in another chapter.

CHAPTER II.

SENSATION AND PAIN—ANESTHESIA AND ANESTHETIC METHODS.

THE ability of the living body to react to stimuli affecting its nervous elements so as to cause reflexes, perception, feeling or conception, is termed sensation. The senses of feeling, hearing, smelling, tasting and seeing, likewise pressure, temperature, and muscle senses, allow us to appreciate the condition of our surroundings as well as the nature of our own bodies, but what interests us particularly in this connection is the subject of pain. Pain is a sensation feared by man, the alleviation of which is being constantly attempted by the physician. It, however, acts as a conservator of the species by giving evidence of illness in the human body. Pain from injury gives evidence of threatened danger from without which can still be avoided, or that damage to the body has already taken place requiring immediate attention to prevent more serious consequences. Pain acts as a monitor, warning us of improper ways of living which, if continued, will interfere with the general health. It precedes or accompanies the outbreak of disease and warns one that the body is sick and needs attention. Pain due to physical or mental overwork requires rest and recreation. The patient seeks to protect a painful organ causing symptoms in a definite diseased part of the body. Pain is the best assistant of the physician. The sick follow its instructions obediently, and demand definite advice for correct living from their medical advisers. Nature, by means of pain, compels even the most active to rest, the most wilful to observe proper living conditions for the diseased body. Pain is a severe but necessary law of nature, but like all her laws is undeviating in its course, insensible in its regard to feeling, appearing, therefore, brutal and grewsome. It appears not only as a beneficent monitor but also as a useless tormentor. In incurable diseases, also in affections which though understood we are unable to influence, pain occurs and takes away unsparingly the pleasures of life without offering any bodily advantage in return (Goldscheider). Pain is often absent in the most dangerous diseases, thus giving the patient false assurance. It is present and must be relieved by the physician whenever the patient undergoes operation. It is certainly the duty of the physician to attempt the relief of pain. That it is not to be banished from the world is a certainty, in fact we would not wish it otherwise. Pain is necessary not only for guarding us in the fight against the forces of disease, but also as a monitor of our emotions, for in the recollection of pain either bodily or mental lies in large part the cause of compassion and the helpful love of mankind (Goldscheider).

Pain sense like all the other senses is associated with the functioning of the cortex of the brain. According to Flechsig the pain-transmitting fibers end in the cortical sensory area, the latter corresponding in part to the cortical motor area. By interrupting fibers from the corona radiata, in the region between the anterior and posterior ends of the thalamus, complete anesthesia is produced on the opposite side of the body (Tuerck's hemianesthesia). Flechsig believes that the centre for painful impressions is located in a different area of the sensory cortex than the sense of touch, probably in the forniculate gyrus. Painful sensations following irritation are probably conveyed to the brain through the peripheral sensory nerves of the brain and cord. In the cord it is generally believed that painful impressions are transmitted through the gray matter. Whether the sympathetic nervous system can receive and transmit painful impressions is doubtful.

A suitable irritant (mechanical, chemical, thermic, or electrical) can produce pain equally as well when affecting the end organs as when affecting the nerve in its course. The former painful sensation appears to be much more severe than the latter. It has been demonstrated by the surgeon that the brain, at least on its convex surface, is absolutely insensitive to pain or pressure. In this respect this pain centre is like controlling the special senses, because it has been fonnd that direct irritation of the brain centres controlling the special senses does not produce impressions of light, hearing, etc. For the brain to become responsive it seems necessary that the irritant must be transformed in some way by the outer sense organs. Clinical experience seems to prove that neither the brain nor cord has pain sense. Painful impressions produced upon the cerebral cortex are projected from the brain to various parts of the body, likewise irritation of a sensory nerve trunk produces its effect in the area of distribution of the nerve. If the trunk of the ulnar nerve is pricked at the elbow with a fine needle, sensation or paresthesia will be experienced in the fourth and fifth fingers; the feeling may be that of pressure, temperature change, or pain. A second pain will now be experienced at the point of irritation, and inasmuch as this nerve trunk has no local branches, this feeling of pain must be transmitted to the brain by the nervi nervorum (Goldscheider). The localization of painful impressions, as is well known, is very often uncertain and gives rise to various errors. Pain in a definite part of the body or in a certain organ, can originate in this part or organ, or be due to the stimulation of its conducting nerves or the brain itself. Although the brain is apparently insensitive to ordinary stimuli, there is no doubt that pain is often not peripheral but of central or cortical origin.

It is still undecided whether pain is produced by a specific action of the senses, or whether the conducting nerves are associated in their course with particular end organs. The most generally accepted theory is that of Goldscheider, who claims that pain is produced by excessive irritation of the usual centripetal nerves of pressure and common sensation. Pain and pressure sensations are not different varieties, but due merely to a difference in degree of the irritant; with slight stimulation, the feeling of pressure occurs, while a greater degree of irritation produces pain. Frey opposes this theory and holds strongly to the existence of special nerves of pain, having their end organs in the intra-epithelial cells of the skin. Both of the above theories are supported by actual observations and clear-cut reasoning, but to decide between them would be out of place at this time, except to say that in certain clinical cases of disease of the brain or cord associated with isolated paralysis of the senses of feeling or pain, it would be very difficult to explain these conditions, if we did not believe in the existence of separate tracks and end organs. The experiencing of excessive pain from irritation is called hyperalgesia; a diminution of pain sense is termed hypalgesia. Hyper- and hypalgesia are very often of central or pyschical origin. The expression and degree of pain varies greatly with the individual and is influenced by innumerable circumstances, such as character, breeding, the intelligence of the individual, his general conception of things, nationality, age, sex, and general physical condition.

The outward expression of pain is of course no guide as to its actual intensity, as pain is largely dependent upon the psychical condition of the patient. A sudden unexpected injury of the body is not found to be painful; a needle-prick is painful when expected. If the mind is otherwise occupied no pain is felt. Kant was able to intentionally concentrate his mind on certain themes, so as not to feel the pains of gout from which he was suffering. The thought of pain, or better, the fear of pain, as we are really not able to imagine severe pain, increases its intensity. Strong-minded, intelligent persons give less expression of pain than weaker or less intelligent ones; the latter will feel pain where others would not. The tolerance of pain varies with the epochs of time and the class of people. Those of the hard and grewsome Middle Ages were less sensitive than those of the modern world of culture; even today the uncivilized races are less sensitive. We cannot compare the atrocities of the Middle Ages and those existing among certain tribes of the present day, or the castigation, self-mutilation, or self-offering of Christian and heathen fanatics with our conception of pain. We need have no sympathy with the actor who in public allows needles to be stuck into his body, as appreciation of pain is entirely lacking in him. Mucius Scaevola, who in a moment of intense excitement thrust his hand into the fire, did not suffer to the same extent as an individual compelled to do a certain act. People of the North seem to be less sensitive than those of the South; city-bred are more sensitive than the majority from the country, while old persons are more tolerant than those in the prime of life. The physician, and more particularly the surgeon, meets with these physical variations of sensation almost daily and he must know beforehand what demands he can make on the patient to be operated upon without an anesthetic. Certain it is that the conduct of patients during painful procedures is often only a variation in the outward expression of pain; nevertheless we must assume that in certain individuals and some races the physiological pain sense is less highly developed than in others. In the newborn the pain sense is only slightly developed, it being very probable that this sense is developed later in life and to a varying extent just as the other senses are developed. How and in what form hyperesthesia and hypesthesia occur in diseases of the brain and cord we will not discuss at this time.

Peripheral causes can produce an aggravation or lessening of pain. The pain sense of organs or tissues, when the latter are subject to disease, is often increased, seldom diminished. Acute inflammation and fluids confined under pressure give rise to spontaneous pain and often excessive hyperesthesia. The fact that an organ in health, without feeling and under pathological conditions, suddenly becomes painful is difficult if at all possible of explanation. The ability to receive and transmit painful impressions to the brain must be present in the healthy state if disease can increase it. It might also be mentioned that local disturbances of nutrition, such as chronic edema, can diminish the sensibility of a part; the cause is probably to be found in the fact that the physical and chemical composition of the edema fluid is different from the normal nutritive fluids so necessary for the correct functioning of nervous elements.

Of no small importance for local anesthesia is the distribution of pain sense in the different organs and tissues. It is certain that organs have parts of marked sensibility, areas of diminished sensation, and in places absence of feeling. To arrive at positive conclusions is not easy, as experiments would have to be conducted on living human beings. Then again we possess no means of measuring the intensity of pain. We are largely dependent for facts of this kind upon experience gained in operating upon the unanesthetized patient. In more recent times Bloch and Lennander have investigated this subject and collected what little there was to be found in the old literature. The observations of Bloch are rather misleading and, therefore, objectionable because they were made among a people apparently very insensitive to pain, and were carried out under the suggestive influence of the operator, and in many cases small doses of chloroform were given sufficient to bring about the so-called stage of analgesia. Some few observations are noted by Schleich and others in their works on surgery and local anesthesia.

The skin with its innumerable nerve endings can be said to be the most sensitive tissue in the body. In olden days when amputations and herniotomies were performed without general or local anesthesia, patients complained most when the skin was cut, while the balance of the operation was comparatively free from pain (Montfalcon). Bloch cites numerous proofs to support the fact that many operations are easily borne if the skin alone is rendered insensitive. Pain perception in the skin is not evenly divided over the surface of the body; the skin of the back, for instance, being much less sensitive than that of the finger tips; the extensor surfaces of limbs being in general less sensitive than the flexor surfaces. In disease, particularly the acute inflammations, the skin becomes extremely sensitive, so that the slightest touch, in fact every manipulation in the region of the inflamed area, is very painful.

The loose subcutaneous connective tissue possesses very little, and at times no feeling, though numerous conducting nerves containing sensory fibers for the skin traverse this area. These nerves are frequently connected with the bloodvessels, and are contained in strong connective tissue sheaths. The larger the nerve trunks the more deeply they are situated, usually in the region of the fascia. Pain of varying intensity, depending upon the location and individual, is often produced by cutting, pressing, or pulling on the nerves in the subcutaneous tissue with hooks or other instruments, or in picking up and tying bloodvessels. The nerve distribution in muscle is practically the same as that in connective tissue. In operating upon unanesthetized patients one finds in the numerous connective tissue septa of the muscle bundles many areas painful to mechanical irritation; these correspond to sensory nerve tracks. Sticking a needle in the muscle of a healthy person is in most situations free from pain, but if one of the sensory tracks is touched by the needle pain promptly occurs. Tendon tissue appears to be without feeling, as can be readily demonstrated during tendon suture; however, the connective tissue surrounding tendons, tendon sheaths, muscle fascia, and the associated layers of connective tissue, possess a varying degree of pain sense due in all probability to nerve endings in these parts. Besides observations made during operations upon injured parts, one can readily demonstrate these facts upon his own body. Use for this purpose a very fine steel needle. This is passed through the skin into the underlying connective tissue in any part of the body, after first making the skin insensitive by the formation of a wheal in the manner to be described later, so that the skin sensation can be excluded. The needle can be moved in all directions parallel to the skin surface and, as a rule, no pain is felt. Only in certain places where the needle encounters nerve trunks will there be sensations of paresthesia or pain. The needle is now passed perpendicularly into the deeper parts and as soon as it comes in contact with the muscle fascia or the surrounding connective tissue, pain is experienced, as a rule not excessive; in some few places there seems to be an absence of sensation. This pain is fairly well localized. Sensations other than pain, such as pressure or touch, are never produced in fascia; likewise sensations of paresthesias which are characteristic of the irritation of nerve trunks going to the skin, never occur.

Pain of a like character is felt when the needle-point touches the surface of tendons such as the tendo-Achillis. The transfixing of this tendon is painless, yet when the needle emerges upon the opposite surface the pain is again felt. The sensation is always one of pain, and never any other. Tenotomy of the tendo-Achillis with only anesthesia of the skin is for most persons a very painful operation, even though contrary to the experiments of Bloch.

Periosteum, according to Haller, Piory, and Bloch, possesses no pain sense, at least in the healthy state. This appears rather extraordinary considering the richness of its nerve supply. This assumption is certainly not correct, for if the periosteum of a healthy person is tested in the manner before described, places will be found where it is extremely sensitive. The anterior surfaces of the tibia, ribs, patella, and alveolar processes have scarcely any point which is not as sensitive as the skin itself, the pain being fairly well localized. On the posterior surface of the tibia and the outer surfaces of the femur, radius, and fibula, experiments will demonstrate that painful areas are much less numerous, and there are places between the painful areas where the needle produces no localized sensation. It appears that the pain was felt only after severe prodding with the needle so as to jar the entire bone. Throughout this structure, moreover, no other sensation than pain is produced by irritation of either periosteum or bone. In head injuries with exposure of periosteum, tests of this membrane or attempts at stripping same from the bone, are without exception very painful. Sensitiveness of the periosteum of the jaw is a daily observation, the degree of sensitiveness as in all other parts being in large measure influenced by the place and the individual. In general, therefore, the periosteum must be considered a very sensitive structure even under normal conditions. Lennander's observations coincide with these findings.

In regard to the pain sense of bone or its marrow, the following should be noted: Montfalcon says that patients undergoing amputations complain bitterly of pain on cutting the skin, less on cutting muscle, and not at all on sawing the bone. Piorry, on the contrary, claims that the medulla of bone in sawing, passing sounds, or on the injection of irritating fluids, is extremely painful. Reid in describing amputations under local anesthesia claims that a sharp narcosis is necessary in sawing through the bone. Schleich also claims that the bone and medulla are sensitive. According to the observations of Bloch, in amputations and chisel operations the medulla has sensation, but no pain sense. The cases in proof of this assertion are not very strong evidence as they were carried out under light chloroform anesthesia. Bichat, quoted by Bloch, claims that pain sense is more marked in the central part of the diaphysis of long bones than toward the epiphysis. The medulla of short and flat bones is less sensitive.

This is certain: bone receives the sensory supply which it undoubtedly possesses from the periosteum. If the periosteum is completely separated from the bone, or rendered insensitive by artificial means, the bone in this location and in its entire cross section becomes absolutely insensitive. In partial removal of periosteum, the bone thus uncovered is painless and can be chiseled. The medulla of bone, according to Schleich is not free from pain sense, and he thought it necessary to anesthetize it. Piorry's observations in sounding bone sinuses indicated that the medulla was painful. This is not correct, according to recent observations made on large cavities in the tibia, the anterior wall of which had been destroyed by osteomyelitis, although the periosteum of the posterior surface of the bone was retained. Painful sensations were only experienced in a few places in the bone, and not of severe degree. Such bone cavities can be curetted, and only when the periosteum at the margin of the cavity is touched does the patient complain of severe pain. Other sensations than pain are not observed in such a bone; pressure and temperature senses are positively absent. Only the shaking of the entire bone or extremity is felt, which is probably due to the change of position.

Cartilage is insensitive (Bloch, Lennander), while perichondrium, when present, is rich in nerves and is undoubtedly sensitive to pain.

Joint capsules, ligaments, and synovial membranes usually require to be anesthetized before operation. The sensitiveness of synovial membranes is very pronounced, even in uninflamed conditions, which is certainly to be expected in consideration of their ample nerve supply. The injection of irritating fluids into a joint is usually very painful; also in arthrotomy of the knee-joint the synovia was found very sensitive. Joint capsules and ligaments contain nerve tracts which cause more or less pain on pulling or cutting. Haller states that ligaments and capsules are insensitive; according to Bloch, no one tissue of a joint possesses marked pain sense. The example which Bloch gives among others to prove the truth of his assertion is as follows: Girl, aged twenty-nine years, suffering from a chronic ostitis of the external condyle of the femur. An Esmarch band was applied, ethyl chloride sprayed on the skin, after which an incision 6 cm. long was made without pain. The knee-joint was opened and its interior probed in all directions to determine its sensibility. The periosteum was separated from the external condyle, and the diseased bone area was removed with chisel and curette. The operation lasted eleven minutes; the patient experienced no pain, which cannot be ascribed to the ligation of the extremity, owing to the short time required for the operation. A similar example of a painless operation may be noted: On July 7, 1899, a laboring man was operated upon for a pseudoarthrosis of the ulna. Except that he was slightly excited his nervous system was perfectly healthy. The skin incision was made after infiltration with cocain, the bone was exposed, periosteum separated, the connective tissue between the bone ends was excised, the bone ends freshened and sutured with wire, and the wound closed with sutures. The patient felt no pain during the entire operation, lasting one hour and a half.

October 19, the operation was repeated without an anesthetic of any kind, as bony union had not taken place. The operation was again performed, without pain according to the statements of the patient. The question of anesthesia in cases of this kind can be readily explained, for whether the skin is deadened with ethyl chloride or not, the patient does not complain and does not feel the pain of operation. To generalize from such experiences, which, no doubt, all surgeons have had, is not possible, and to use such patients for studying sensation is of no value. It is scarcely worthy of consideration to believe that the tissues before mentioned, innervated by the cerebrospinal nerves, can develop a high grade of pain sense in consequence of an acute inflammation or a central or physiological hyperesthesia, and under ordinary conditions be free from pain.

The mucous membranes of the mouth, nose, and pharynx are all more or less sensitive to pain in the healthy state; this can likewise be said of the mucous membrane lining the antrum of Highmore, the frontal sinuses, and tympanic cavity.

We encounter now for the first time a truly insensitive organ, namely, the mucosa of the stomach and intestinal tract. Absence of sensation, even in the most sensitive persons, begins in the esophagus, the swallowed morsel being lost to sensation as soon as it passes the pharynx. This lack of sensation extends to the rectum, painful sensation again appearing in this part and becoming most pronounced in the anal portion. The absolute lack of sensation of the mucous membrane of the colon to mechanical, chemical, and thermic irritation was observed by Steinhaeuser in 1831, and can be readily demonstrated on the anus preternaturalis when fixed to the anterior abdominal wall, or after excision of the rectum; on the sigmoid, fixed either to the anal or sacral region. These experiments were carried out, among others, by Bloch and Lennander; the author has also been able to demonstrate the insensitiveness of the sigmoid years after the excision of the rectum. The sensibility of the abdominal organs will be considered again later. The degree of pain sense in the larynx does not seem to be very pronounced, but it is difficult to determine, owing to the highly developed reflexes in this organ. Foreign bodies in the larynx, or a diseased condition, only cause severe pain when producing pressure on the perichondrium. The tracheal mucosa, according to Bloch and Lennander, is insensitive.

The urethral mucous membrane under normal conditions is very sensitive, though Bloch declares the cutting of the urethral orifice to be but slightly painful. This statement will be borne out by very few patients. Whether the pain following the stretching of the urethra occurs in the mucous membrane is questionable. The mucous membrane of the normal bladder is but slightly sensitive, in fact parts are found without sensation. Bloch reported on opening the bladder by sectio alta, that the inflamed mucous membrane at the fundus was insensitive, while that at the neck of the bladder was quite tender. Suprapubic cystotomy is frequently performed today under local anesthesia, and has demonstrated that the bladder mucosa is everywhere more or less sensitive and requires to be anesthetized. The mucous membrane of the introitus vaginæ is extremely sensitive, that of the vagina very much less so, notwithstanding Lennander's claim that the vagina is insensitive. The mucous membrane of the uterus is only slightly sensitive.

Another organ which gives absolutely no reaction to outside stimuli is the brain. As has already been stated, clinical experience with diseases of the brain does not sustain the assumption that this organ has any pain sense. Observations by surgeons have established the fact that at least the convexity of the hemispheres is insensitive. On two occasions this observation was made with patients who were perfectly conscious; the first was a patient in whom an abscess was opened in the motor area, because it was thought in this instance that the abscess was deeply located in the hemisphere on account of persistent temperature; the other observation was made during a secondary operation on a patient with a bone defect in the skull, when recurrence was expected following the removal two years before of a gliomatous brain cyst. In both cases the hemispheres were punctured in all directions, and in the first case the abscess was incised. The patients complained of neither pain nor other sensations. Bloch, Schleich, and Lennander have demonstrated the insensitiveness of the exposed brain. With the change of dressing following operations on the brain and in complicated fractures of the skull all surgeons have observed that the brain is insensitive. The dura mater, according to Piorry, quoting Berefield, Legat, Fontana, and Caldani, is sensitive to pain, while Chaussier, Richerand, and Portal (Cited by Bloch) hold the dura to be absolutely insensitive. At the present time it has been found in operations on the convexity of the skull that the dura is absolutely insensitive, while operations toward the base are painful. These facts were demonstrated on two different occasions, the first time during an osteoplastic resection of the skull for the removal of a glioma in the motor area. Toward the convexity, the dura was insensitive as usual, while toward the base about the height of the malar bone the dura was painful. In the second case a dermoid of the occipital bone in the region of the occipital tuberosity had perforated both the external and internal table of the skull and was adherent to the dura. After anesthetizing the external nerves it was possible to dissect free the cyst and remove the overhanging parts of the external table without pain; cutting the dura, however, was very painful notwithstanding the absence of pain in all other parts.

Observations as to the results just mentioned have been proved in late years by numerous operations on the skull and brain carried out under local anesthesia. It has also been found in operations on the cerebellum that the dura of the posterior fossa of the skull, as well as the cerebellum itself, is free from pain on moving, pressing, crushing, or cutting it.

We have to thank Lennander for his interesting and important observations on the sensibility of the abdomen and the abdominal organs. The older statements in this regard are very conflicting. Haller claimed that the peritoneum and mucous membrane of the intestines were without sensation, while the submucosa possessed feeling. In animals the liver, spleen, and kidneys were found to be very slightly sensitive. Piorry claimed the serous membranes were sensitive, and cites the experience of Bichat as proof, the latter having seen dogs eat their own intestines which had been extruded through an abdominal wound. E. H. Weber held that prolapsed human intestines were insensitive to cold and pressure. Since the introduction of cocaine many abdominal operations have been performed without general anesthesia, and surgeons have had ample opportunity to convince themselves of the insensitiveness of the stomach and intestinal tracts, together with their peritoneal covering. The opinions of Flourens, Richet, and Bloch were that abdominal organs in an inflamed condition could become painful. Lennander refuted these statements in consequence of many individual observations, carried out partly under local anesthesia on organs brought outside of the body or sewed in the abdominal wall. He proved conclusively that the peritoneum of the anterior and posterior abdominal wall, pelvis, and diaphragm, the latter as far as it is supplied by the spinal nerves, were sensitive to pain whether in a normal or diseased condition. The visceral peritoneum of the stomach, intestines, omentum, gall-bladder, kidneys, and liver, even in the state of acute peritonitis or other diseased conditions, does not possess sensory nerves reacting to the usual mechanical and thermic irritation, for the production of pain, touch, warmth and cold. These parts can, therefore, be crushed, cut or burned without producing any sensation. The pain elicited from the parietal peritoneum by the use of clamps, cutting, burning or pulling is very pronounced even in health, and as a rule is much increased in inflamed conditions. The pain can be localized in so far as the patient knows whether the irritation is right or left or in the upper or lower parts of the abdomen. Lennander, experimenting on the mesentery, could not arrive at positive results; pulling on the mesentery produced pain, and he believed that operations on the mesentery were pain-free if pulling was avoided; nevertheless he observed that clamping the mesentery of the appendix with an artery forceps produced severe pain.

That the observations of Lennander are correct, as far as they concern the walls of the stomach and intestines, has been proved by surgeons in hundreds of cases. No matter under what conditions the operation is performed, whether the patient's abdomen is opened under "ether narcosis" or the abdominal wall is made insensitive with cocain or other anesthetics, whether the operation is carried out under general anesthesia or other sedatives, whether the intestines are operated upon after being out of abdomen for a long or short period, or whether the stomach or intestines are sutured through a small incision of the abdomen and immediately opened, whether this particular part of the intestine is normal, inflamed, or otherwise altered, the stomach and intestinal walls are always found to be without sensation. At the same time the parietal peritoneum is extremely sensitive everywhere, unless made artificially anesthetic. Ritter is the only author who is supposed to have seen the small intestine in the human being sensitive to mechanical and thermic irritation.

Lennander has added much to our knowledge regarding the sensibility of the mesentery. In a communication from Bier, he states that according to his observations ligation of the mesentery is usually painful. Other observations made during an intestinal resection have also been described, in which every ligature caused severe pain. In many cases these painful reactions do not occur, particularly when the mesentery is ligated close to the intestinal wall. These observations seem to point to the conclusion that the sensibility of the mesentery varies, sometimes being close to the intestines, and at other times farther away from them. Wilms has verified these observations. It has also been demonstrated that the pinching of the mesentery in an avascular area 6 cm. or more from the bowel is free from pain, while pinching the vessels 2 to 3 cm. from the bowel elicits distinct pain. The close association of nerves and bloodvessels in the mesentery has been studied in animals and man by Ritter and Propping. It should also be noted that in strangulated hernia the mesentery is without sensation, as the strangulation not only can but must produce loss of feeling. It is a fact well known to surgeons that the clamping of the mesentery in the deeper parts of the abdomen or the ligating of the lesser omentum, as a rule, causes severe pain to patients not under the influence of a general anesthetic. No one doubts today that the mesentery of the human being is possessed of a pronounced sensibility. The observations of Wilms and Hesse on the appendix and its mesentery are of much importance and coincide with the experience of others, viz., that the appendix has no pain sense but its mesentery is painful to manipulation. In ligating or clamping the mesentery of the appendix pain is complained of, not localized to this region but, as a rule, referred to the epigastrium. The intensity of this pain is quite variable, at times so slight as to be only determined by questioning the patient, at other times so severe as to require general anesthesia for its relief. This same sensation occurs from pulling on the appendix or cecum. The remainder of the mesentery reacts in a similar manner. The great omentum is usually, but not always, insensitive.

According to the experiments of Kast, Meltzer, Ritter, and Propping the walls of the stomach and intestines of dogs and rabbits are sensitive to pain, these results being alone denied by L. R. Moeller. Meltzer and Kast have made the observation that in animals poisoned with cocain not only is the skin, cornea, and parietal peritoneum insensitive, but the sensation of the stomach and intestinal tract is also lost. It has been claimed by these authors that the diminished sensibility and absence of pain sense in the intestines of persons injected with cocain for purposes of local anesthesia is of a similar nature, but Wilms, Propping, and Nystroem have taken exception to this theory, as disturbances of sensation of this sort are brought about only by toxic doses of cocain. This appears likewise in paralyses which are of central and not, as Ritter claims, of peripheral origin. Small non-toxic doses of cocain (0.08 to 0.01 per os [Mosso]) do not cause diminished sensibility, but rather increase it. There is, therefore, not the slightest reason for doubting observations made on persons operated upon under local anesthesia, as they coincide with those made on patients operated upon without cocain or similar drugs (Haim, Mitchell, Wilms, and Propping). Sensations during operation caused by pulling, clamping, or ligating the mesentery differ from other sensations, inasmuch as they are not localized and are apparently of a different character. Some patients do not speak of them as being painful but complain more of uneasiness; this latter feeling can become so severe as to be unbearable to the patient; others complain of colic-like pain. It might be suggested that we alter our terminology and call these expressions of feeling abdominal sensations.

In view of the marked variability of painful sensations in races and individuals and the more pronounced character of abdominal sensations in certain animals, it is not surprising that a sensory zone of the mesentery is occasionally found reaching the intestine in man. It is only surprising that this observation was made by a single experimenter—Ritter.

Lennander's experiments prove conclusively that the cerebrospinal nerves can receive and transmit painful impressions, while the sympathetic nervous system can not. Froehlich and Meyer have verified these results beyond dispute by their important experiments on dogs. The disappearance of abdominal sensation following Bier's lumbar anesthesia or paravertebral conduction anesthesia (Kappes) indicates that sensation is transmitted to the brain through the spinal cord, independent of the vagus nerve. The active discussion, consequent upon the work of Lennander, regarding the cause of pain in the intestines in diseased conditions cannot be entered into here.

The author opened the gall-bladder twice under local anesthesia and can verify the findings of Lennander, namely, that the fundus is absolutely insensitive to pressure, clamping, or cutting, while pulling on the gall-bladder or sounding the gall ducts is painful; this latter can be demonstrated in all fistulæ of the gall-bladder. According to Ritter the ligation of the cystic artery and tying off of the gall-bladder are painful.

That the liver is without pain sense has long been known to surgeons. The opening of an ecchinococcus cyst of the liver, sutured to the abdominal wall, requires no more anesthetic than the opening of a loop of intestine fixed in like manner. In the opening of a liver abscess in two stages the convex surface of the right lobe, as well as the liver parenchyma absolutely was found insensitive to pain and movement.

Lennander found the kidney, exposed by operation, to be insensitive to operative procedures as well as to heat and cold. It might be added that the kidney was freed of its fatty capsule. Bloch believes that the kidney has very little sensation, while Schleich contends that the kidney parenchyma is practically free from pain sense.

In regard to the uterus, Lennander found the surface of the fundus insensitive to the thermocautery, likewise the ovary and tube. He cited a communication from Viet in which the latter had repeatedly performed Cesarean section without anesthesia, of course not tying off the uterus or removing it from the abdomen. Reclus and Schleich state that in extirpation of ovarian tumors anesthesia of the pedicle is necessary. In three cases of ovarian cystoma which were removed under local anesthesia the ligation and cutting of the pedicle was without pain; the pedicle was not anesthetized. The portio vaginalis is not sensitive to pain, but the pulling down of the uterus during operation is painful. The peritoneum of the fundus of the bladder was found by Lennander to be insensitive.

Investigations regarding sensation in the testicle and epididymis are so incomplete that there is very little to be said at this time. This much is certain, that in operations on the testicle, complete anesthesia of the organ and its coverings is necessary.

The parietal pleura acts just as the parietal peritoneum, and is very sensitive to pain. This can be noted in every exploratory puncture. At the moment of puncturing the pleura the patient complains of pain. This is equally true in thoracotomy if the anesthesia has been incomplete. This observation has also been verified by Lennander. The pulmonary pleura is insensitive. Garré, in describing the technique of lung operations, says: "In operating in two stages, pneumotomy can be performed in the second stage without general or local anesthesia; the lung tissue is absolutely insensitive." It is generally recognized that pleurisy is painful, while central pneumonia and chronic inflammation of the lungs unaccompanied by pleurisy is painless. Lennander has also positively determined that the thyroid gland is absolutely insensitive to mechanical, chemical, or thermic stimuli.

The sense of pain, as we see, is a property of the tissues widely distributed throughout the body. It is often present where the other senses or ordinary sensation is absent. Under the circumstances it is very probable that pain sense has special nerves with specific end organs for its transmission. From a practical point of view local anesthesia will only have a future and be able to compete with general anesthesia if all the tissues in the operative field having cerebrospinal nerves can be made insensitive. The only tissues not requiring anesthesia are those of the brain, abdominal organs, and lungs.

By anesthesia we understand the complete loss of sensation; analgesia signifies only the absence of pain. Anesthesia can be produced by a break in the centripetal conducting sensory nerves, by a paralysis of function in the central end organ in the brain, or by a paralysis of the peripheral end organs in the tissues. If paralysis affects the function of the centres in the brain, we speak of a central anesthesia; this extends over the entire body and is usually associated with a disturbance of consciousness. The latter is intentionally attempted in general anesthesia for surgical purposes, very seldom in hypnosis.

Paralysis of the peripheral sensory nerve organs brings about a condition which in the terminology of the physiologist is called peripheral or terminal anesthesia. It is exactly confined to those tissues in which the function of the end organ is inhibited. If the conductivity of a sensory nerve is interrupted at any point between the brain and periphery, all the tissues supplied by this nerve alone will become anesthetic. This is termed conduction anesthesia.

Terminal and conduction anesthesia when used in eliminating pain in surgery are classed together under the terms local anesthesia or local analgesia. Inasmuch as our methods of local anesthesia produce a paralysis of all sensation just as often as a paralysis of pain sense, without interfering with the special senses such as touch etc., there is no reason for abandoning the old and now universally used term of local anesthesia.

The remedies at our disposal for the production of local anesthesia are partly physiological, and partly chemical in their action. Severe pressure on a nerve trunk renders it incapable of conduction. Severe or long-continued cooling, causing either a swelling or owing to the loss of water a shrinking of nerve elements, will cause a temporary loss of function. This same thing occurs when certain drugs, local anesthetics, are brought in contact with nervous elements. The object of the following chapter will be to give the theory and practice of anesthesia from pressure, together with the history not already mentioned.

CHAPTER III.

THE PAIN-RELIEVING ACTION OF NERVE COMPRESSION AND ANEMIA.

Mechanical pressure on a nerve trunk can cause a break in conduction, with consequent motor and sensory paralysis in the tissues supplied by it (conduction anesthesia). Daily observations in the living, such as the going to sleep of a limb, radial paralysis from pressure on a nerve trunk, experience gained in ligating a limb during amputations for purposes of checking hemorrhage, caused the physicians of former times to utilize this measure for purposes of local anesthesia. We have already followed this history up to the time Esmarch used the elastic tube or bandage for purposes of blood-letting or hemostasis, at which time it became a part of surgical technique. Many investigators at this time studied the physiological action of the anemia in limbs thus ligated, and the majority believed that both sensation and motion were affected. The actual results of these experiments in animals, and in healthy or diseased persons, seem to the majority of observers (Nicaise, Verneuil, Billroth, Fischer, Bruns, Chauvel, Riedinger, Kappeler, Karewski) to produce various forms of paresthesias in the ligated limb but little or no diminution to sensations of pain. Some few experimenters (Neuber, Iverson, Le Fort, Stockes), after ligating an arm or leg, found a fairly extensive anesthesia following, beginning in the fingers or toes and gradually extending to a greater or less degree over the entire extremity. Inasmuch as they all rendered the limb on which they were experimenting bloodless, to the point of interrupting the blood-supply, it seems that the prevailing opinion as to the anemia of the tissues causing disturbance of sensation was not very probable. The old surgeons, Juvet, Thedon, Liégard (see Chapter I) were never of any other opinion than that the pressure on the nerve trunks caused by ligating a limb produced conduction anesthesia in the peripheral parts. If attempts are made to control these experiments in such a way as not only to interrupt the blood-supply but also to exercise a certain measured pressure on the nerve trunks, the following will be noted: Peripheral ligation-anesthesia, as already noted by Krieshaber, Verneuil, etc., only occurs when the pressure of the constricting rubber tube far surpasses the pressure necessary to interrupt the blood-supply. Very strong ligation is necessary in order to produce a diminution of sensation in a reasonable length of time, and then this is usually confined to a hand or foot. The intensity and extent of ligation anesthesia will be in direct proportion to the degree of pressure on the nerve trunks. The more widely distributed the peripheral sensory disturbance, the greater the subjective pain at the point of ligation, the pain being often unbearable. The degree of pressure on a nerve is not only dependent upon the tightness of the ligature but also on the condition of the limb, the nature of the ligature, and the place of ligation. In the upper arm of a thin woman or child a carefully placed rubber band readily interrupts the blood-stream without causing peripheral sensory disturbance or subjective pain of any consequence. In muscular limbs this is not sufficient, and strong pressure is necessary for the interruption of the blood-stream which at the same time interferes with nerve conduction. A wide rubber band naturally causes less pressure than a narrow one placed on a circumscribed area. A rubber tube wrapped tightly about a thin upper arm, rapidly produces muscular and sensory paralysis, and as is well known the motor paralysis may be persistent. Motor and sensory paralysis occurs quickly in the area supplied by the radial nerve if a rubber tube is wrapped about the upper arm where the nerve trunk lies to the outer side and unprotected by muscle. For the reasons just mentioned the degree of pressure for the nerve trunks is difficult to estimate and easily explains the difference in the observations of the before-mentioned authorities.

The fingers are much more suitable for these experiments than the larger sections of the limbs, as the finger base is readily compressed, light pressure being sufficient to control the blood-stream, thus producing constant experimental conditions so that the questionable factor of the degree of pressure can be eliminated. The fingers will stand a severe degree of constriction for a considerable length of time without danger. For these experiments a number of rubber bands are necessary, varying in thickness and strength. The bands which we will term No. 1 will stop the circulation with the least possible pressure, as judged by the color of the fingers, the bands No. 2 exert medium pressure and those designated as No. 3 strong pressure. All these bands are applied by rolling them along the finger from tip to base.

The results of these experiments can be explained in a few words. Bands of weak and medium strength are left in place two hours. With bands No. 1, besides paresthesia and numbness, only a diminution of the sense of touch in the phalanx is noted. With bands No. 2, loss of the same sense of touch is present, which, beginning in the end phalanx gradually extends to the middle phalanx. The feeling of a needle-prick is probably increased after two hours; at any rate it is not diminished. Bands No. 3, exerting strong pressure after half to one hour, besides the previously mentioned sensations, cause a distinct diminution of the sense of pain in the terminal phalanx which occasionally extends to the middle phalanx. Severe sensory disturbance is present during the time of ligation. On releasing the ligature, sharp, shooting pains of short duration occur in the finger. Although disturbance of sensation begins in the finger tips and extends toward their base, and the extent and intensity of this anesthesia is in direct proportion to the pressure, still the anemia of the tissues remains the same.

According to more recent investigations by Boeri and Silvester, pain sense of all the senses is the most resistant to pressure on the nerve trunks and disappears last. The first senses to disappear are those of touch and pressure, temperature sense occupying an intermediate position.

The author observed complete anesthesia of the finger but once sufficient for operative work. In this case the base of the middle finger was bound very tight with several turns of a very thin rubber band. In about fifteen minutes the finger was perfectly insensitive, and remained so after the removal of the band, and not until several months later did normal sensation gradually return. There were no disturbances of circulation at the site of ligation, the condition being due to a pure nerve lesion, a nerve crushing, as it were, with its usual consequences. After tight ligation of an arm or leg a persistent motor paralysis is more likely to result than a sensory paralysis. According to the experiments of Luederitz the motor nerves are more easily paralyzed and injured by pressure of a band than the sensory nerves; at the same time the sensory nerves recover sooner than motor nerves from pressure paralysis. These observations coincide exactly with clinical experience (anesthesia paralysis and compression myelitis).

We must conclude from these observations and experiments that the surgeons of old were perfectly right in attributing ligation anesthesia to pressure on the nerves. The anemia accompanying ligation, with its consequent disturbance of nutrition, is only of secondary importance, as a diminution or loss of sensation from this cause occurs quite late, as can be observed in tightly ligating a limb. A finger rendered anemic requires considerable time before a benumbed or painless condition ensues.

The reaction of nerve tissue to diminished or interrupted circulation is not uniform. The brain, medulla and spinal cord of warm-blooded animals is very sensitive to fluctuations of blood-pressure, while the peripheral nerve trunks, on the contrary, are independent of the oxygen supply to a great extent (Ranke and Ewald) and retain the power of transmission hours after the cessation of the blood-supply (Schiffer). The end organs of sensory and motor nerves, exclusive of the retina, occupy a middle position between these extremes. Schiffer's experiments on warm-blooded animals demonstrated that it requires about one hour after the cutting off of the blood-supply for loss of function to occur. In apparent contradiction to this is the so-called Stenson experiment (the high ligation of the abdominal aorta) of the physiologists, in which an immediate sensory and motor paralysis occurs in the lower extremities. Schiffer and Weil have shown that this sudden paralysis was due to the simultaneous complete anemia of the lower segment of the cord, and did not occur if the aorta were ligated lower down just above the point of its division, thus limiting the ischemia to the lower extremities. It was possible for Ehrlich and Brieger, in carrying out the Stenson experiment on rabbits, in those that lived long enough, to demonstrate that the largest part of a cross section of the gray matter of the cord in its lower segment was destroyed as well as the more important motor areas in the white substance. Singer and Spronck later studied in histological detail the cause and course of this anemia-necrosis.

This question will probably require further investigation, consequent upon the recent animal experiments of Katzenstein and the cases of Schlesinger, in which the latter saw ischemic sensory paralysis of the lower extremities occur a few minutes after the sudden blocking of their bloodvessels by embolism. The work of Schiff again disproves these observations; however, no matter what the outcome of this controversy may be, the fact remains that ligation anesthesia is due to pressure on the nerve trunks.

Ligation anesthesia is used just as seldom today in operations on the lower extremities as in former centuries. Esmarch, in his description of artificial anemias, says that he uses this procedure in all small surgical operations on fingers and toes, such as incision for felons, removal of ingrown nails, exarticulation of phalanges, etc. Stockes and Le Fort describe major operations as the extirpation of a carcinoma from the back of the hand, resection of the elbow-joint, amputation of the leg, performed in this way without pain. Again, in recent times Kofmann has advocated ligation for the production of anesthesia of the extremities, but this in all probability will not restore this measure to use again. The effect is too uncertain and the evil consequences too great. The necessary pressure on the nerve trunks must be so severe, and the pressure dosage so uncertain that the danger of gangrene, permanent motor and sensory paralyses are avoided with difficulty. Kofmann experienced his first serious consequence of this method on himself. It should once again be emphasized that long-continued ligation of an extremity is extremely painful even for those not necessarily sensitive. For these reasons compression anesthesia was given up, even in those times when better and more certain methods of general anesthesia were unknown.

CHAPTER IV.

ANESTHESIA BY MEANS OF COLD.

Of much practical importance is the paralysis of nerve function by means of low temperatures. Although long known (see Chapter I), Arnott (1848) was the first to use this method in surgery to any extent. For the rapid chilling of the tissues he used rubber bags and pigs' bladders filled with a mixture of ice and salt and laid them upon the skin in the field of operation. He made the following observations: anesthesia of the tissues produced by cooling was confined to the outer sensitive parts, and inasmuch as the most painful part of many operations was located in these tissues, the application of cold was sufficient even if the patient experienced some pain, and was to be preferred to chloroform and ether which caused loss of consciousness. The application of cold in this form is free from injury and danger to the tissues. According to Velpeau, Arnott's method of chilling the skin suffices for all superficial operations. Num, Herzog, Illig, Wittmeyer, and others heartily recommend this measure, and Galeczowski used this method in lid operations. Ice and salt mixtures were soon discarded for the simpler method of using rapidly evaporating fluids.

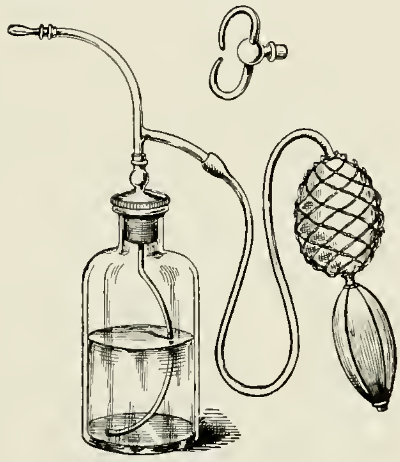


Fig. 1.—Richardson's ether spray.

Demarquay, Guérard, Richet, and others used sulphuric ether, by dropping it on the skin in the field of operation and later constructed a blower for causing the ether to evaporate on the surface to which it was applied, and by this means found that the skin could be rendered insensitive. Ricket's experience (1854) showed that much progress had been made, for until this time local anesthesia never gave uniformly good results. The first real impetus to the use of cold as an anesthetic came when Richardson, in 1866, devised the atomizer, suggested to him by Giraldés, for the purpose of using ether and chloroform in a finely divided spray on the skin. Richardson's ether spray (Fig. 1) consisted of a finely pointed metal tube through which a strong stream of air could be blown by means of a double rubber bulb, this mixed with the ether sucked through another metal tube from a glass container. By this means ether was finely subdivided and in condition to be rapidly evaporated, producing intense cold. For the extraction of teeth a fork-shaped end-piece with two openings was used. Under the influence of the ether spray the temperature rapidly dropped to $-15°$ or $-20°$ C., sufficient to quickly turn a test-tube of water into ice.

If the ether spray is used at a distance of about 5 cm. from the skin the latter becomes reddened, and in a few minutes white, hard, and insensitive; in fact, the skin is frozen. Sometimes the white and hard appearance of the skin does not occur, yet the parts are insensitive; but these parts are irritated mechanically by rubbing the back of a scalpel over the surface, or by pricking it with the point of the knife, the tissues change their color and consistency immediately and present the usual frozen appearance. All grades of ether can be used for this purpose. The best to obtain sufficient heat dissipation, is pure water-free sulphuric ether having a specific gravity of 0.720 and a boiling-point of 34.5° C.; this is the so-called anesthetic ether of commerce. Sensitive tissues, as the skin of the scrotum, must be protected from the direct ether spray by coating the parts with vaseline or glycerine, or by interposing a metal plate (Prosoroff) between spray and skin. To prevent the unevaporated ether running over the skin, Lesser constructed metal boxes to fit various parts of the body. These boxes were filled three-quarters full of ether and by blowing a stream of air rapidly through them, evaporation quickly occurred; the box was then pressed against the skin until frozen. Braatz constructed an apparatus along these same lines, which was used particularly for making very small areas of skin or mucous-membrane insensitive for the purpose of injecting anesthetic fluids. These contrivances were unnecessary and never came into general use. The action of ether on the tissues is more intense, lasting and acting better on the deeper lying parts, if the extremity is first ligated to prevent the access of fresh warm blood (Girard, 1874). The freezing of the tissues occurs very quickly by this method, and the thawing and return of sensation is very slow. Instead of ether, various other hydrocarbons can be used in the Richardson apparatus, only the more important of which can be mentioned here. Ethyl bromide (boiling-point $+38°$, Terrilon, Monad, Perrier, and Berger), carbon disulphide (boiling-point $+48°$, Simonin, Delcominette, Claude Bernard), petroleum ether (boiling-point $+38°$, Bigelow, Warren), chloroform (boiling-point $+61°$), ethylene chloride (liquor hollandicus, boiling-point $+58°$), amylene (boiling-point $+35°$), Robbins' anesthetic ether (a mixture of methyl alcohol and chloroform). The local anesthetic property of all these preparations is in inverse proportion to their boiling-point (Rosenthal, Bumm), the action being brought about by dissipation of heat due to rapid evaporation. Anesthesia must not be attributed to chemical or narcotic action on the sensory nerves at the point of application, as was supposed to be the case by early investigators. The only agent of those mentioned having advantages over ether is ethyl bromide, as it is not inflammable.

The experimental work of Gruetzner, Gendre, Heinzmann, and Fratscher takes up the physiological effect of cold on the nerve substance in animals.

Slightly cooled nerves retain their property of reacting to stimulation for considerable time; cooling to +5° C. inhibits the stimulation of all nerve fibers cooling to the point of ice formation intercepts nerve function, the nerve, however, regaining its property of reacting to irritation on thawing. Sudden intense cold acts as a stimulus; slow cooling even to −4° to −6° does not stimulate. It is undoubtedly the cooling alone which brings about the molecular change and injury to nerves, which require a normal temperature for normal action. The effect of prolonged low temperature on the human skin is first to cause a contraction of the smooth muscle fibers of the skin and vessels. This is followed later by paralysis in them; the skin seems, therefore, at first pale, later livid. The circulation in the vessels of the skin is finally stopped, and partly from this, and partly from the direct action of the cold on living protoplasm, certain functions are rapidly destroyed, the tissues become insensitive, necrotic or gangrenous, or serious disorders of circulation remain. These changes have been observed with temperatures above 0° C., but require a much longer time for action. The various senses of the skin do not react uniformly to cold. According to Boeri and Silvestro the sense of pressure remains intact a long time in the presence of cold; the sense of touch is less resistant than the temperature sense. The sense of pain is lost more quickly and completely than any of the other senses.

For the practical application of cold in local anesthesia very low temperatures are necessary for the rapid cooling of the tissues to the freezing-point (−0.55° to −0.56°). The length of time necessary to freeze the tissues depends not only on the rapidity of heat dissipation, but also upon the nature of the tissues, that is, the amount of blood in them, the rapidity of the blood-current, etc.; hyperemic tissues being cooled much more slowly than anemic ones. Sensory nerves lose their function as soon as the tissues are cooled below the freezing-point. There is a paralysis of the sensory nerve organs that is a terminal anesthesia, and the degree of anesthesia depends upon the duration of the freezing process. In rapidly cooling the tissues, anesthesia is preceded by pain; with the thawing of the tissues sensation rapidly returns, provided there has not been permanent damage to the parts in consequence of severe freezing long continued. In this case the insensitive area is converted into one of marked hyperesthesia, which is due solely to the freezing. As previously described in connection with the ether spray, namely, that the already reddened skin with continued cooling suddenly becomes bloodless and white, and that this can readily be brought about if the reddened area is scratched with an instrument, is explained in a very weak and unsatisfactory way by Letamendi. He believes that anesthesia is brought about by a severe cramp of the vasomotor nerves. For this to occur the dilated capillaries must undergo contraction. This is rarely brought about by the ether spray, while a slight emptying of the hyperemic vessels, or an increase in tension of the vasomotor nerves which is produced by a superficial irritation, rapidly brings about the vessel cramp. Regarding this theory it is sufficient to say that a sudden contraction of the bloodvessels, with its consequent anemia, never immediately interrupts sensory impulses; moreover, loss of sensation often precedes the white appearance of the skin. The sudden hardening and white appearance of the skin can be more readily explained on a physical basis, these changes being due to the formation of ice in the tissues. The delay or non-appearance of this condition, as well as its sudden occurrence following mechanical irritation in tissues cooled below the freezing-point, is due to delay in crystallization. In determining the freezing-point of liquids, we find that albuminous fluids, such as blood, require cooling far below that of pure water before ice formation begins.

With the use of the newer agents for producing anesthesia by means of cold, the Richardson spray has been almost entirely superseded by sprays of more rapid action, these freezing the tissues very quickly without any other aid. The chemicals which are now being used have a much lower boiling-point than ether, producing intense cold on evaporation; for this purpose, ethyl chloride, methyl chloride, and liquid carbonic acid gas are the most useful. These agents at the ordinary room temperature and under normal atmospheric pressure change to gas, so that they must be kept in containers under pressure.

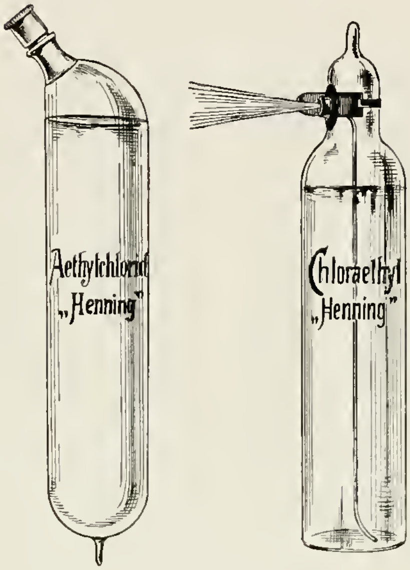


Fig. 2.—Ethyl chloride tubes.

Ethyl chloride (Kelen) C_2H_5Cl is a colorless gas which at a temperature of +11° C. is converted into a colorless liquid. Pure or mixed with sulphuric ether, Rottenstein in 1867 used it for purposes of local anesthesia, but it was only through the efforts of Redard, Baudouin, Ehrmann, Gans, and von Hacker that ethyl chloride became extensively used in surgery and dentistry. This agent was formerly made only in France and Switzerland, but is now produced in almost all countries, the quality being equal to the imported article and the price more reasonable. It is handled in the shops in the form of either metal containers or glass tubes, sealed or having metallic closing devices, the quantity varying from 10 to 100 c.c. The most convenient package is the glass tube with a metallic screw top, having a capillary opening at one end or at right angles to the tube. The tubes are opened by unscrewing the cap or breaking the capillary tube. Another convenient container is on the market with an opening closed by a cap operated by finger pressure. The warmth of the hand is sufficient for vaporizing the fluid which is forced out in a strong stream. The evaporation of ethyl chloride produces a temperature of $-35°$ C. and causes immediate freezing of the skin if held between 30 to 40 cm. from the surface. The freezing is much facilitated by blowing on the liquid, thus aiding its evaporation. The so-called Kuehnen's fork spray is a valuable addition to the ethyl chloride container for use in the extraction of teeth. This apparatus permits a constant stream of air to pass through the two openings through which ethyl chloride is passing, thus causing rapid evaporation, both sides of the tooth and gums being sprayed at the same time. For the method of application see Chapter XI.

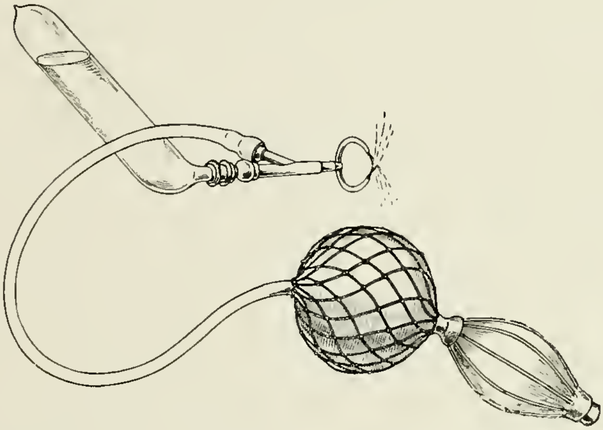


Fig. 3.—Kuehnen's forked freezing apparatus.

Methyl chloride, CH_3Cl, under high pressure, is a clear liquid which boils at a temperature of $-23°$ C., for which reason it must be kept in metal cylinders. Lallier and Debove were the first to use this agent for local anesthesia. They allowed the stream of liquid to play upon the skin direct from the container, producing a temperature of $-55°$. This very low temperature could easily cause injury to the skin, as blistering, or even gangrene.

It seems safer and more practical, if one desires to apply this liquid, to use Bailly's indirect method. Tampons varying in size and form, consisting of cotton on the inside, the exterior of floss silk, and a single layer of silk gauze, are saturated in methyl chloride either by playing a stream of methyl chloride upon them or dipping them into the fluid, which may be kept nearly three hours in the thermoisolator constructed by Bailly. This apparatus consists of a glass tube 15 cm. in length, placed vertically in a glass vessel resting upon a wooden support. The circular space between the upper edge of the tube and the outer glass vessel is hermetically sealed and the air between the tube and the surrounding glass vessel is exhausted. The whole apparatus is then isolated by a poor conductor of heat and the inner tube containing the methyl chloride closed with a cork containing a capillary glass tube in order to allow the escape of the volatilized fluid. The tampons are held in wooden or vulcanite tongs or forceps, and are saturated in the above fashion in the methyl chloride. Bailly calls the forceps for holding such a tampon "Stype" and the procedure "Stypage." The tampons are placed upon the skin at the point to be anesthetized and left there until the tissues are frozen, which usually occurs after a few seconds. By means of a camel's-hair brush soaked in methyl chloride the anesthesia can be confined to minute areas. This agent even when used in this indirect manner can, by careless manipulation, cause destruction of tissue (Feibes).

Under the trade names of Anästol, Anästyl, Metäthyl, Koryl, various mixtures of ethyl chloride with methyl chloride find their way into the market. They act more quickly but less thoroughly than ethyl chloride and are used in the same manner.

Still greater care is necessary in using the fluid and solidified carbon dioxide recommended by Wiesendenger and Kuemmell, for anesthesia. The direct application of a stream of this fluid, boiling at $-78°$ C., upon the skin is naturally prohibited. According to Wiesendenger the fluid CO_2 is passed into a metal tube or the container is filled with closely packed CO_2 snow. Anesthesia is produced by contact of the metal tube with the skin. Caution is also necessary with this method.

Of all the cold-producing agents referred to, pure ethyl chloride next to the ether spray is highly recommended and has rapidly come into extensive use. The small glass containers used in dispensing ethyl chloride are very convenient for use, and the cost small; 100 c.c. costing about 75 cents. Inducing anesthesia by freezing the skin or mucous membrane, even in vascular tissues, is produced in the fraction of a minute, injury to the tissue being easily avoided; provided proper precaution is used. The spray of ethyl chloride should be discontinued as soon as the superficial layers of the tissues are frozen, as continued freezing for the purpose of obtaining deeper anesthesia will almost always result in permanent injury to the tissues. Inducing artificial anemia in the part to be anesthetized is very essential with the use of the ether spray, but is unnecessary when using the spray of ethyl chloride, as the cold produced by the latter is so intense that a dermatitis, vesiculation or superficial gangrene may occur in a short time on extremities made anemic by ligation. Covering the skin with vaseline or glycerine as recommended by many does not noticeably reduce the effect of the cold. It serves merely to protect the skin from chemical irritation of the anesthetic agent, as when using sulphuric ether. Ethyl chloride does not irritate the skin.

There is no reason to use fluids having a lower boiling-point than that of ethyl chloride, the supposed advantage of a more rapid anesthesia being more than counterbalanced by the shortening of the anesthetic effect. The use of Richardson's spray requires slightly more time to freeze the skin and make it insensitive owing to the slower cooling of the tissues, but the deeper parts are made insensitive without the danger of injury to the skin. The preceding nerve irritation is also lessened the slower the freezing is induced.

The inflammability of many hydrocarbons and their vapors requires great caution. In the presence of an open flame or a glowing cautery the ether spray should not be used. Fluid methyl chloride or ethyl chloride, though combustible, are not explosive and their vapors will not ignite in an open flame. Consequently there is no danger following the use of ethyl chloride spray with the thermocautery. Ethyl bromide and carbon dioxide are not at all inflammable. Ethyl chloride having pure basic cocain in solution has recently come into use in connection with the latter drug (Bardet), but inasmuch as ethyl chloride serves merely as a solvent we will discuss this mode of application of cocain in another place.

Anesthetizing by means of cold has the advantage of simplicity of application. By the addition of tubes of ethyl chloride to the physician's armamentarium he can without much previous technical training induce anesthesia by cold. Care must be exercised so that damage to the tissues does not occur, although this is not to be feared in parts abundantly supplied with blood. The usefulness of this method is curtailed by the fact that the anesthesia does not penetrate very deeply and that the healthy and diseased tissues are not easily differentiated after being frozen. Another disadvantage is that the freezing as well as the thawing of the tissues is painful, especially in inflamed and hypersensitive parts. For this reason the production of local anesthesia by means of cold has from its introduction until the present day been used solely for short and superficial operations. The attempt to use it in major surgery has been limited to isolated cases. Dolbeau made a resection of the scapula with satisfactory results by the repeated application of the ether spray to the cut surfaces. This method must be considered most impractical owing to the imperfect anesthesia in most cases and hemorrhage not being controlled by the ether spray. In large part the cold itself is a disadvantage, because it prevents a careful dissection of the deeper layers, coats the instruments with ice, and robs the fingers of the sense of touch (Kappeler).

Spencer Wells attempted an ovariotomy under the ether spray. The abdominal incision was free from pain, but loosening the adhesions necessitated chloroform anesthesia. Richardson and Greenhalgh completed a Cesarean section almost painlessly by aid of the ether spray. There is no doubt that of all the major operative work the abdomen lends itself most readily to this method of anesthesia. The reason for this is not because of the perfection of the method, but owing to the fact that many abdominal operations can be performed painlessly. If the skin and abdominal wall are made insensitive, the subsequent manipulations often give little discomfort. The general introduction of this procedure, recently suggested by Bloch, should be accepted with the same misgivings. Bloch believes that the anesthetizing of the skin by means of ethyl chloride suffices for many major operations without causing the patient much pain. He reports 503 such operations, including many herniotomies, tracheotomies, thoracotomies, colostomies, etc. It is undoubtedly true that in many major surgical operations, especially abdominal section, the skin incision is the most painful part of the operation, and this can be rendered insensitive with the aid of ethyl chloride; nevertheless to bear up under the subsequent steps of the operation requires, as a rule, a heroism not found in all patients. The misgivings of all uncertain and imperfect methods of anesthesia are also to be noted with Bloch's method. Anesthetizing the skin incision alone, or following this with general anesthesia, can be replaced by methods more reliable than the application of ethyl chloride.

The use of cold as a local anesthetic can generally be said to be of use for superficial incisions, as in opening an abscess, or furuncle, incising fistulæ, aspirating cavities of the body, and minor operations on the skin and mucous membranes. In these conditions when the skin is frozen, the anesthesia is often insufficient, owing to the deeper tissues being made sensitive by the accompanying inflammation, all pressure and pulling on the tissues causing intense pain.

It is often possible to make simple extraction of teeth more bearable or even painless if the gums on both sides of the alveolar process are frozen by means of a stream of ethyl chloride. In pulpitis, on account of the presence of great pain, this method is not applicable.

The fact that the chilling of exposed nerve trunks in animals can interrupt the transmission of sensation, has encouraged experiments on human subjects, attempting by freezing the skin overlying nerve trunks to produce conduction anesthesia in the area supplied by these nerves. The possibility of so influencing superficially situated nerve trunks can be easily demonstrated by experiments on one's own body.

In one case the ethyl chloride spray was played upon the ulnar nerve at the internal condyle of the humerus. After freezing the skin, the spray was continued about half a minute before the nerve trunk was affected. Suddenly intense pain developed in the entire area of distribution of this nerve, followed in about a minute by a feeling of numbness with irregular areas of anesthesia on the forearm and the fourth and fifth fingers. On account of the severe pains it was impossible to continue the freezing to the point of complete interruption of nerve conduction. Two minutes after stopping the ethyl chloride spray no evidence of interruption of nerve conduction remained; nevertheless, at the point of application blisters and a painful infiltrate formed. Experiments with the radial nerve, close to the wrist, proved more successful in so far as the conduction of the nerve could be totally interrupted. It was shown here, as before, that as soon as the cold reached the nerve, severe pains ensued; the skin at the point of application of the ethyl chloride was severely damaged, causing the formation of a painful, slowly healing ulcer.

As before mentioned, the ether spray is more suitable than ethyl chloride when deep action is desired. It requires several minutes to cause interruption of nerve conduction, as for example, in experimenting on the ulnar or radial nerve, the ensuing pains are, as with ethyl chloride, very severe, but the damage to the tissues is avoided. The attempt to anesthetize the finger by the use of the ether spray applied to the base was without result; as soon as the chilling of the tissues penetrated deeply, the pain became unbearable. The practical usefulness of conduction anesthesia produced by freezing the nerve trunks, particularly when applied to the larger nerves, has not proved of much value; however, a reduction of sensibility, if not total anesthesia, can be obtained. Experiments in this direction have been repeatedly made, Rossbach stating that he succeeded in anesthetizing the superior laryngeal nerve and with it the trachea, by applying the ether spray for two minutes to both sides of the neck below the ends of the hyoid bone. Scheller and von Hacker, for the extraction of teeth, do not allow the ethyl chloride spray to act upon the gums, but externally upon the skin, in the region of the anterior surface of the lower jaw, canine fossa, and in front of the ear. Both authors state that an obtunding or total anesthetic effect, sufficient for the extraction of teeth, could be occasionally obtained in this manner, though both acknowledge the uncertainty of the method.

Local anesthesia by means of cold was attempted in other ways, one of which consisted in injecting cold fluids into the tissues. Heinze and the author have studied the physiological effects produced by the injection of fluids of different temperatures into their own skin in the neighborhood of sensory nerves. We used for this purpose a 0.9 per cent. sodium chloride solution, which, injected at body temperature, caused neither irritation nor loss of feeling in the sensory nerves. It was shown that a decided lowering of the temperature of the solution below that of the body produced a corresponding painful irritation, the colder the solution the greater the pain. Reducing the temperature of the solution to 0° or below caused pain, following which anesthesia occurred, lasting a few seconds; whereas solutions of a higher temperature produced absolutely no diminution of sensation. Injecting large areas with solutions at 0° produced more decided effects, as the tissues resumed their normal temperature more slowly. Létang, for purposes of local anesthesia, injected 0.5 to 1 per cent. of chloride of sodium at 0° or mixtures of water, glycerin, and ether, but these methods are not worthy of recommendation. For a short anesthesia one cannot expect as much from methods of this kind as from the ether or ethyl chloride spray, the latter causing rapid cooling, never obtained by injecting cold solutions. Létang claimed that by repeated injections the duration of the anesthesia may be prolonged indefinitely. In practice this would be a decided inconvenience and tend greatly to prolong the operation. It has been proposed by Schleich to use cold solutions of cocaine as an injection, but results from this method should not be attributed to the direct action of cold, but rather to a retardation of absorption from the chilled tissues, thus intensifying the action of the cocaine. The use of cold as an aid to various anesthetic agents will be discussed in Chapter VIII.

CHAPTER V.

THE EFFECT OF OSMOTIC TENSION OF WATERY SOLUTIONS INJECTED FOR PURPOSES OF LOCAL ANESTHESIA.

If a glass cylinder, closed at the bottom by means of an animal membrane and filled with a concentrated salt solution, be suspended in a vessel filled with pure water so that the surface of both fluids lie in the same plane, an exchange of molecules will take place between the two fluids; the water passing from the outer to the inner vessel and the salt from the inner to the outer vessel. The former being much stronger than the latter causes the volume of water in the inner vessel to be increased, as shown by the rise of its surface. This exchange continues until the salt solutions in both vessels are of equal concentration. The same exchange takes place when, without the interposition of a membrane, pure water is poured over a concentrated salt solution. In the latter case we speak of a diffusion, in the former of osmosis, or osmotic diffusion. The energy causing the exchange of molecules and the rising of the surface of the salt solution in the suspended vessel is called osmotic pressure or osmotic tension. This is an intrinsic latent physical property of water and all watery solutions, and is dependent upon the number of molecules per liter and their degree of dissociation. The rapidity of diffusion of the salt solution has a definite relation to the character of the dissolved substances, the concentration of the salt solution, and the permeability of the separating membrane. The rapidity of diffusion of the water toward the salt solution is almost in proportion to the concentration of the latter and increases with a rise in temperature. The rapidity of movement of the salt solution is less dependent on change of temperature. Colloids, albumin, mucous, glue, rubber, etc., diffuse with difficulty and sparingly through dead animal membranes, as opposed to the crystalloid substances and do not alter the osmotic pressure of the fluids in which they are dissolved. If, instead of pure water and a salt solution, a weak and a concentrated solution of salt are so placed as to act one upon the other, a movement of water takes place from the weaker to the more concentrated solution, the salt passing in the opposite direction. The rapidity of exchange will in this instance, other things being equal, be proportionate to the difference in concentration of the two solutions.

When solutions of different salts are placed together one will find in each a solution of the other salt, but inasmuch as there is no interchange of water the concentration of the solutions is not altered. Solutions having the same osmotic pressure are called isosmotic or isotonic; if one of the solutions be diluted by the addition of water, it is said to be hyposmotic or hypotonic, and gives off water to the more concentrated solution; if the solution be made more concentrated, it is called hyperosmotic, or hypertonic, and absorbs water until both solutions are again isotonic. An interchange of the molecules of different salts in solution occurs at the same time, and independently of the movement of water, even if the solutions be isotonic, so that eventually the salt molecules on both sides will be equal. These osmotic changes are constantly taking place throughout nature, wherever living cells and body fluids come into contact with one another. The modus operandi by which the organism maintains a constant and definite salt content in the body juices, under normal conditions, has recently been given much study and bids fair to be of great significance in future pathology and therapy.

The proper functioning of nerve elements, in fact all living tissues, is known to be dependent upon their being immersed in a nutritive solution, consisting of water, albuminous substances, and salts. The composition of this solution must not only be of definite chemical and physical constancy, but likewise of definite temperature and concentration of its salt content, etc., as determined by its osmotic pressure.

The concentration of the salt content varies in different animals and plants. It is of much interest to know that living tissues, especially nerve elements, can be kept alive in certain watery solutions having a definite salt content, without otherwise corresponding in their chemical composition to the nutrient fluids, so-called physiological solutions, whereas slight changes in the salt content occasion a rapid loss of function and change of form of the tissues. The cause of these conditions is dependent upon the presence or absence of osmotic tension between the salt solution and the body fluids. The solutions in which the form and function of the tissues is best preserved are those which are isotonic with the normal nutrient fluids.

Nasse was the first to make attempts in this direction. By placing the muscles of frogs in salt solutions, he demonstrated in which concentration their irritability was longest preserved. Solutions found to be best suited for this purpose were solution of 0.6 per cent. sodium chloride, 1.75 per cent. solution of sodium iodide, 1 per cent. solution of sodium nitrate. These solutions and frogs' blood have almost the same osmotic pressure.

De Vries was the first to accurately describe isotonics. He determined the isosmotic concentration of a large number of organic and inorganic combinations, and studied their relations to molecular weight. The discovery of isotonicism resulted from the observation that watery solutions of whatever composition, but of definite concentration, produced phenomena in plants which could only be caused by dehydration (plasmolysis) of plant cells and young sprouts. The weakest concentration of solutions able to produce the above described dehydration are said to be isotonic to one another.

In a similar manner, Hamburger, Koeppe and Hedin, by physiological experiments with the red corpuscles of various animals and man, noted the swelling and dehydration of the corpuscles under the microscope, and in this way were able to determine the isotonic concentration of aqueous solutions. Hamburger determined first the concentration in which the red-blood corpuscles were most quickly and completely precipitated, and the weakest concentration causing hemolysis; the mean of these two values being identical with De Vries' results regarding the isotonic concentration of the various salt solutions. Koeppe and Hedin by certain special methods made use of the volumetric change in the red corpuscles for the determination of the isotonicity of solutions; with hypotonic solutions, the volume being increased, and with hypertonic solutions diminished in volume. These interesting physiological methods are used very seldom today, as physical chemistry has devised simpler and more exact methods for the determination of osmotic tension of fluids.

Osmotic tension is most easily determined by finding the freezing-point of water holding crystaloid substances in solution. Solutions having the same freezing-point are called isomotic. Osmotically indifferent, in reference to the absorption and giving up of water in their action upon human tissues, are those solutions having the same freezing-point as the normal body fluids, for example, the blood. The determination of the freezing-point of human blood, lymph, transudates, exudates, were first made by Dreser, later by Hamburger, Koranyi, Tauszk, Winter, and the author. The determination of the freezing-point of the blood has of late become an important method of clinical research.

The freezing-point of the blood of healthy individuals was found by Dreser to be $-0.56°$; Hamburger, $-0.55°$; Koranyi, $-0.56°$; Winter, $-0.55°$.

The mean freezing-point of the blood is held by most investigators to be $-0.56°$ although the mean value as determined by some is placed at $-0.55°$. Variations from these figures, above or below, are exceedingly small under normal conditions. Values of $-0.54°$ and $-0.57°$ can hardly occur in healthy individuals; in certain diseases variations of a few hundredths of a degree above or below are noticed.

Watery solutions, therefore, with a freezing-point of $-0.55°$ to $-0.56°$ have approximately the same osmotic pressure as human blood. Solutions with a freezing-point near $0°$ are hyposmotic, those with a lower freezing-point than $-0.55°$ are hyperosmotic, compared to the nutrient fluids of the human body. Monocellular plants and animals can live in water without tumefaction of their structure or undergoing any change of their salt content by reason of the structure of their encapsulating membrane. In the same manner epithelium of the skin and that of most mucous membranes protects the human tissues from the action of solutions of varying osmotic pressure. If such solutions, however, are brought into intimate contact with wounds or injected into the tissues, osmosis will take place, according to the physical experiments previously mentioned with plant cells and red-blood corpuscles, resulting in their change of volume. Hyposmotic solutions cause cells and other tissue structures to swell, hyperosmotic solutions by their dehydrating action cause them to shrink, producing what is called plasmolysis. The more the solutions vary in their freezing-point from that of the blood, the greater the osmotic change in the tissues.

Tumefaction as well as dehydration influences the action of the sensory nerves and injures the tissues irrespective of the substances in solution. Experiments have been carried out by the author and confirmed by Heinze in reference to the physiological effect of the differences of osmotic tension. For this purpose injections of lukewarm water and salt solutions of varying degrees of concentration were injected into his skin and that of other subjects. If a fluid is injected into the dense tissues of the skin by means of a needle passed parallel to its surface, avoiding the loose subcutaneous connective tissue, a round, pale wheal raised above the surface of the surrounding skin will be immediately apparent. Changes of sensation in this wheal, produced by the injection of a foreign fluid, can be readily tested in consequence of the rich nerve supply of the skin. Wheals produced in this manner were first used by Schleich, but the credit for the practical adaptation of this method must be given to Heinze. The observations made by Schleich upon the skin wheal have been proved very indefinite by control experiments made by many others. The results of our experiments are shown in the table (Fig. 4).

On the horizontal line chloride of sodium solutions are noted, varying in strength from 0 per cent. (water) to 10 per cent.; the freezing-point for a number of these solutions is also shown. The curve designated by the solid line denotes sensory irritation, evidencing itself as pain when the solution is injected into the skin; the dotted curve represents paralysis of sensation, anesthesia having followed the irritation. Points on the curve denote the relative intensity of irritation and paralysis. Salt solution of 0.9 per cent. occupies a middle position in the chart having a freezing-point of −0.55° and therefore having about the same osmotic tension as the human blood. All solutions placed to the left of this point cause swelling of the tissues, those to the right causing dehydration. If a 0.9 per cent. solution of lukewarm sodium chloride is injected into the skin neither pain nor irritation follow, there is no alteration of sensibility in the skin of the wheal, at least there is no diminution of sensation, the wheal disappearing in a short time without leaving any evidence of its previous existence. If the concentration of the solution is now reduced to 0.55 per cent. pain occurs upon injection, which is increased upon a further reduction of the strength of the solution, becoming very severe when pure water is used. The pain following these injections is called the pain of tumefaction, which is of short duration, followed

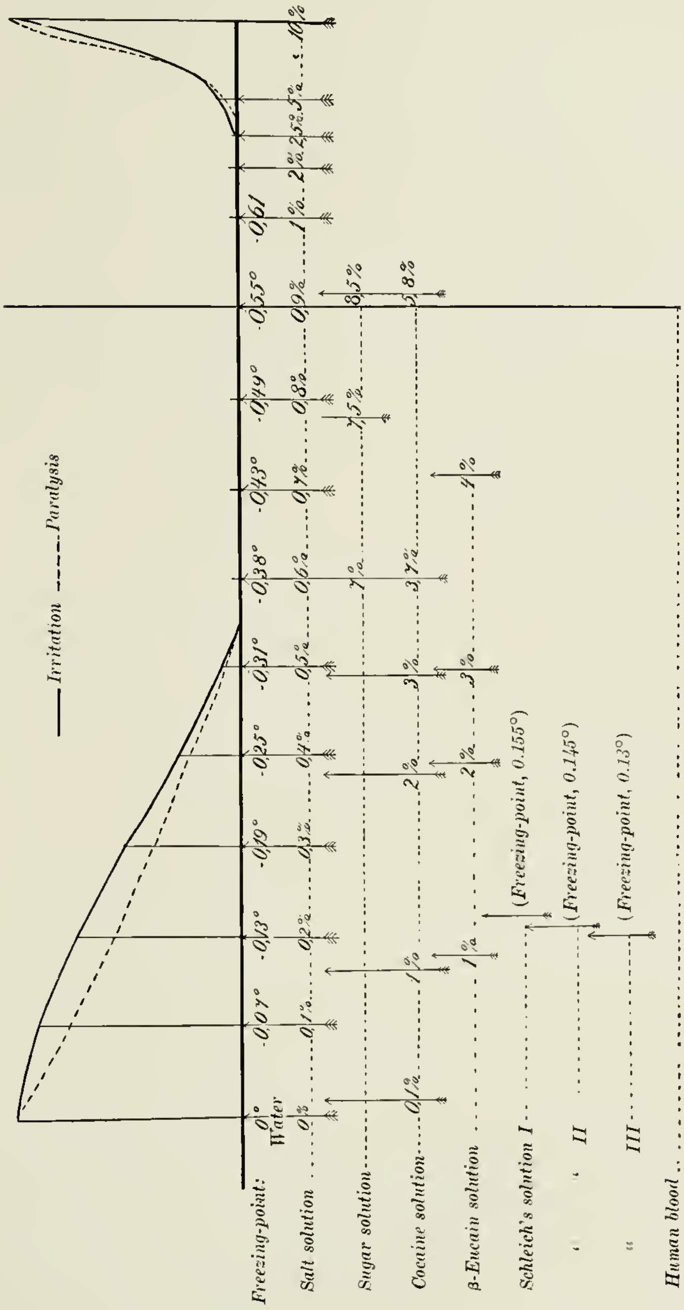


Fig. 4.—Irritation and paralysis curves, showing the effect of osmotic tension of water solutions on nerve substance.

by a diminution or loss of sensation in the area involved. It is increased in intensity and duration by a reduction of the concentration of the solution. The use of pure water causes anesthesia of the longest duration, lasting about fifteen minutes. This is called tumefaction anesthesia. Weak salt solutions may cause damage to the tissues, painful infiltrations remaining; pure water frequently causes superficial necrosis, so-called tumefaction necrosis. With the use of solutions containing more than 0.9 per cent. of sodium chloride, symptoms of dehydration will be noted such as irritation, paralysis, or damage to the tissues. The irritation from this solution is quite different from the pain of tumefaction. It follows a comparatively painless injection lasting several minutes, the wheal becoming markedly hyperesthetic, and is then followed by anesthesia. During this time the swelling undergoes peculiar and typical changes of form. With the subsidence of the burning pain and the beginning of anesthesia, the wheal sinks quickly in the centre, the margins remaining elevated in the form of a circular ridge. The anemic centre and surrounding margin are separated by a narrow red ring. In about fifteen minutes the swelling flattens out uniformly, extending from the centre toward the periphery, and sensation gradually returns. Concentrated salt solutions furthermore injure the tissues. The intensity of all these phenomena increases with the concentration of the salt solution. They are noticeable at 2.5 per cent. and more than 10 per cent. salt solution can hardly be borne. In the diagram on each side of the 0.9 per cent. salt solution, is noted the so-called indifferent zone in which a number of solutions from 0.55 to 2.5 per cent. do not produce noticeable swelling or dehydration of the tissues, or any of the symptoms above mentioned. The curve indicating pain and paralysis naturally does not represent absolute values, and was determined by experiments carried out upon the skin of our forearms. When salt solution is injected into the tissues of very sensitive persons, or into hyperesthetic areas, weak solutions must be used to avoid swelling or dehydration of the tissues. In this manner the pain and anesthesia curve will approach the horizontal, nearer to the middle point than has previously been shown, and the indifferent zone will be narrower.

That these are the real symptoms of tumefaction and dehydration, we may conclude from the following circumstance. Inasmuch as water and salt are constantly present in the body and act chemically upon the tissues very slightly, we must consider the pain, paralysis, and injury to the tissues as due to the physical properties of the solution. The symptoms must be due to the osmotic tension of the solutions, as the symptoms vary with the change of osmotic pressure, and disappear when osmotic tension between the blood and the solutions is equal. There are a number of other salts which chemically react slightly or not at all upon the tissues. To these belong most of the sodium salts, as phosphates, carbonates and borates, also sugar and some of the urea compounds. The solutions of these salts have been examined systematically in the foregoing way, and found to have, like the chloride of sodium, an indifferent zone as determined by the freezing-point, isotonic with the blood or physiological solutions, and that their solutions produce the same symptoms as salt solutions with a like freezing-point, from tumefaction pain to the peculiar change of form of the wheal due to the strong dehydrating actions of the solutions. For this reason the curves for irritation and paralysis are applicable for watery solutions of all substances. The symptoms of their physical effect are often obscured in consequence of their difference chemically, irritating or paralyzing the sensory nerves, damaging or destroying the tissues. It is in this case necessary to find the freezing-point of the solution, in order to determine physical effect upon the tissues.

In Fig. 4 the freezing-points of watery solutions of a few other salts are charted in their respective positions. We see that the physiological concentration of cane sugar is about 8.5 per cent. This solution is totally indifferent and causes upon injection neither pain nor anesthesia. The solutions frequently used for injection beneath the skin are very dilute and must necessarily cause pain, owing to the differences in osmotic tension. The table shows, furthermore, the freezing-point of several anesthetic solutions to which we shall return later.

For a considerable period of time, ever since anatomic and physiological studies were followed, it has been known that water itself has the elements of a protoplasmic poison, that it destroys the structure of those cells not protected by an impermeable membrane. The injurious effect of swelling can be observed under the microscope; the tissues saturated with water increase in volume, lose their structure, the sarcolemma of muscle fiber ruptures, and nerve fibers are completely destroyed. This change of form or total destruction of tissue was long known to the older anatomists. It has also long been known to physiologists that the function of the tissues is destroyed by swelling consequent upon immersion in water, or by their desiccation. Concentrated salt solutions can likewise injure the tissues by their dehydrating action. Fresh muscles when placed in water lose their properties of contraction and response to stimuli, becoming rigid (Swammerdam).

Tumefaction and dehydration, when affecting a nerve trunk, act as a stimulus and lower its excitability. Water injected between the fibers of a nerve trunk at once interrupts conductivity and seriously injures it (Biberfeld). The fact that these phenomena failed to appear when definite quantities of salts were dissolved in the water led finally to the discovery of the isotonicity of solutions and their connection with the molecular weight of the dissolved body. This was of far-reaching importance to theoretical chemistry, and van t'Hoffts theory of solutions is dependent upon this work of De Vries and Hamburger.

Saturating the body of animals with water causes severe general symptoms, in consequence of the diminution of osmotic tension of the blood and body fluids.

According to Falck, dogs are killed by the intravenous injection of 88 c.c. of water per kilo of body weight. Subcutaneous injections of about 200 c.c. of water cause death in rabbits, with symptoms of difficult respiration, impaired heart action, subnormal temperature, convulsions, and hemoglobinuria (Falck, Emmerich). Custer made the same observations upon injecting rabbits subcutaneously with large quantities of a very weak cocain solution. The animals died, not as a result of cocain poisoning but in consequence of the absorption of water, a consequences which could have been avoided by the addition of salt.

The prevailing opinion seems to be that a 0.6 per cent. salt solution is the most suitable fluid to use in connection with the tissues of the body and has therefore been called physiological salt solution. Hamburger and Koeppe called attention to the fact that this solution, used in the previously mentioned experiments of Nasse on frog muscles, still produced tumefaction, while a salt solution of 0.92 per cent. produced the same osmotic tension as the human blood. A 0.6 per cent. salt solution is therefore physiological for frogs, and a 0.92 per cent. salt solution is physiological for man.

The observation that the subcutaneous injection of water relieves pain has been verified by many. The first of these observations dates from Potain (1869) and Dieulafoy (1870). Lafitte states he has achieved good results in various painful affections, as sciatica, neuralgia, and rheumatism, by water injected directly into the affected part; the occurrence of severe burning pain, though of short duration was the only unpleasant feature. The soothing effect he ascribed to the compression produced by the injected fluid, or to the inhibition of water by the sensory nerve fibers, whereby the latter momentarily lost their ability to receive and transmit their impressions. Similar communications have been received from Lelut, Burneys, Yes, and Griffith.

Liebreich and Schleich have observed that water produces irritation, to be followed by anesthesia, likewise the indifference of these solutions upon the addition of salt, and finally the anesthetic action of very concentrated salt solutions.

Under the guidance of Liebreich, Bussenius conducted animal experiments in order to determine the local anesthetic effect produced by different substances. He injected these solutions subcutaneously into rabbits and found that while 0.6 per cent. chloride of sodium solution produced no alteration of sensation, 5 per cent. and 10 per cent. solutions did so to a slight degree. We have shown above that more exact results can be obtained by experimenting on one's own body, using Schleich's method. Schleich believed that there must be a solution of such concentration between pure water and a 0.6 per cent. salt solution which would not provoke pain upon injection; but on account of similarity to pure water it would later produce anesthesia, and he thought that he had found a useful anesthetic in the 0.2 per cent. salt solution. The anesthesia and pain of tumefaction are closely associated with one another. If the tumefying action of the water is reduced, the pain is lessened and the anesthesia is unsatisfactory.

Tumefaction anesthesia has been seldom used in performing operations, it has been occasionally attempted by Halstead and Gant. Schleich reports that he has been able with the aid of injections of water to excise a carbuncle painlessly. Isolated attempts were later made by him to produce local anesthesia by the injection of 0.2 per cent. salt solution. The injection of this solution is always very painful, its consequent anesthesia imperfect, and of very short duration. An anesthetic which necessitates pain for its induction has been called by Liebreich "anesthesia dolorosa." Tumefaction anesthesia can be called an anesthesia dolorosa, and owing to its injurious action upon the tissues is practically useless. The results of our researches concerning the physical by-effects of watery solutions may be classified in the following manner:

Injections into the tissues for whatever purpose must be composed of fluids of the same osmotic tension and freezing-point as the body fluids. Inasmuch as solutions for local anesthesia must be used more dilute than their physiological strength, a corresponding quantity of an indifferent salt, as sodium chloride, must be added to prevent any injurious action upon the tissues.

CHAPTER VI.

ACTIVE AND INDIFFERENT SUBSTANCES. ABSORPTION AND LOCAL POISONING. TESTS, GENERAL PROPERTIES, AND METHODS FOR USING LOCAL ANESTHETICS.

In the preceding chapter we studied the effect of certain substances which did not produce noticeable changes in the tissues, thereby making possible a study of the physical effects of their watery solutions when injected into the tissues. Let us now consider the ultimate result of these substances when injected into the tissues. A small part may find its way at once into a vein or lymph space and be quickly taken up by the circulation; the larger part, however, remains at the point of injection, being slowly absorbed after a more or less extensive diffusion into the surrounding tissues, without causing any noticeable local change.

When osmotic differences of tension are present, there is a tendency on the part of the body to equalize them, at least the interesting investigations of Hamburger regarding the absorption of watery solutions from serous cavities seem to support this theory. In this connection Hamburger noticed the following: (1) Serous fluids and salt solution placed in the abdominal cavity of animals are absorbed. (2) These fluids do not change the osmotic tension of the blood of the animal when isotonic. (3) Hypotonic and hypertonic solutions become isotonic in the abdominal cavity during absorption. (4) While present in the abdominal cavity there is a molecular exchange between the solution and the blood plasma.

After the injection of an isotonic 1.7 per cent. solution of sodium sulphate into a rabbit, a considerable amount of chloride of sodium, sodium phosphate, and albumin are found in the remaining isotonic solution. Hamburger's experiments do not show that the absorption of the dissolved substance is delayed when differences in osmotic tension between the solution and the blood plasma exist. Hamburger expressly states that the equalizing of the pressure differences takes place during but independent of the absorption. This is not without practical interest, because it has been erroneously assumed (Legrand) that cocaine is absorbed more slowly from hypotonic than isotonic solutions, and that for this reason the use of isotonic solutions is of no particular advantage.

The investigation of Schnitzler and Ewald likewise show that the rapidity of absorption is dependent upon the concentration of the salt solution. It can be shown that a definite quantity of a salt (iodide of potash, salicylic acid) is more rapidly excreted by the kidneys, and therefore more rapidly absorbed the more concentrated the solution introduced into the abdominal cavity. The great rapidity with which substances introduced into the abdominal cavity reappear in the urine verifies the important observations made by Klapp, Heidenhain, Orlow, Starling, Tubby, O. Cohnheim, and others, that the absorption from serous cavities of substances dissolved in water takes place principally through the circulation. The authorities mentioned, contrary to the belief of Hamburger and Cohnstein, hold it as undoubtedly proved, that in addition to osmosis, and filtration under increased intraperitoneal pressure, the vital forces of the living abdominal wall play a leading part, and must influence the merely physical processes concerned in the absorption from the abdominal cavity.

The phenomenon of absorption of injected watery solutions from the subcutaneous connective tissue does not differ materially from what takes place in the abdominal cavity. Independent of the water, which causes swelling or shrinking of the tissues, an interchange of molecules takes place between the salts in the solutions and the tissue fluids, as in a physical experiment. In fact, an osmotic indifferent salt solution is, in this respect, not entirely indifferent, as the tissue fluids contain other substances than salt; in fact, Hamburger found that the red-blood corpuscles will give up their coloring matter in such a solution. According to Hoeber's observations, an isotonicity of the body fluids would be temporarily disturbed by this solution. The amount of the dissolved substance diffused in the region of injection in a unit of time must be dependent upon the concentration of the solution and the diffusibility of the substance, which in turn is influenced by the varying permeability of the membranes and skin with which it comes in contact. If the injected solution be under great pressure, it will by means of simple filtration escape into the surrounding tissue. The process by which finally the largest part of the dissolved substance as well as the solvent enters the circulation, that is, absorption, is surely a vital process; it is associated with the vitality of the tissues, taking place slowly in those with impaired vitality, much more quickly in the presence of active metabolism, and entirely absent in lifeless tissues. It is an established fact that watery solutions absorbed from the subcutaneous connective tissue enter the circulation in largest part without the assistance of the lymph vessels (Magendie, Lebkuechner, Asher, Munk, Hamburger); whereas, on the other hand, oily solutions are almost entirely absorbed by the lymph vessels, in consequence of which absorption takes place more slowly.

Opposing the previously mentioned indifferent, or almost indifferent, substances, solutions of which exert a physical reaction on living tissues, are an endless number of other substances which cause other than physical changes in the tissues, due to their chemical composition. All of these changes may be grouped under the head of local poisoning, and give evidence of their presence in the living body by an increase, a disturbance or loss of function, stimulation or paralysis of sensory nerves, tissue injury, or local death. These symptoms are sometimes transient, that is, after a certain time, the living tissues are able in some way or other to dispose of the foreign substances affecting function or threatening the life of the structure, and again take up their former activities practically unchanged. In most cases the local poisoning causes permanent changes resulting in a more or less severe injury, inflammation, or necrosis of the tissues. The majority of all active substances cause the tissues at the seat of their activity to become hyperemic, some do not appreciably change the blood-content, some few induce a contraction of the bloodvessels and make the tissues anemic. Many finally bring about, immediately following their application, peculiar transient local edema, a symptom at once recognized by any one remembering the effects of insect bites.

The process of absorption must progress differently with active than with inactive substances, as the local changes as described can hardly be conceived without a loss of substance; a local action can, as a rule, only take place when a portion of the active substance is chemically combined with the structures in the immediate locality and is thus prevented from being carried into the circulation. What ultimately becomes of the remaining portion of most substances is unknown. Concerning certain alkaloids it is known that after their incorporation with the living tissues they are not absorbed in their original form, but that the organism eliminates them by disintegration; cocain and suprarenin belong to this group. In this manner the living body is freed from poison. The more slowly a substance is absorbed from the place of application the more thorough is the permeation of the tissues, and the more intense and extensive the local action than when more quickly eliminated by a rapid absorption. It is therefore of importance for us to study the methods of producing a retardation of absorption as an important aid to local anesthesia.

When chemically active substances are brought into contact with sensory nerves, they invariably bring about a transient or lasting paralysis, namely, anesthesia, usually preceded by a state of severe irritability. Some few substances have been found which produce local poisoning with transient sensory paralysis, without irritation or injury to the tissues. These are the substances useful in the practical application of local anesthesia.

The research methods having for their object the determining of the local anesthetic properties of various substances, are uncertain because of the fact that the local anesthetic power of a substance is dependent in large measure upon the place and method of application. The first attempts in this direction were associated with the belief that if inhalation anesthetics were brought into direct contact with the nerves that they would have the same action as when carried to the brain through the circulation. It was found that ether and chloroform interrupted the conductivity of an exposed nerve, when acting upon it, in the fluid or gaseous state (Longet, Bernstein, Ranke and others). This property is shared by many other non-anesthetic substances as the function of a nerve is dependent upon its saturation with a fluid of a definite composition.

Much experimental work in reference to chemical stimuli and their connection with the composition of chemical compounds is being undertaken by physiologists (Gruetzner). These studies are of no importance to local anesthesia.

Liebreich and his pupils, Bussenius, Muellerheim and Kunowski, were the first to systematically experiment with a number of organic and inorganic compounds in reference to their local anesthetic properties. Those substances not already fluid were dissolved and injected subcutaneously or placed in the conjunctival sac of guinea-pigs, rabbits and frogs. Sensation was then tested by pricking with needles, irritating the cornea, or by using Tuerck's test. The subcutaneous tissue is not very suitable for such experiments, as it is not sufficiently sensitive, and inasmuch as it is not situated upon the surface of the body it is not possible to determine the disturbance of sensation from the substance injected, but only that of the overlying skin. Notwithstanding the uncertainty of this method the above-mentioned authors found that by far the most of the anesthetic or non-anesthetic substances which they tried did not leave sensation intact, but were, according to Liebreich, "anesthetica dolorosa," that is, irritating before anesthetizing.

The number of the anesthetica dolorosa are found to be more numerous when dilute chemical solutions are used in connection with the Schleich wheal on the bodies of persons suitable for experimentation. Only after we knew the physiological effect of tumefaction and dehydration and the determination of the osmotic pressure of the solutions in question as described in the foregoing chapter, was it possible to place an experimental value on these methods. The solution must have a freezing-point similar to that of blood, due either to the active substances contained in it, or made so by the addition of indifferent substances. In studying the differences of osmotic tension between the tissue fluids and the injected solutions, we have already determined that this difference alone can interrupt sensation. The specific action of a substance dissolved in water should therefore be studied when the solution is osmotically indifferent. With the aid of the wheal and a consideration of the facts just mentioned, Heinze and the author found that there were few chemically indifferent, or almost indifferent, compounds which upon contact with the sensory elements left sensation intact. Most substances are active but only a few of these are able to temporarily influence the function of sensory nerves without severe irritation and damage to the tissues. By means of the wheal on the human body it is possible to determine relative if not positive values as to the local anesthetic properties of a substance.

This may be determined, first, by finding the lowest possible concentration of a substance in solution which will produce a local anesthetic effect. This is done by using constantly weaker solutions, making allowance for the difference in their physical characteristics. The weaker the solution the greater must be the affinity of the substance for the protoplasm of the tissue cells, that is, its local anesthetic power. All of our so-called local anesthetics are characterized by their ability to influence nerve substance in very dilute solution.

The second means at our disposal for the approximate determination of the time of occurrence of anesthesia consists in producing several wheals next to one another upon the skin of the person to be experimented upon by the injection of the same quantity of solutions of like concentration, that is, equimolecular solutions. The longer the duration of anesthesia, the more lasting must be the changes which this agent produces on the nerve substance. The duration of anesthesia is dependent upon many other circumstances, such as the nature of the person experimented upon, the quantity of blood in the part, the location of the part experimented upon, the rapidity of absorption, and the concentration of the solutions.

On the plainly visible skin wheals other tissue changes may be readily noticed. For instance, it can be readily determined whether the wheal disappears rapidly and completely, showing that the substance was absorbed without local tissue damage, or whether painful infiltrates remain which may undergo inflammation or necrosis, or whether the bloodvessels dilate or contract. Following experiments with codeine, morphine, peronin, and tropacocain upon the skin, an acute local edema occurs resembling that of insect poisoning. In this manner substances can readily be tested and compared in their action with other substances without danger to the individual experimented upon, provided very dilute solutions are used at the start. The results of such investigations can be at once put to practical use. When the solution of a substance is not brought into immediate contact with nerve elements by injection but reaches it indirectly by diffusion, then the local anesthetic effect cannot be determined alone by the above-mentioned experiments, but will depend upon this permeability of the membranes with which it comes in contact, and the diffusibility of the substance. Thus a substance having pronounced anesthetic properties may become useless because unable to diffuse through a membrane or layer of tissue and reach the nerve elements. Cocain, having marked local anesthetic properties, is ineffective when placed upon the skin, as it cannot penetrate it while a similar application of dilute solutions of carbolic acid which have only slight anesthetic properties cause a marked diminution of sensation. A comparison of various substances previously shown to be harmless can be obtained by observing the extent of anesthesia as affected by the process of diffusion, if solutions of like strength be injected into the subcutaneous cellular tissue in the region of the nerves of the skin, and noting the duration and extent of the anesthesia in the area of distribution of these nerves. Recke has taken up the very important comparative study of the newer substitutes for cocain along the lines mentioned above; the results of his work will be referred to later. Gradenwitz has determined the relative values of the local anesthetic power of chemical compounds in their actions on the skin of a frog. His method of procedure was as follows: the brain, medulla oblongata, and heart were removed from frogs, the blood was washed from the vessels, the object being to prevent the general absorption of the substances and thus isolate their local action. The solution to be tested was brushed upon the left leg of the frog, and after being allowed to act for a definite length of time was washed off. Both legs were then immersed in a $\frac{1}{6}$ per cent. hydrochloric acid solution, according to the direction of Tuerck, and the condition of the reflexes tested. Four distinct phenomena were recognized: (1) Both legs were simultaneously drawn up; the substance was ineffective. (2) After a short time the left leg was drawn up; the substance had increased the sensibility. (3) The right leg was drawn up sooner than the left; the sensibility of the left leg was diminished. (4) The left leg was not drawn up; sensation was absent. This last experiment was controlled by immersing the legs in a 25 per cent. hydrochloric acid solution.

The results of the investigations of Gradenwitz apply only to the skin of the frog, the physiological properties of which must materially influence the local action of the substance. It was particularly noticeable that stimulation of any sort was practically never observed even with substances which, according to the investigations of the pupils of Liebreich and the writer, must be classed as anesthetica dolorosa. The practical application of the observations of Gradenwitz and a comparison of their value with other methods of investigation is not possible so long as the permeability of frogs' skin for various substances is unknown.

A different sort of animal experimentation was advised by Loewy and Mueller for the testing of yohimbin, a supposed new anesthetic. If animals are allowed to inhale vapor of ammonia, expiratory paralysis at once takes place, due to irritation of the trigeminus fibers in the nasal mucosa. If the nasal mucosa is previously anesthetized, the action of the ammonia is diminished, that is, respiration becomes slower, more superficial, or may cease. To those who have had experience in animal experimentation the difficulties of obtaining exact results in testing sensation is well known the results are only of approximate value.

Important results, to which we will repeatedly refer, have been obtained through the researches of Laewen and Gross. They allowed the anesthetizing solutions to act directly upon the sciatic nerve of frogs and, after observing their effect upon the motor excitability of the nerve, compared results with those obtained in the tumefaction experiments.

It has been shown that the anesthetic property of various chemical compounds is associated with certain groups of atoms inherent in the molecule, which Ehrlich has termed the anesthesiphore. The other groups of atoms can be readily replaced in the construction of new anesthetic substances. Experiments along these same lines resulted later in the discovery of salvarsan by Ehrlich. After the discovery of the chemical composition of cocain with its atomic grouping by Einhorn, the synthetic preparation of this alkaloid became possible and served as a starting-point for interesting experiments in combining the anesthesiphore atomic group with new atomic groups. This chemical research resulted in the discovery of a number of new local anesthetics, such as holocain, eucain, and those of the orthoform group; later stovain, alypin, and novocain—certainly a triumph of an exact science. In regard to the chemical relation of these substances to one another, the reader is referred to Einhorn's comprehensive compilation.

The previously discovered practical local anesthetic substances have the following properties in common. They are all protoplasmic poisons, paralyzing not only the nerve elements but the function of all protoplasm with which they come in active contact. This action they possess in common with many other active substances, even with the physical action of water upon the protoplasm. Their intense selective affinity for nerve substance is particularly characteristic. They paralyze the function of nerve tissues with which they come in active contact in solutions too weak to appreciably influence other kinds of protoplasm. These substances, when introduced rapidly and in sufficient quantity into the circulation, besides their local effect, produce general symptoms of poisoning. The affinity of these substances for nervous tissue makes them particularly toxic to the central nervous system.

It is of practical importance to remember that these secondary symptoms are not dependent upon the dose used, as local anesthetic substances have no so-called maximum dosage, but rather upon the rapidity with which they are introduced into the body and absorbed from the same. This will be discussed more in detail in the following chapter on cocain.

Local anesthetics are characterized by their reversibility of action. They are able to temporarily interrupt nerve function without any permanent injury remaining, being thus distinguished from Liebreich's anesthetica dolorosa which cause irritation before paralysis, followed by injury to the tissues.

Gross summarized the above-mentioned experiments regarding the general properties of local anesthetics in the following manner: The base of local anesthetics (cocain, novocain, stovain, eucain and alypin) all have a more intense action than their salts, for the reason that the basic local anesthetics acted more quickly and in weaker solutions than their salts. The anesthetic potential of a local anesthetic salt is dependent upon the anesthetic potential of the base and upon the hydrolytic dissociation of the solution. The difference in action of solutions containing the chloride salts of the local anesthetics in general use is shown to be dependent upon the degree of hydrolytic dissociations of the solutions. The weaker the salt-forming power of an acid the greater the hydrolytic dissociation of the solution; thus the activity of a solution of a local anesthetic salt is greater the weaker its acid radical; for example, a novocain-bicarbonate solution is five times as active as an equimolecular novocain-chloride solution. The sensory nerves as will be shown with cocain (see page 87) are more sensitive to the action of local anesthetics than the motor nerves.

Following the experiments of Meyer and Overton on anesthesia, Gross attempted to explain the processes underlying anesthetic action. They maintain that anesthetics act upon the lipoid substance of the central nervous system. Anesthesia, therefore, depends upon the fat-dissolving power of the drug; the more powerful the anesthetic the greater is its ability to dissolve fat, so-called splitting coefficient—that is, the relation between their fat-dissolving power and their water-dissolving power. In consequence of their strong solvent action on fat, anesthetics accumulate in the central nervous system where, according to Meyer and Overton, they do not enter into chemical combination, but only bring about a physical change in the lipoids, forming a fixed solution, as it were. According to Gross this theory has a corresponding value for the action of local anesthetics on the peripheral nervous system.

Verworn, Buerker, and others, though not denying the theory of Meyer and Overton regarding the relation of anesthetics to the lipoids, nevertheless hold to the older theory that anesthetic action is due to the formation of chemical compounds in the central nervous system. Both maintain that anesthetics act by depriving nerve substance of oxygen, causing a temporary suffocation, combined with paralysis of their physiological function. The fact that a portion of the anesthetic remains at the place of application and does not enter the circulation before being destroyed, seems to favor the chemical theory, at least for local anesthetics. Leaving out of consideration the finer changes in nerve tissue resulting from general and local anesthesia, without detracting from our present knowledge we may mention the older theory of Preyer, who stated that general and local anesthetics produce changes in the central nervous system and peripheral nerves, causing a temporary loss of function of the cells, for the restoration of which their entire vital energy is necessary.

Before taking up for consideration the various local anesthetic agents it is important for us to know in what way their application produces terminal and conduction anesthesia in man.

The schematic cross-section (as shown in Fig. 5) represents the surface of any part of the body; the line *A–B* representing skin, mucous membrane, serous membrane, or synovial membrane, on the surface of the body, or lining one of its cavities. N_1

and N_2 represent two sensory nerve trunks ramifying in the tissues, and as usual overlapping one another in their area of distribution, so that a certain area is innervated by the terminal branches of several nerves. We shall now attempt to anesthetize the circular area marked *I* with an active anesthetic substance. Area *I* can be rendered insensitive by bringing the sensory endings in contact with a sufficient quantity of an anesthetic which will inhibit their function. This is called terminal anesthesia and can be brought about in several ways.

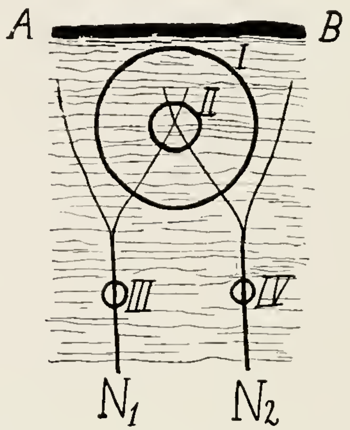


FIG. 5.—Schematic diagram of the methods of local anesthesia.

1. A solution of an active substance is injected into the tissues under slight pressure, so that area *I* is thoroughly saturated with the solution, replacing the normal tissue fluids. The molecules of the dissolved substance, mechanically injected, immediately come in contact with the tissue elements and promptly give evidence of their uniform action in the entire area. A chemical action will also be observed when the solution is diluted to the lowest limit of activity of the dissolved substance; this type of infiltration is seen in the skin wheal and has been designated by Schleich as infiltration anesthesia. The duration and intensity of this anesthesia is in proportion to the change produced in the nerve substance and the strength of the solution. The more concentrated the solution the longer the duration of the anesthesia. The duration and intensity of the anesthesia is the same in the entire area, as the nerve elements have been equally affected.

2. In the area designated in the figure by *I*, other methods can be employed for producing terminal anesthesia. If an anesthetic solution be injected in the centre of the area represented by *II* in the diagram the same local conditions will occur in this area as have been mentioned for infiltration anesthesia. Whether the solution

has the same or different osmotic pressure than the blood, there now takes place an exchange of molecules between the dissolved substance and the salts in the tissue fluids. The former diffuse with more or less rapidity, depending upon their diffusibility, the permeability of the membranes surrounding the area, and the concentration of the solution, affecting the tissues after a certain time in the entire area designated in the diagram by *I*, producing the same symptoms as originally took place in the centre of the area designated by *II*. A difference nevertheless exists, as the solution during the process of diffusion becomes constantly more dilute, containing less of the active substance owing to portions of it being combined with the tissues the farther it is removed from the place of injection. In consequence of which in a given case the intensity of anesthesia will diminish from centre toward the periphery in the area marked *I* in the diagram. The action by diffusion of a substance can scarcely be expected if the solution is so dilute that the dissolved substance is only sufficient for producing anesthesia in the area infiltrated, the number of molecules capable of diffusion into the surrounding tissues being too small to be effective. It is therefore necessary that small quantities of a concentrated solution be used to produce in this manner a local anesthetic effect, the same as though the entire area designated *I* had been infiltrated. This is the so-called indirect infiltration anesthesia.

An anesthetic solution when placed upon the surface *A–B* can, by means of diffusion, reach the nerves in the area designated *I*. Local anesthetic action can, however, only occur when the protecting membrane is permeable to the solution, and the solution much more concentrated than that used for injection.

Local anesthetics can affect the function and conductivity of nerve trunks at points remote from their area of distribution, as when solutions are injected in the region of the nerve trunks *III* and *IV* supplying area *I*. By means of diffusion their conduction will be interrupted, causing the so-called conduction anesthesia in this area. With the use of very weak solutions the nerve must be injected directly, diffusion under these circumstances being insufficient to interrupt conduction. Results of diffusion require waiting a certain time for anesthetic action.

If an anesthetic substance be injected into an artery or vein the circulation in which has been interrupted, terminal and conduction anesthesia will occur in the area of distribution of the respective vessels (arterial and venous anesthesia).

CHAPTER VII.

LOCAL ANESTHETIC AGENTS.

Local anesthesia received its greatest impetus following the discovery of substances of specific activity. From ancient literature we learn of the attempts which were made to produce local anesthesia by various drugs, which remained, however, without results until appropriate agents were discovered. The oldest of these, and for years the only local anesthetic, was the alkaloid cocaine, derived from the cocoa plant. Its properties have been carefully studied, and inasmuch as these are typical of all local anesthetics, we will devote more time to it than to its substitutes, even though these have detracted in great measure from the parent drug.

COCAIN.

The coca plant (Erythroxylon coca Lam.) is indigenous to Peru and Bolivia, has been cultivated since prehistoric times, and been prominent in the religious and political life of the people. This plant was regarded as a gift of God which "satiated the hungry, gave renewed energy to the tired and weary, and caused the unfortunate to forget sorrows" (Novinny). During the reign of the Incas only the royal families had the right to cultivate the coca plant and to enjoy its consumption. Francisco Pizarro, in 1532, while exploring the interior of Peru, found the coca leaves widely distributed and their use much abused. Under Spanish regime the cultivation of the coca plant was at first prohibited, later monopolized by the government, and finally the people were again accorded the privilege of cultivating the plant, which was, however, subject to taxation. According to Wedell, in Bolivia alone, in 1850, three million Spanish dollars were collected as a revenue from this plant. The interest of the scientific world was first aroused by the reports of travellers, as Tschudi and Poeppig, according to whom the coca leaves were chewed by the natives of South America in order to alleviate hunger, to produce wakefulness, and increase their physical powers of endurance. The continued and excessive use of the coca leaves ultimately resulted in a shattered nervous system. The natives still feel the necessity of the coca leaf when undertaking work which requires great physical effort. The green leaves when mature, are picked, dried in the sun, and immediately packed.

Scherzer was the first to bring a large quantity of these leaves to Europe; later Woehler, of Göttingen, received some of these leaves and from them his pupils, Niemann and Lossen, extracted cocain. Cocain was later synthetically prepared by Merck, Skraup, Einhorn, Liebermann and Giesel.

Cocain ($C_{17}H_{21}NO_4$) crystallizes in large four- to six-sided colorless prisms. It is sparingly soluble in water, but dissolves readily in alcohol, ether, and ethyl chloride. It has a bitter taste and is of alkaline reaction. It melts at 98° C., being decomposed and converted into ecgonin. It combines readily with the acids to form salts, of which the hydrochloride is the best known and most frequently used therapeutically. Cocain hydrochloride ($C_{17}H_{21}NO_4$ HCl) is a white crystalline powder, readily soluble in water and alcohol, and when placed upon the tongue has a bitter taste. For the sake of brevity the term cocain will be used to denote cocain hydrochloride in the following paragraphs.

History of Cocain Anesthesia and Cocain Poisoning.—The discovery of the local anesthetic properties of cocain gave a new impetus to local anesthesia, its history for more than twenty years being practically identical with that of cocain anesthesia. Substitutes for cocain have only been known in late years. The first reports regarding the anesthetic properties of cocain were made by Scherzer, who noticed that the chewing of coca leaves caused a feeling of numbness in the tongue. The same properties were observed from the use of erythroxylin prepared from coca leaves by Garnicke (1855) and Percy (1857), and in a more pronounced manner from cocain itself. (Niemann 1860, Demarle, Schroff 1862, Moreno y Maiz 1868, von Anrep 1879). Von Anrep investigated the local action of this new remedy upon the skin and conjunctiva. He injected a weak solution of cocain under the skin of his arm. There was at first a feeling of warmth, then loss of sensation to the prick of a needle at the point of injection. In about fifteen minutes the skin injected became red, which, after the lapse of twenty-five to thirty minutes, disappeared together with the previously mentioned symptoms. Upon instilling a solution of cocain into the conjunctival sack of animals he noticed only the previously well-known mydriatic action of the drug. On the other hand, Coupard and Borderau, in 1880, made positive observations as to the loss of corneal reflex in animals following the use of solutions of cocain. Fauvel, Saglia, and others had already learned to use coca leaves and their extracts in the treatment of painful affections of the larynx and pharynx. This was the situation when Koller, and shortly thereafter Koenigstein, demonstrated that by the instillation of a 2 per cent. cocain solution, the eye could be made sufficiently insensitive to carry out many operations without pain. Koller reported his observations on this subject at the Ophthalmological Congress held in Heidelberg in 1884, his results being soon affirmed by Agnew, Moore, Minor, Knapp, Hirschberg, Graefe, Abadie, Panas, Trousseau and Horner.

Rapidly following upon these reports the use of cocain upon the eye and its mucous membranes was universally accepted and put to practical use in all operations on the eye. In the same year cocain was extensively used in laryngology (Jellinek, Schroetter, Stoerk, Zaufel, Fauvel) and rhinology (Bosworth, Lublinski). Otis and Knapp used this method of anesthesia upon the mucous membrane of the male urethra, while Fraenkel carried out similar experiments upon the female genitalia. This new discovery was of great value to ophthalmology, as many eye operations could be more exactly performed than with general anesthesia. It was of like importance in laryngology and rhinology, where operations previously impossible could now be carried out. Schroetter, who at first was skeptical regarding the experiences of his pupil, Jellinek, shortly thereafter made the following statement: "One may now say that the technical difficulties of operating upon the larynx have been overcome and that laryngeal surgery can now be generally practised by all physicians." The present perfection of technique in laryngology and rhinology is inconceivable without an agent like cocain, which not alone allays pain and inhibits reflexes but likewise causes a contraction of the mucous membrane, so that the larynx and nasal cavities become easily accessible.

By means of injections of solutions of cocain into the tissues, this form of anesthesia became applicable in surgery and dentistry. At first very concentrated solutions were used (2 to 20 per cent.), a few drops of which injected into the subcutaneous connective tissue produced in a short time, by diffusion of this agent, anesthesia, not only of the overlying skin but also of the deeper fascia, a fact long recognized by Anrep. By means of a number of such injections made near one another, large areas could be anesthetized, a method formerly in use by Corning, Roberts, Landerer, Woelfler, Dujardin-Beaumetz, Verchère, Hall, Witzel and others. An observation of great importance was made by Corning, in 1885, who reported that by interrupting the circulation better anesthetic effects could be obtained by the use of dilute solutions (0.25 to 0.33 per cent.), and without the danger of poisoning, than had formerly been obtained with more concentrated solutions where the circulation was not interrupted. For the purpose of interrupting the circulation in the extremities he used the Esmarch bandage; for other parts he constructed clamps and wire rings covered with rubber which were pressed upon the skin. He placed special stress upon the necessity of injecting the cocain solution before interrupting the circulation. By the aid of this method Roberts was able to perform a partial resection of the elbow (cocain used 0.06), and later an osteotomy of the femur for genu valgum (cocain used 0.19) without pain. He made the observation at this time that after the injection of cocain beneath the periosteum the latter could be separated from the bone and the bone itself divided without pain. Conway used this same method in anesthetizing fractures for the purpose of reduction. Anesthesia of a hydrocele sac by means of cocain injections was performed by Burdel, Thiéry, and others. In the year 1887, thanks to the efforts of Woelfler, a large number of reports were collected regarding operations carried out under cocain anesthesia (Schustler, Fraenkel, Spitzer, Chiari, von Fillenbaum, Lustgarten, Frey, Hoffman, Fux, Hochstetter, Orloff and others). Cocain anesthesia was used in all branches of surgery and was not limited to minor operations. Amputations of the leg, tracheotomies, extirpation of large tumors, herniotomies, and abdominal operations of all sorts were attempted with more or less success. Many surgeons (Woelfler, Fraenkel, Orloff) emphasized the necessity of infiltrating thoroughly the entire area to be operated upon with the anesthetic solution rather than depend upon its diffusion if one desired to anesthetize the tissues with certainty. Roberts, in 1885, described his method of saturating the skin with cocain solution; he made superficial injections in the proposed line of incision, followed this by a subsequent injection at the periphery of the anemic zone produced by the first injection, continuing thus until the entire operative field was made insensitive; the deeper parts were anesthetized in a similar manner. The systematic development of this method, which is known today as Schleich's infiltration anesthesia, was made by Reclus and Schleich. The properties of this new agent were utilized in many ways outside of the field of surgery. The observations of Corning and Goldscheider, made on both animals and man, that the conductivity of nerve trunks could be interrupted by cocain solutions, with the result that the area innervated by these nerves became anesthetic, was put to practical use by Halstead, in 1885, in the extraction of teeth. In this operation cocain was not injected around the tooth to be extracted but into the trunk of the infraorbital nerve, the injection being made from within the mouth. Later by means of a similar method Kummer and Pernice were able to amputate fingers and toes (Oberst). A very important contribution to the literature was made by Corning in 1885; he injected a 2 to 3 per cent. cocain solution between the spinous processes of the lower dorsal vertebræ into the spinal canal and noted the occurrence of anesthesia in the lower extremities from the effect of this agent upon the cord. Only in recent years has this so-called anesthesia of the cord become of practical value. We can only briefly mention that in 1886 Wagner and Herzog used the cataphoric action of the galvanic current in attempts to make the unbroken skin anesthetic, it being well known that cocain solutions alone could not penetrate this structure. Thus in a short time local anesthesia by means of cocain solutions was attempted in all possible ways, but the enthusiasm attendant upon the efforts made to replace general anesthesia by local anesthesia was destined to suffer the disappointments consequent upon its unrestricted use.

The first objection against the general use of local anesthesia was given expression by Hoffman and Fraenkel. The association of unconsciousness with general anesthesia became so fixed in the minds of the people that it was not readily controverted, or, as Fraenkel stated, most people desire to pass unconsciously the serious crisis associated with every operation. The second and more serious objection at that time was the great danger associated with cocain anesthesia. Attempts were made in vain to counteract these serious consequences by the use of remedies known to be of value for other poisons and the determination of the maximum doses. Too little attention was paid to the warning of Corning who stated: "A remedy which has such a strong chemical affinity for nerve substance must also affect the heart and central nervous system when introduced into the circulation in concentrated solution."

Mild, severe, and fatal cases of cocain poisoning have been observed in great numbers following the use of this drug internally and subcutaneously, and by local application to mucous membranes, but most frequently, of course, when used for surgical purposes. A compilation of the published cases of cocain poisoning was made by Falk and later by Weigand. These cases naturally represent but a small part of the entire number observed. These statistics were lacking in exactness, inasmuch as the strength of the solution used was not mentioned; nevertheless, if one may judge from the tendencies of the times, concentrated solutions were used. A distinction must be made between those cases in which cocain is introduced directly into the body and entirely absorbed, as in the internal administration or injections into the tissues, and those cases in which only a portion of the quantity used is absorbed, as in anesthetizing mucous and serous membranes. In the latter case the size of the absorbing surface to which the cocain is applied is of great importance. Ophthalmologists who use cocain very frequently seldom have cases of poisoning; among Weigand's 26 cases there was not one fatality. The cause of death in the case reported by Bottard (*La Normandie med.*, 1887, cited by Huber) following the instillation of a 2 per cent. cocain solution into the eye, must be considered questionable, as the strength of the solution is seldom more than 2 to 4 per cent. and the extent of the mucous membrane treated is very small. In 17 cases of poisoning following the application of cocain to the nasal mucosa Weigand reports no death; in 12 cases of poisoning following applications to the mouth and pharynx there were two deaths; in 11 cases of poisoning after applications to the larynx there was one death. Three deaths are noted following the application of cocain to the rectal mucous membrane, two of which no doubt refer to one and the same patient whose death caused the unfortunate surgeon, Kolomnin, to commit suicide. The use of cocain solutions of from 2 to 10 per cent. is particularly dangerous in closed cavities lined with mucous or serous membranes, such as the urethra, bladder, and scrotal cavity. In the 24 cases collected by Weigand there were many very severe cases of poisoning, with three deaths (Sims, 0.8 cocain, concentration not given; Reclus, 1.0 cocain in 5 per cent. solution; Pfister, 1.0 cocain in 20 per cent.

solution). In a later case reported by Czerny, death followed an injection of 7 c.c. of a 1 per cent. cocain solution into the urethra. Two similar but unpublished cases were reported to the author personally where death followed the injection of several cubic centimeters of a 5 per cent. cocain solution into the bladder. Berger reports a case in which exitus lethalis followed the injection of about 0.35 cocain in 2 per cent. solution into the scrotal sac. A similar death occurred in 1905 after Prouardel injected 40 c.c. of a 5 per cent. solution of cocain into the scrotal sac, although the solution was allowed to drain out after three to four minutes. The number of deaths which actually occurred in this manner is certainly greater than the number reported, for which reason we must conclude that the application of strong cocain solutions to large absorbent surfaces is dangerous and not to be recommended. Weigand reports 15 cases of cocain poisoning with 4 deaths, the cocain being administered by the mouth, the quantity varying from 0.8 to 1.5. There have been 132 cases of poisoning reported following the hypodermic injection of cocain, with 8 deaths; this does not include the cases already reported by Berger. The strength of solutions used was 4 per cent. or more, as near as could be determined, the total quantity being unusually large, as much as 4.00 having been given; in 2 cases, however, only 0.04 and 0.06 were given. The latter 2 cases Reclus and Auber do not regard as cases of cocain poisoning. In the case reported by Bettelheim severe symptoms manifested themselves following the injection of 0.01 of cocain in the forearm, the etiological explanation of which appeared doubtful to Woelfler. It is immaterial how one views these cases; nevertheless the fact is that Weigand's records show no less than 40 cases in which usually harmless doses of 0.01 to 0.05 in 5 to 30 per cent. solution were injected, causing symptoms of poisoning, in some cases very severe. On the other hand, occasionally after the injection of a large dose (2.0 to 2.5, Buebler), only relatively slight symptoms of poisoning were observed. We can conclude from these observations that, although the quantity of cocain injected was accurately measured, there are many circumstances to be considered in the causation of poisoning other than the dosage. There may be a peculiarity in the constitution of the individual, an idiosyncrasy toward cocain, or it may be that the cocain itself is not of uniform action in all cases. Which one of these views is correct? Can cocain poisoning be prevented, and how?

Physiological Action of Cocain.—The physiological action of cocain is that of a protoplasmic poison, affecting protoplasm whenever it comes in contact with it. The symptoms, therefore, manifest themselves at the place where the cocain enters the body and also at distant points, on account of which we distinguish between a local and a general poisoning.

Character and Mechanism of Local Cocain Poisoning.—Cocain paralyzes temporarily and without permanent damage to the tissues the function of sensory and motor peripheral nerves (Alms, Mosso), the striped and smooth muscle fibers (Albertoni, Sighicelli), and the heart muscle (Mosso), provided the solution is not too dilute when brought into contact with these structures. When cocain solutions are applied to freely exposed nerve trunks, first the sensory and later the motor fibers lose their power of conduction (Torsellini, Feinberg, Alms, Kochs, Witzel, Goldscheider, Corning, Mosso). Herrenheiser showed that cocain applied in this way can paralyze the optic nerve, while Aducco and Mosso (1890) demonstrated that a few drops of a 10 to 20 per cent. cocain solution placed on the floor of the fourth ventricle of the brain promptly paralyzes the respiratory centre, but the animals could be kept alive by artificial respiration. The symptoms of general cocain poisoning in men and animals show how particularly sensitive the central nervous system is to this drug. Albertoni found that cocain, applied locally, inhibited the secretion of glands, the movements of spermatozoa, ciliated epithelium, blood-corpuscles of the cray-fish, lepidoptera larvæ, and amebæ. The same author and Maurel noticed that solutions of cocain in the blood paralyzed the leukocytes. The latter lost their contractility and power to penetrate the vessel walls, and became round and collected in capillaries. Danilewski, by the application of cocain to the feelers cut from the sea anemone, was able to see and study all the elementary symptoms of cocain poisoning, which promptly disappeared upon the removal of the cause. Charpentier, Mosso, and others, showed that plants are similarly affected by cocain.

The local application of cocain causes contraction of the small capillaries and arteries, especially of the mucous membranes, so that locally the blood content of the tissues is temporarily diminished. Eversbusch, Laborde, and others, regarded this oligemia as the basis of local and general cocain poisoning. Maurel, after the most painstaking efforts, endeavored to prove that the paralyzed leukocytes obstructed the contracted capillaries, thus causing a disturbance of function of the protoplasm of the tissues. It was known long before these observations of Maurel that the action of cocain was independent of the blood contents of the organs. As proof of these facts it might be mentioned that cold-blooded animals which can live for some time without blood, and organisms which have no circulatory system, react constantly upon cocain. If the blood of frogs is replaced by a solution of sodium chloride they will show the same symptoms of local and general cocain poisoning as normal frogs or other warm-blooded animals. Excised organs (nerve-muscle preparation) of warm-blooded animals, while still in a living state, do not react differently upon cocain than those in the living animal. Arloing cocainized the eye of a rabbit and then cut the sympathetic of the same side; although the conjunctiva immediately became markedly hyperemic, the anesthesia persisted. It might be mentioned in this connection that the newer local anesthetics in part act similarly to cocain, except that they do not cause contraction of the bloodvessels, with consequent oligemia and anemia of the tissues; likewise many symptoms of cocain poisoning, particularly the rapidly ensuing loss of pain sense, do not occur. The influence of the anemia of the tissues indirectly causes a retardation of the circulation, the absorption of cocain taking place more slowly, thereby producing a more intense local effect.

A direct effect of anemia on the symptomatology of cocain poisoning can only be considered when organs easily affected by variations in their blood-content or pressure like the brain cortex are concerned. We will consider this subject again in another chapter.

The paralysis of leukocytes, contraction of bloodvessels and anemia, are not the cause but the consequence or the effect of cocain poisoning, and are best explained as due to a chemical affinity of cocain for the protoplasm. The nature of the chemical combination of the protoplasm with cocain is not known; it can be assumed, however, that it must be a very loose one, which can be broken up as readily as it occurs, permitting the function of the affected tissues to return to the normal. The disintegration of these combinations is intimately associated with the vital forces of the tissues, and the symptoms of local cocain poisoning can under certain conditions be continued indefinitely by interrupting the circulation of the part. From certain peculiarities of cocain poisoning it is probable that cocain which has once entered into chemical combination is not taken up by the circulation as such, but is split into its component molecules. This is in accord with the fact that in the excreta and organs of animals poisoned by cocain, little or no cocain can be found. According to Wiechowski's investigations, a dog eliminates 5.1 per cent., a rabbit no part of a toxic dose of cocain; nevertheless, from the organs of recently killed animals treated with cocain solutions the larger part (80 per cent.) may be recovered. The disintegration of the alkaloids must have some association with the vital processes. The older experiments of Helmsing (1886) are not very valuable, since at that time there was no known chemical reaction for cocain; still, the author supposes that the cocain was disintegrated within the body of the animal.

Various forms of protoplasm, different organisms or parts of organisms, are not equally susceptible to cocain; one variety of protoplasm requires a larger dose than another before showing evidence of poisoning. The extent of cocain poisoning is quite variable; at times the stage of excitation preceding every cocain paralysis is very slight or not at all noticeable; at other times the paralysis is preceded by the most severe irritation. Very slight degrees of poisoning evidence themselves merely by excitation and functional stimulation, which symptoms produced by the use of coca leaves, gave the latter historical prominence. The cerebral cortex is most sensitive to the action of cocain, then the medulla oblongata and cord. The symptoms of general cocain intoxication in warm-blooded animals are evidenced by a disturbance of function in these organs, giving rise to such symptoms as intense excitement, convulsions and paralysis.

The peripheral sensory nerves are likewise very sensitive toward cocain, whether it reaches them by absorption, from a mucous membrane, from injection directly into the tissues, or by means of the blood-supply (Alms, Maurel). The sensitiveness of the sensory end organs of the human skin can be definitely determined by means of the skin wheal. The addition of 0.005 per cent. (1 to 20,000) of cocain to an indifferent solution, such as 0.9 per cent. salt solution, when injected into the skin is sufficient to obliterate the sense of pain for a short time in the area injected (Braun, Heinze).

More dilute solutions show no such effect. Dilute and osmotically indifferent solutions of cocain are painless when injected; concentrated solutions of 3 to 4 per cent. cause sudden sharp pain, to be immediately followed by complete local paralysis. The duration of anesthesia varies with location and individual susceptibility, and increases with the strength of the solution. If the anesthetic wheal produced by the injection of a 1 per cent. solution lasts twenty-five minutes, the injection of a 0.1 per cent. solution in the same person and the same place will last only eighteen minutes. The freezing-point of various cocain solutions is as follows:

0.1 per cent. solution, freezing-point	0.02 °
1.0 per cent. solution, freezing-point	0.115°
2.0 per cent. sulution, freezing-point	0.23 °
3.0 per cent. solution, freezing-point	0.305°
4 0 per cent. solution, freezing-point	0.41 °
5 8 per cent. solution, freezing-point	0.565°

It will be seen that the physiological concentration is about 5.8 per cent. Weaker solutions than this (as low as 0.5 per cent.) cause cellular swelling and pain upon injection, the latter often being obscured by the rapidly following paralysis. Watery solutions of 0.01 per cent. cause severe pain upon injection. Injury to the tissues is not noticed after the use of weak, osmotically indifferent cocain solutions. The swelling rapidly disappears without leaving any infiltration or other local changes. The intensity and extent of anesthesia produced by diffusion of the solution depends upon its concentration; the anesthesia following the use of weak solutions is limited to the area injected. Following the injection of 2 per cent. cocain solutions a relatively large anesthetic and hemianesthetic area surrounds the place of injection. If a 0.1 per cent. solution of cocain is injected into the subcutaneous connective tissue the overlying skin, as a rule, will not show any pronounced change of sensation; but if the strength of the solution is increased to 2 per cent. or more, not only does the skin become anesthetic but also the deeper parts, such as fascia, muscle, periosteum, etc. In like manner cocain solutions will interrupt the conductivity of nerve trunks if injected into their immediate neighborhood in sufficiently concentrated solution (2 to 4 per cent.). We will again refer to the history, theory, and practical application of this method. In regard to increasing the local effect of cocain by preventing its absorption see Chapter VIII.

Goldscheider found upon studying the relation of cocain to the various sensations of the skin that the temperature sense and sensation of tickling were most susceptible to its action. He likewise made the remarkable observation that although the skin or mucous membrane of the tongue was anesthetized and the temperature sense completely obliterated, nevertheless hyperalgesia to irritation from heat was present. To be more definite, he found that where moderate warmth applied to the normal skin produced only a feeling of difference in temperature, in the cocainized skin or mucous membrane it produced severe pain. The correctness of these observations of Goldscheider have been verified.

Touch and pressure sense are less sensitive to the action of cocain than the pain sense, it being frequently observed that after the local application of cocain, although analgesia is present, touch and pressure sense are not disturbed. After the application of cocain, in a solution of definite strength and when complete anesthesia has been induced, touch and pressure sense return first, then pain sense, and lastly the temperature sense. These observations do not agree with those of Goldscheider.

This experiment can best be carried out by injecting into the cutis 0.001 to 0.1 per cent. cocain solution in 0.9 per cent. salt solution. A considerable area will thus be anesthetized, the degree of anesthesia depending upon the concentration of the solution. In this area the reaction of the senses to irritation can be accurately tested. The quantity of cocain used is so small that any symptoms of a general nature can be excluded, although Mosso (1890) noticed an increasing hyperesthesia of the entire skin after the internal administration of 0.05 to 0.1 cocain in man. It can also be determined that the duration of anesthesia increases with the concentration of the solution. It can be further shown that the weakest solutions (0.001 to 0.003 per cent.), the concentration varying with the time and individual, cause a loss of temperature sense only and a hyperalgesia toward irritation from heat. Slightly stronger solutions (0.005 per cent.) cause analgesia, and still stronger solutions cause a loss of all sensation. If the course of the anesthesia is now tested, it will be constantly noted that touch and pressure sense return first, pain sense next, and last the temperature sense. It will also be noticed during the disappearance of the anesthesia, when cutting, pricking the skin, and faradic irritations are scarcely recognized as pain, that hyperalgesia to the irritation of heat is present. This observation is of considerable practical significance in surgery and offers an explanation of the fact that the use of the thermocautery on tissues anesthetized with cocain causes a rapid return of pain sense. We now have no further need for the improbable theory of Reclus, that the effect of the heat of the thermocautery caused a more rapid destruction of the cocain present in the tissues.

Cocain applied to mucous membranes paralyzes not only the pain sense but also the other inherent senses such as taste and smell (Zwaardemacker).

The motor nerves are so much less sensitive to cocain than the sensory nerves, that it has been held that they are immune, but Alms and Kochs, later Mosso (1890), Laewen, and Gros demonstrated that this was not the case. Mosso, following the application of cocain to the nerves of the diaphragm of a dog, observed a rapidly ensuing paralysis of this structure. Frank utilized this property of cocain in his physiological experiments on living animals, in place of cutting the nerves. Alms and Maurel injected cocain into an artery of an animal and noted a motor paralysis in the area supplied by it. Mosso replaced the blood in the vessels of the extremities of frogs and warm-blooded animals with salt solutions and defibrinated blood containing cocain in various quantities. If the solution contained 0.6 per cent. of cocain, the muscles were first stimulated, then paralyzed, returning to normal when the vessels were flushed with salt solution or blood. If the above solutions contained larger quantities of cocain, paralysis ensued immediately. In experiments on conduction anesthesia in man, an interruption of conductivity of both motor and vasomotor tracts of mixed nerves occurred when the action of the cocain was sufficiently intense; the sensory tracts were, however, more quickly paralyzed and the anesthesia was of longer duration than the motor paralysis. If the action of the cocain was less intense, motor paralysis did not occur, whereas sensory paralysis was complete.

According to Mosso the frog's heart becomes stimulated when salt solution containing 0.04 per cent. cocain is passed through it, and paralyzed when 0.08 per cent. of cocain is contained in the solution, the heart returning to normal if no further addition of this substance is made. Albertoni was able to paralyze the larvæ of lepidoptera and ameba, when placed in 0.5 per cent. cocain solution. In regard to the sensitiveness of plants it has been found that 0.05 to 0.1 per cent. cocain solutions accelerate the germination of the seed and the growth of the plant, 1 per cent. solutions hinder these processes, while 2 per cent. solutions cause a complete interference with growth and development. The leukocytes are particularly sensitive to cocain. Maurel states that the leukocytes are paralyzed by the addition of 0.02 per cent. cocain to the human blood. The collection of immobile leukocytes in the capillaries constantly occurs in general cocain poisoning, but has not the significance ascribed to them by Maurel. Since the sensory nerves have been shown to be most sensitive to cocain, it is only natural to ascribe to cocain a certain specific action upon the peripheral sensory nerves. Until the discovery of cocain, there was no known substance which was able to exert a decided action upon the peripheral sensory nerves without marked irritation or permanent damage to them.

The term "sensitive curare," which was applied to cocain by Anrep, Laffonte, Laborde, and Dastre, is certainly applicable, as the motor and sensory paralysis following the ingestion of toxic doses of cocain are central in nature, and are not due to the action of this agent upon the peripheral nerves (Mosso).

Character and Mechanism of General Cocain Poisoning.—Cocain introduced into the body and absorbed into the circulation may act upon the protoplasm of organs in places remote from the point of introduction. These organs will respond to the toxic agent with irritation or paralysis, if the blood passing through them contains cocain in sufficient quantity to effect them. This rule formulated by Albertoni is the key to the understanding of the peculiar manifestations of local or general cocain poisoning.

The historically important property of small doses of cocain was studied by Mantegazza among the natives who chewed the coca leaf. He observed that motion and sensation were temporarily stimulated within normal limits, perception and transmission of nerve impulses, as well as metabolism, were increased. This was later observed by Anrep, Mosso, Fleischer, Freud, and others, to apply to the use of pure cocain. This undoubted central action of small doses of cocain is of little importance in the consideration of our subject. To better understand the rapidly changing picture of acute cocain poisoning following the introduction into the body of large doses of this poison, we will follow the description of Husemann. In studying the symptomology of this condition we find the chief disturbance in the organs most sensitive to cocain, namely, the central nervous system. In the mildest form of poisoning there is a sudden but usually transient attack of vertigo quickly following the application of the cocain. This attack may, however, become more severe and be followed by collapse, small compressible pulse, formication, cold extremities, irregular, difficult respiration and cold sweat. In more severe cases these symptoms are accompanied by unconsciousness, and followed by symptoms of general weakness lasting several hours. Vomiting is frequently associated with this condition. As previously mentioned, it is possible, or rather probable, that the cerebral anemia present in the milder forms of cocain poisoning has a certain but unimportant part. The symptom complex indicates a severe degree of poisoning of the central nervous system, characterized by more or less excitation of the cerebral cortex (cocainrausch). The patients are unnaturally excited; they are usually in good spirits, laugh, chatter, have hallucinations and very frequently melancholia and ideas of persecution. Various abnormal subjective sensations occur, such as dryness of the throat, precordial fear, parasthesia, anesthesia, loss of sight, smell, and hearing. The pupils are dilated and fixed as after the local instillations of cocain into the eye; the excitation may develop into mania. Severe, dangerous cocain poisoning almost always begins with severe epileptiform convulsions with exophthalmos and unconsciousness, followed by loss of sensation, motion, reflexes, and lastly the corneal reflex. The patients are in deep coma and death ensues in consequence of paralysis of the respiratory centre. A succession of the phenomena of cocain poisoning is similar to that of the inhalation anesthetics, such as chloroform, ether, etc., except that in the latter the symptoms of irritation are slight, those of paralysis predominating, while in the former the symptoms of irritation of the central nervous system are most prominent. Individuals having a tendency to convulsions develop these symptoms much more readily than others after the use of cocain. It has been noticed in nervous individuals that convulsions have occasionally occurred three to four weeks after the poisoning. The manifold symptoms of acute cocain poisoning have not been exhausted with this description, as there is hardly a pathological symptom of the body which has not been observed in this condition. Experimental investigations regarding general cocain poisoning in animals have been made by von Schroff (1862), Danin (1873), von Anrep (1879), Volpian (1883), Mosso, (1887), Albertoni (1890), Maurel (1892), and many others, and the association of the phenomena explained. As in man the symptoms are confined almost entirely to the central nervous system. In intelligent animals, as dogs, after the use of small doses of cocain a similar irritation of the psychic centres is observed the same as in man, excitation, depression, and hallucinations (Feinberg, Blumenthal, and Mosso). Every severe case of poisoning in warm-blooded animals begins immediately after the administration of cocain, with severe clonic convulsions, exophthalmos and loss of consciousness. In cold-blooded animals convulsions are absent. In warm-blooded animals they may be absent or almost so, if the poison is administered gradually in dilute solutions. As is observed in man, the convulsions are succeeded by coma, with loss of consciousness, motion, and the reflexes, death ensuing during or after the stage of convulsion from paralysis of respiration. Feinberg and Blumenthal have demonstrated the central origin of cocain convulsions, the symptoms not occurring in animals in which the cortical motor centres have been extirpated. These symptoms are likewise absent in newborn animals in which the cortical centres, according to Soltmann, cannot be stimulated before the twentieth day. Finally, these symptoms do not occur if the cerebral cortex has been previously paralyzed with chloroform, ether or chloral hydrate (Mosso). The observations of Feinberg and Blumenthal, which were later verified by Soulier and Guinard, seemed to point to cerebral anemia as the cause of the convulsions. There can be no further doubt at present that the specific effect of the poison on the central nervous system is the cause of the stimulation of the cortex. In the first place, the brain is not anemic during the stage of convulsions, but, to the contrary, enormously overfilled with blood, for which reason we notice the condition of exophthalmos, and, secondly, drugs closely related to cocain in their action, but which do not cause cerebral anemia, give rise to similar convulsions (tropacocain). Sensory and motor paralyses, caused by cocain, are purely of central origin, as shown by Mosso, for even in the deepest coma, muscles and peripheral nerves retain their power of reacting to stimuli, while on the other hand paralysis of an extremity does not occur when excluded from the circulation of the poisoned animal.

During the experiments on animals poisoned by cocain many peculiarities of the effect of this drug should be noted which find their explanation in the action of this alkaloid upon the protoplasm. We have learned that the chief properties of cocain are: (1) Its marked affinity for living protoplasm of all kinds, which causes its fixation as soon as the substance is introduced into the body. (2) Its ability to enter into less stable compounds with the protoplasm whose functions are temporarily interrupted and its rapid disintegration, which, therefore, prevents its entering the circulation again as cocain. These properties form the basis of the local anesthetic qualities of the drug and explain the following peculiarities of cocain poisoning:

If cocain solutions be injected intravenously into animals, they react promptly and uniformly to definite doses of cocain, provided the doses are dissolved in the same quantity of water or other solvents. The same dose will act differently, however, if of different concentration, or if instead of being administered as one dose is injected at short intervals. This reaction of cocain was first studied by Maurel.

According to the experiments of Maurel, if 0.01 cocain in 5 per cent. solution be injected into a vein in the ear of a rabbit, death immediately follows; 0.005 per kilo causes violent convulsions; 0.0025 causes mild symptoms of poisoning. If 0.002 per kilo in 5 per cent. solution be repeatedly injected intravenously at intervals of five to ten minutes, 0.03 per kilo of cocain can be given without the occurrence of poisoning. Poisoning will likewise not occur if 0.03 per kilo of cocain be injected in 0.25 per cent. instead of a 5 per cent. solution. Similar experiments by the author were reported by Weigand as follows: three rabbits of approximately the same weight (1800 gm.) were injected in a vein in the ear with cocain, the first, 0.005 in 10 per cent. solution; result: severe convulsions and paralysis; the second, 0.005 in 1 per cent. solution; result: no poisoning; the second 0.01 in 1 per cent. solution; result: short, violent convulsions; the third, 0.02 in 0.2 per cent. solution; result: transient weakness; the third, 0.02 in 0.1 per cent. solution; result: no poisoning.

It will be noted from the above that four times the quantity of cocain will be borne by an animal in 0.01 per cent. solution without injury, which in a 10 per cent. solution causes very severe symptoms on the part of the central nervous system. The weakening of the toxic effect of a quantity of cocain injected intravenously in divided doses was observed by Feinberg and Blumenthal in their experiments on dogs. The explanation of these facts is determined by the properties of cocain. The latter, introduced into the blood, irritates and paralyzes the susceptible nervous system, before the other organs have had an opportunity to react, although they were equally exposed to its toxic action. Cocain poisoning of the central nervous system, that is, the picture of general cocain poisoning, occurs when the blood passing through the central nervous system contains the alkaloid in a sufficiently active concentration for this organ, even if the contact with it be but momentary. If this concentration be less, repeated doses of cocain may be administered for a time, as the small quantities contained in the blood become immediately combined and ultimately disintegrated. Acute poisoning will therefore not occur, as the living cells of the central nervous system can withstand and render harmless the small doses they receive as long as the cocain and its disintegration maintain a definite balance. These conditions are very similar to those resulting from the inhalation of ether and chloroform. These substances do not possess a maximum dose. A small quantity of either of them can cause a paralysis of the centres in the medulla oblongata with instant death of the patient, if contained in the blood in concentrated form. Many hundred times this quantity can be gradually administered, as the degree of poisoning from either chloroform or ether depends entirely upon the quantity of their vapor in the respired air of the individual. The occurrence and intensity of cocain poisoning are not alone dependent upon the quantity given, but also upon the time during which it is administered. If introduced into the blood suddenly, that is, in concentrated solution, death may occur immediately, while if gradually introduced, that is, in dilute solution or if given in divided doses, poisoning will not manifest itself, as the concentration of cocain in the capillaries of the central nervous system is never of sufficient concentration to be toxic to this organ. The toxic effect of concentrated and dilute solutions is not so marked with other substances as it is with cocain. Poisons which at their point of application produce stable changes and accumulate do not show the phenomena to such a marked degree, as they must be administered gradually in repeated doses, in consequence of their cumulative action. This finally brings about the same condition as when a like dose is rapidly absorbed. We shall later study the action of the drug "akoïn," a local anesthetic which belongs to this class of poisons.

Animals can withstand much larger quantities of cocain solution injected into the subcutaneous connective tissue, or between the muscles, than when the same quantity and of like concentration is injected into the veins, leaving out of consideration temporarily some of the irregularities of action of this alkaloid. Custer observed that 0.03 per kilo in a 5 per cent. solution was the smallest quantity that would show evidence of poisoning in rabbits, and that 0.1 per kilo was always a fatal dose. Experiments by the author show that 0.02 per kilo in a 10 per cent. solution caused no symptoms, 0.03 per kilo was, as a rule, followed by poisoning, and exitus lethalis occurred regularly after the administration of 0.1 per kilo. Most authorities consider the dose of 0.1 per kilo fatal for rabbits. The dose which can be administered to rabbits subcutaneously without toxic or fatal effect is almost ten times as large as that which can be administered intravenously. The cause for this difference lies mainly in the delayed absorption of the alkaloid, part of which enters into a local combination with the tissues, the remainder reaching the central nervous system in more dilute form. However, in intravenous injections the full dose cannot reach the central nervous system, inasmuch as the paralyzed leukocytes fill the capillaries and must necessarily absorb a portion of the poison. The affinity of cocaine for all tissues, and their power of reducing portions of the drug is best shown when the solutions are introduced subcutaneously. It will again be seen that the effectiveness of the dose administered subcutaneously is dependent in large measure upon the concentration of the solution. Ponchet injected two guinea-pigs of equal weight, one with 0.04 cocain in 4 per cent. solution, the other 0.1 in 0.66 per cent. solution; the first died after a few seconds, the second was poisoned but did not die. Experiments on rabbits demonstrated that a 5 to 10 per cent. solution containing 0.1 of cocain per kilo was fatal, whereas the same quantity administered in a 1 per cent. solution caused mild symptoms of poisoning or none at all. It was also shown that cocaine in dilute solutions did not produce convulsions to the same extent as the more concentrated ones. According to Maurel, 0.025 of cocain in 0.1 per cent solution is fatal for rabbits, while experiments by Custer and others demonstrated that 0.1 per kilo in 0.1 per cent solution did not produce poisoning; the first toxic symptoms showed themselves only after the administration of 0.15 per kilo, and even after the administration of 0.3 per kilo death did not occur. The widely varying results of Maurel's experiments can be explained by the fact that he used large quantities of a watery solution of cocain for subcutaneous injections. The animals did not die of cocain poisoning, but, as Custer has shown, in consequence of the injection of water, which could have been prevented by the addition of salt to the solution.

Thus a quantity of cocain injected subcutaneously in 5 to 10 per cent. solution causes the same toxic symptoms as 5 times the quantity in 0.1 per cent. to 0.2 per cent. solution, the reasons for which have been previously given. Maurel made most interesting observations following the injection of cocain solutions into the arteries of rabbits instead of into their veins. He found that he could inject 0.1 per kilogram in 10 per cent. solution into the femoral or renal artery without causing any evidence of poisoning, whereas the control animals died after injecting 0.02 per kilogram into their veins. Maurel's explanation of the action of cocain is certainly incorrect, no matter how plausible it may seem. In 1909, the author injected into the femoral artery of a rabbit weighing 3000 grams 0.1 cocain, corresponding to 0.033 per kilogram in 10 per cent. solution, with an immediately fatal result. In the case of a second animal the injection of 0.01 per kilogram in 10 per cent. solution into the femoral artery caused severe symptoms of poisoning, but the animal did not die. It is very necessary in these experiments to be sure that the arterial circulation is not in any way interferred with during and after the injection, so that the cocain as intended, can immediately enter the circulation.

Mosso noticed that dogs sometimes respond differently than usual to concentrated cocain solutions injected subcutaneously. One dog failed to be poisoned by 0.02 to 0.03 per kilo, while another one died quickly after the same dose (0.03). Any one who has made such experiments must have come to the conclusion that we cannot without some reserve speak of a fatal toxic or non-toxic dose when using cocain in this manner. In experiments on animals the same uncertain action of cocain is encountered as has been noted in the history of cocain anesthesia in man, causing the widespread belief in an idiosyncrasy toward this drug. It is certain that there are persons more susceptible to the action of cocain than others, but in the large majority of cases poisoning following the injection of small doses of cocain must be explained otherwise than by an idiosyncrasy. The difficulty of determining the proper dosage of cocain is noted in animal experimentation as well as in the later observations in man. In animals the irregular action of cocain, such as the toxicity of relatively small doses or the harmlessness of correspondingly large ones, becomes evident when concentrated solutions are used subcutaneously. Intravenous injections of cocain show a positive relation between the concentration of the solution and the symptoms following. It has been repeatedly demonstrated that the so-called idiosyncrasy in man disappears if, instead of a concentrated, a dilute solution of cocain is used for injection. It has been shown that an animal will react differently to a certain dose of cocain at different times. If 0.03 per kilo of cocain in a 10 per cent. solution is injected subcutaneously into a rabbit, severe symptoms of poisoning will usually occur, such as convulsions with consequent paralysis, without, however, causing its death. On June 19, 1898, a rabbit weighing 2850 grams was injected under the skin of the back with 1 c.c. of a 10 per cent. cocain solution (0.035 per kilogram) without being poisoned. This animal reacted in like manner several days before to 0.03 per kilogram, and did so again three days later. This speaks against Aducco's theory of a cumulative action of the drug, and also against a tolerance of the drug as suggested by Custer. Similar observations have been frequently made on human beings, principally following the anesthetizing of mucous membranes where exact dosage was impossible. Weinreich reports a severe case of poisoning following an injection into the bladder of 2.0 cocain in 20 c.c. of water, although five times this quantity had previously been borne by the patient; seven days later 1.0 cocain in 30 c.c. of water was used in the same manner without poisoning. This same author reports a second case which reacted in the same manner. Bergmann reports a case in which severe cocain poisoning followed the injection into the thigh of 0.02 in a 5 per cent. solution, although 0.05 in 5 per cent. solution had been well tolerated the day before. Hobbs and Rieke make similar reports regarding the anesthetizing of nasal mucous membranes, and Hobbs is therefore of the opinion that we cannot speak of a toxic or of a non-toxic cocain dose, since the same persons will react differently to like doses of cocain at different times. On the other hand, very few cases have been reported in which there is a permanent hypersusceptibility to cocain. It is not at all necessary in order to explain all these phenomena to assume an idiosyncrasy toward the drug. The typical and regular action of cocain is noticed only after intravenous injections. Extremely small quantities of a concentrated solution are sufficient to severely injure the central nervous system. The more dilute the solutions used in this manner the larger the dose necessary to produce the same toxic symptoms.

Much larger doses of a concentrated cocain solution can be applied to mucous membranes, and injected subcutaneously than can be injected intravenously, as its absorption is delayed, causing the cocain reaching the central nervous system to become more dilute, thus preventing symptoms of poisoning. Should a small quantity of a concentrated solution find its way into a blood or lymph vessel or be very rapidly absorbed owing to the nature of the part injected, then relatively small doses act as though injected intravenously. In this manner the affinity of cocain for protoplasm can be explained, as well as its local anesthetic properties, which before the discovery of the drug was never observed in connection with any other substance. This also explains its general action, the difference in toxicity between concentrated and dilute solutions, and the apparent irregularity of like doses when injected intravenously and subcutaneously. In order to understand local and general cocain poisoning it is necessary to always keep in mind the fact that general and local poisoning stand in definite relation to the rapidity of absorption.

The Prevention and Treatment of Cocain Poisoning.—The Dosage of Cocain.—How to avoid the dangers of cocain can be learned from a study of the preceding observations and the following experiments on human beings. It is not sufficient to consider a certain dose as the absolute maximum, as the authorities differ widely upon what they consider a safe dose. The difficulties in this connection will be realized after a consideration of the doses recommended by the following authorities: Landerer, 0.01; Woelfler, 0.02 to 0.05; Kocher, 0.1; Reclus, 0.2; Gluck, 0.2 to 0.3. In the German pharmacopeia 0.05 is given as the maximum dose. These statements must be changed, as reliance upon them has recently resulted in severe poisoning (Bergmann). The maximum dose of cocain is not 0.05, as this dose neither protects one from cocain poisoning nor represents at all times the largest dose that can be used with safety.

The largest quantity of cocain which can be injected directly into the bloodstream in concentrated form without producing symptoms of intoxication should be considered the maximum dose. This quantity will be found much smaller than that recommended by the German pharmacopeia and will be found to be a portion of a centigram. This fixed maximum dose is without the least practical value, for by the observance of certain precautionary measures much larger doses of cocain can be introduced into the body without danger. These precautionary measures consist principally in preventing a too rapid absorption of the drug, so that the smallest maximum dose enters the blood-stream at one time. Very large doses of cocain can be used without toxic effect if introduced gradually into the body or if a too rapid absorption is prevented; whereas small doses if rapidly introduced into the circulation can give rise to symptoms of poisoning. The latter can be most readily avoided by using very dilute solutions for anesthesia, so that in the dilution of solutions of cocain we have the secret of preventing poisoning.

The necessity of using very dilute solutions of cocain for injection was suggested by Corning shortly after the introduction of this agent. He demonstrated that anesthesia could be produced by using 0.33 to 0.2 per cent. solutions with the aid of the Esmarch bandage. Fraenkel likewise observed that larger areas could be anesthetized by a certain quantity of cocain if 1 instead of 10 per cent. solution was used. In the discussion of Berger's case of cocain death, at the Paris Surgical Society (1891) Motty stated that he used 0.5 per cent. cocain solutions entirely without having one serious accident in thousands of cases in which it had been injected. Oberst (Pernice) since 1889 used principally 0.5 to 1 per cent. solutions of cocain, and the author who studied his methods and has employed them almost daily, has never observed a case of cocain poisoning, We are indebted for the knowledge of these principles to the efforts of Reclus and Schleich. Reclus, in numerous original articles and those of his pupils (Auber, Fillon, Delbose, Legrand), offered the opinion that cocain poisoning was due to an idiosyncrasy and demonstrated that it could be avoided by proper technique. He perfected a method whereby he could use a 1 per cent. solution, later a 0.5 per cent. solution, without the use of the Esmarch bandage, for performing major operations which were formerly only possible under general anesthesia. He reports over 7000 cases to prove the harmlessness of cocain when used in this way. Ceci, Hackenbruch, and many others, promulgated this teaching. Schleich later taught that with even more dilute (0.1 to 0.2 per cent.) cocain solutions and with the aid of a special technique and the use of cold, the field for cocain anesthesia could be materially extended. Solutions containing 1 per cent. and more of cocain should never be used for injection.

In what dosage can dilute solutions be used? The older literature only deals with cocain poisoning following the use of concentrated solutions, the maximum dose of which, according to the experience of Woelfler, should not exceed 0.05

It has already been shown that this supposed maximum dose neither protects the patient from poisoning nor does it represent the quantity of cocain which can be used without danger. The experience of Reclus with more than 7000 patients seems to indicate that if a 0.5 to 1 per cent. cocain solution is used, at least double the quantity above mentioned can be injected. He has used as much as 0.2, and beyond an occasional transient excitability has never experienced serious consequences since using the dilute 0.5 to 1 per cent. solution. Reclus holds that certain measures of precaution are absolutely necessary. Cocainization should only be performed in the horizontal position, the patient to continue this position two to three hours following major operations and twenty minutes after minor operations. The injection is never to be made with the needle stationary, but should be made continuously during its insertion and withdrawal to avoid injecting a considerable quantity of cocain into a vein. With the use of the still more dilute Schleich solution (0.1 to 0.2 per cent.), 0.1 of cocain can be used without danger. An efficient method of avoiding the too rapid absorption of cocain and serious after-effects was described by Corning in 1885. He ligated the extremity to be anesthetized. No serious cases of poisoning have been reported in which the extremities were ligated before injection, and if the advantage would warrant the use of concentrated solutions, there would be no serious consequences attending their use with this precaution. It is essential that the constricting band should be allowed to remain at least half an hour after the injection; or the method as recommended by Dumont, Wyeth, Barton, and Mattison can be used, in which the band is loosened several times for two or three minutes before entirely removing it, permitting in this way a gradual absorption of the cocain remaining in the extremity. For more definite information concerning the artificial production of anemia and the prevention of the too rapid absorption of cocain, see Chapter VIII. The same precautions must be observed in anesthetizing large absorbent surfaces, as when injecting the tissues, that is, the prevention of the rapid absorption of even small doses of cocain. Anesthesia of the mucous membranes of the eye, nose, mouth and larynx can be rapidly induced by using a 20 per cent. cocain solution. We cannot speak of dosage under these conditions, but it is necessary to see that only small areas are anesthetized at one time, and that the surplus solution does not run into the mouth, nose, pharynx and esophagus; in this way all danger of severe cocain poisoning can be avoided. To expose large absorbent surfaces, such as the mucous membrane of the bladder, urethra, scrotal sac, and joint cavities to the action of concentrated solutions of cocain is extremely dangerous, as has been noted in the history of cocain anesthesia. This danger cannot be avoided, no matter what quantity of a solution is injected into a body cavity. The case of Berger has already been mentioned in which 0.35 of cocain in 2 per cent. solution was injected into the scrotal sac and immediately drained off again; nevertheless death promptly followed. We cannot attribute this unfortunate experience to the dose of 0.35 cocain any more than we can explain similar results following the injection of cocain into the bladder and urethra. In the latter cases the bladder is emptied and washed out, and the fluid injected into the urethra runs out of its own accord. These accidents would no doubt have happened even if small quantities of the solutions used had been injected. It is to be assumed that as much cocain will be absorbed from 5 c.c. of a 5 or 10 per cent. solution allowed to act for a certain time on the bladder mucosa as will be absorbed from 10 c.c. of the same solution allowed to act for the same length of time. General or local conditions (ulcer of the bladder) can in some cases cause a more rapid absorption of cocain with consequent symptoms of poisoning. The question, therefore, confronting us is not how large a dose of cocain can be introduced into these cavities but what is the maximum strength of the solution to be used. The answer to this question in reference to the body cavities, as the bladder, scrotal sac, and joint cavities, is to use 0.1 to 0.2 per cent. solutions, and if sufficient time is allowed for the action of this solution the resulting anesthesia will equal that induced by a 10 per cent. solution. The urethra in the male can be anesthetized with a 1 per cent. solution in a short time, but solutions of this strength should not be used for the other cavities of the body. With the before-mentioned dilute solutions, however, cavities can be filled with any quantity desired, the absorption in twenty to thirty minutes being only a few milligrams of cocain, the exact quantity being impossible of measurement, and consists only of that amount of cocain which can diffuse through the wall of the cavity. It is immaterial if we inject 100, 200, 300 or more cubic centimeters of the solution containing cocain in the dosage mentioned, as toxic symptoms will positively not occur.

It has been attempted, by the addition of various substances, to localize the action of cocain. Stuver suggested the addition of antipyrin (5.0 cocain, 10.0 antipyrin, 100 water), Gluck carbolic acid, and Parker resorcin. Many experiments have failed to prove that the addition of 4 per cent. carbolic acid to watery solutions of cocain lessens its toxicity or increases its local anesthetic properties. Gauthier, Thomas, and Guitton recommend the addition of nitroglycerin (10 drops of a 1 per cent. solution nitroglycerin to 10 c.c. of a 1 per cent. cocain solution), expecting by the dilating effect of nitroglycerin to counteract the contraction of the bloodvessels as produced by cocain. Inasmuch as the contraction of vessels is only one symptom of cocain poisoning this agent would, by its dilating effect on the vessels, be of value only in those cases associated with anemia of the brain. Instead of adding nitroglycerin regularly to cocain solutions for its prophylactic action, it would seem that the use of amyl nitrite in cases of poisoning would be better, as this drug acts similarly to nitroglycerin, causing dilatation of vessels immediately upon being breathed. What is better is the avoidance of anema of the brain by keeping the patient in the horizontal position.

According to Woelfler toxic symptoms occur more readily following injections of the face and scalp than those of the trunk and extremities, for which reason he considers 0.02 as the maximum dose for injections of the head against 0.05 for the body. Animal experiments, as well as the collection of the published reports of cases of cocain poisoning, give no information on this question. Reclus, with his large experience, never observed this difference when using more dilute solutions, and believes that the experience of Woelfler was due to the fact that many operations on the head were performed with the patient in the sitting posture.

If, as has been mentioned, an idiosyncrasy does not exist, and the irregular action of cocain can be ascribed to peculiarities of the drug itself, it cannot be denied that the central nervous system reacts differently to nerve poisons in different individuals, and likewise in its reaction toward cocain. With the presence of such an indefinite susceptibility we cannot formulate rules for the use of cocain.

In cases in which the use of concentrated solutions of cocain cannot be avoided, as in laryngology and rhinology, the bodily condition of the patient must be taken into consideration. Intoxication from cocain seems to effect both sexes alike. According to Trzebicki, children are less tolerant than adults, while Felizet regards children as particularly tolerant toward cocain. Great care must be exercised in administering cocain to debilitated and nervous persons, those with serious heart lesions, patients weakened by the loss of blood or prolonged illness, alcoholics, and those suffering from hysteria and epilepsy (Lewin). However, with the cautious use of weak cocain solutions this method of anesthesia is indicated in these conditions to avoid the use of general anesthesia. With the increase in knowledge of the action of cocain this dangerous drug can be used very extensively in surgical operations without danger to the patient, if the proper rules for its administration be observed. With the proper prophylaxis toxic symptoms on the part of the central nervous system seldom occur.

As there is no known antidote for cocain our efforts must be directed to combating the symptoms of poisoning. The head is placed low and, according to the recommendation of Schilling, the patient is permitted to inhale a few drops of amyl nitrite, an agent which seems to be of decided benefit in the early stages of poisoning. By this means anemia of the brain can be prevented, permitting the central nervous system, owing to its richer blood-supply, to more easily eliminate the cocain. It is a matter of common observation that the local effects of cocain disappear much more quickly in hyperemic than in anemic tissues.

Opiates are necessary for the control of convulsions. Observations by Mosso in animal experiments showed that convulsions do not occur if the animal has been benumbed with chloral hydrate, ether or chloroform. These drugs cannot be used in man without great caution, and opiates should only be given during the period of excitement. If the poisoning progresses to the point of causing paralysis of the central nervous system, narcotic drugs are no longer antagonistic but act in the same manner as the poison which they are intended to control. It is, therefore, advisable to use a rapidly acting substance such as ether inhalations for the control of the convulsions, but its administration must be stopped as soon as it has accomplished its purpose. In severe cases of cocain poisoning it is most important to stimulate the action of the heart by rubbing the skin, by the administration of stimulants by mouth or subcutaneously, and in case of threatened paralysis of the respiratory centre artificial respiration must be immediately instituted.

Legrand reports a case in which a patient was injected subcutaneously with 1.0 cocain and kept alive by artificial respiration continued for five consecutive hours. In poisoning by mouth the stomach must, of course, be washed out. In acute poisoning following injection into an extremity, the latter must be immediately ligated by a rubber tube or band which is kept in place for about an hour; in case the injections are made into other parts of the body attempts must be made to delay absorption by cooling the part either with the ether spray or the application of an ice-bag.

Local Injury to the Tissues from Cocain Solutions; the Preparation and Sterilization of Cocain Solutions.—Reports of local damage to the tissues from subcutaneous or submucous injections of cocain solutions are found only in the older literature. Local gangrene has been observed several times at and around the point of injection; and local edema has been frequently observed (Strauss, Bousquet, Johnson). These conditions are usually ascribed to the use of unclean preparations, the presence of molds, insufficient sterilization of the solution or operative field. It has also been observed that very concentrated solutions irritate the tissues, and by their dehydrating action injure the tissues more than when dilute solutions are used.

Up to the present time injury to the tissues has never been observed following the injection of dilute cocain solutions. The use of 0.1 to 1 per cent. cocain solutions causes swelling of the tissues. The more dilute the greater the swelling. Injection of 0.1 solution into the cutis is followed by a painful infiltrate, an evidence of tissue injury, whereas if absorption takes place no damage to the tissue occurs. To prevent swelling following the use of dilute solutions sufficient salt must be added to make its freezing-point the same as that of the blood (-0.55 to $-0.56°$). The freezing-point of a 0.1 per cent. watery solution of cocain varies only $\frac{2}{100}$ of a degree from that of pure water, while a 1 per cent. solution freezes at $-0.115°$. By the addition of a 0.6 per cent. salt solution to the latter and 0.8 per cent. solution to the former both solutions will become approximately osmotically indifferent and will not cause injury to the tissues when used. Injury to the mucous membrane of the mouth, larynx, nose and bladder from the use of solutions of cocain has not been observed. Injury following the instillation of cocain into the eye will be described in Chapter XI.

Watery solutions of cocain are not very stable, and are frequently contaminated by the growth of molds, causing them to become cloudy. The more dilute the solutions the more quickly do these changes occur. Regarding the sterilization of watery solutions it can be said that a single rapid boiling of a small quantity of a solution is not followed by a material loss of cocain, whereas the repeated boiling of large quantities of the solution or sterilization in a steam sterilizer cause a diminution in the cocain content with a diminished activity of the solution.

The oprator who has used solutions treated in this manner is not conversant with the greater activity of freshly prepared solutions. To avoid these changes Tuffier advised the fractional sterilization at a temperature of 60° to 70° It has been claimed by Herissey (Reclus) that watery solutions of cocain can be sterilized in the autoclave under pressure (115° to 120°) without change, and can be thus preserved for a long time in a sterile condition. According to Dufour and Ribaut cocain will deteriorate when sterilized by this method if the ordinary alkaline reacting glass vessels are used. It is more advisable when preparing cocain solutions to make them fresh from tablets just before use, we can then be certain of their uniform action. A simple procedure for the preparation of fresh sterile solutions of cocain has been suggested by Mikulicz. He dissolves a definite quantity of cocain in alcohol in a sterile glass flask closed with cotton. After allowing the alcohol to evaporate, the residue is dissolved in water or salt solution.

The Use of Other Cocain Combinations for Local Anesthesia—Combinations other than cocainum hydrochloricum have been up to the present time only occasionally used for anesthesia. Bignon believed that the almost insoluble basic cocain in alkaline solution produced a more intense anesthesia. Inasmuch as the acid salts of cocain usually contained free acid it was necessary to neutralize them in the following manner: An excess of sodium bicarbonate was added to a solution of cocainum hydrochloricum. This caused a precipitation of the pure alkaloid which was held in a finely divided state in suspension. This "cocain milk," according to the reports of Bignon, possessed the most intense anesthetic action, but had to be freshly prepared. The acid salts of cocain as marketed today are not acid in reaction but neutral. The author compared the action of a 1 per cent. watery solution of muriate of cocain with a like solution of basic cocain by injecting like quantities into the skin and subcutaneous tissues, and found that the potency of "cocain milk," both in its action on the sensory nerve endings as well as its action by diffusion, was far behind the muriate of cocain in its anesthetic effect.

It was likewise found that the duration of anesthesia following injection of basic cocain into the skin was twelve minutes, while with the usual solution it was double this time. If 0.2 c.c. of a 1 per cent. cocain solution was injected subcutaneously into cooled tissues, an extensive area would become anesthetized, while cocain milk

7

used in the same manner never caused the skin at the point of injection to become completely anesthetic. We must, therefore, avoid bringing cocain solutions in contact with the alkalies.

Tubes of ethyl chloride containing 1 to 5 per cent. of the readily soluble alkaloid have been placed on the market (Bolognesi, Touchard, Legrand). If a stream of this fluid is allowed to play upon the mucous membrane of the lip until frozen, it will be observed upon thawing that sensation returns and the mucous membrane has become markedly hyperemic. About five minutes later a gradual and very intense anesthesia of long duration will occur (cocain anesthesia). This intensity is due to the application of finely divided cocain crystals left after evaporation of the ethyl chloride. This latter agent at the same time causes a delay of absorption by the chilling of the tissues. These observations upon the action of cocain ethyl chloride offer an incentive for the closer study of cocain anesthesia in cooled tissues, the results of which will be described in another chapter. Bolognesi and Touchard recommend this method for the anesthesia of the gums for extraction of teeth, opening of abscesses in the mouth, dilatation of the anal sphincter for hemorrhoids and fissure, and when using the thermocautery on the glans penis and vulva. The method is also very useful in superficial operations on mucous membranes. It has never been successfully proved that cocain, used in this manner, could penetrate the unbroken skin, as has been suggested by Legrand. The cocain ethyl chloride spray applied to the skin acts no differently than pure ethyl chloride. The anesthesia results from cold and not from cocain. Various cocain salts prepared by Merck have been tried, such as the salicylate, benzoate, nitrate, and hydrobromate, but they do not possess any advantages over the hydrochlorate.

Space may be taken here for a few words in reference to synthetic cocainum phenylicum (Merck). This is not a chemical combination but a mixture of cocain and pure phenol, and was obtained by Viau by melting together one part of pure phenol with two parts of cocain. The resulting mixture was of the consistency of syrup, and when applied to mucous membranes produced intense local anesthesia without burning. This preparation was not practically applied by Viau, because he used only watery solutions of cocain with the addition of the phenol. This preparation was again recommended by Oefele, Veasy, and Kyle, and was prepared by Merck according to the formulà of Oefele. Cocainum phenylicum is a brown, sticky mass, partially crystalline, insoluble in water, readily soluble in castor oil and alcohol. Alcoholic solutions (cocaini phenyl 1 to 0, alcohol, aquæ dest. āā 50.0) are not suitable for injection, as their action is injurious to the tissues (Reclus); wheals made from this solution become gangrenous. The cauterizing effect of this solution is not due to the cocainum phenylicum but to the presence of alcohol. Oily solutions of this substance are absolutely non-irritating and non-cauterizing. The injection of pure olive oil into the cutis is painless; if, however, the oil has been previously sterilized by heat, fatty acids are set free and cause considerable pain on injection. This oil is usually indifferent in its action; if injected into the skin it does not cause any diminution of sensibility, and is gradually absorbed without injuring the tissues. If cocainum phenylicum is dissolved in oil its injection into the skin is painless even if the oil has been previously sterilized, and its absorption takes place without any damage to the tissues.

If a 1 per cent. oily solution of this preparation is injected into the skin complete anesthesia of long duration ensues (thirty minutes and longer). Five to ten minutes after the injection anesthesia extends a considerable distance beyond the point of injection. By the aid of a small quantity of a 5 per cent. oily solution injected subcutaneously, a large area can be made anesthetic and the conductivity of nerve trunks can be interrupted for one to two hours.

It is important to know that these concentrated oily solutions with their intense local anesthetic effect do not cause toxic symptoms following injection, as has been observed after the use of concentrated watery solutions of cocain hydrochlorate. Regarding the comparative toxicity of cocain hydrochlorate and phenyl-cocain, Dillenz has noted death in rabbits following the subcutaneous injection of 0.08 cocain hydrochlorate, while the same animals injected with 0.3 phenyl-cocain in oil had only mild toxic symptoms, and death did not occur after the injection of 0.6. Unfortunately the concentration of the solution was not mentioned. Dillenz also reported comparative experiments in the painless extraction of teeth following the subgingival injection of watery solutions of cocain and solutions of phenyl-cocain in oil. He found that dilute solutions of the hydrochlorate did not produce the desired result, while the concentrated solutions, as is well known, frequently gave rise to toxic symptoms. The injection of a 4 to 5 per cent. solution of phenyl-cocain in oil always produced results, and in about 700 injections of a 1 to 6 per cent. solution general toxic symptoms were never observed. These statements have been verified. If the gums are injected on both sides of the tooth with one-quarter of a syringeful of a 5 per cent. solution of phenyl-cocain in oil, a painless extraction can be performed five to ten minutes later.

There is no doubt that the slight toxic action of this remedy is less dependent upon the phenol than the oily solvent. This can be explained by the fact that watery solutions injected under the skin are rapidly absorbed by the blood-stream, whereas oily solutions are more slowly taken up by the lymph vessels. This same action will take place if basic cocain is injected in an oily solution without the addition of phenol. The use of oily solutions is associated with considerable discomfort.

TROPACOCAIN.

Giesel, in 1891, discovered a new alkaloid in the leaves of the Java coca plant which in 1892 was synthetically prepared by Liebermann as benzoylpseudotropein and later was given the name of tropacocain by Chadbourne. The salt of the hydrochloride is practically the only one used. It consists of a white crystalline powder, readily soluble in water, having the formula C_8H_{14} NOC_6 H_5 CO HCl.

The solutions are stable and can be sterilized by boiling. For the sake of brevity tropacocainum hydrochloricum will be designated by the name tropacocain.

The local and general physiological action of this drug was first studied by Chadbourne. He found that the instillation of a 1 per cent. watery solution in the eye was followed in a few minutes by a complete anesthesia of the cornea and conjunctiva, with only a slight degree of mydriasis and no paralysis of accommodation. Anemia of the parts did not occur and symptoms of irritation were only noted after the use of a preparation made from coca leaves, which was entirely absent in the synthetic preparation. Subcutaneous injections of solutions of this new alkaloid produced local anesthesia, and Chadbourne's reports regarding the local action of tropacocain were soon verified by many observers. This agent in a 2 to 3 per cent. solution was soon recognized as a useful, non-irritating anesthetic for the eye by Schweigger, Silex, Ferdinands, Bockenham, Groenouw, Rogmann, Veasey, and others. The absence of paralysis of the pupil and accommodation was considered an advantage over cocain. Anesthesia occurs very quickly following its use, but is of shorter duration than that following cocain; the anesthesia, however, can be indefinitely continued by repeated instillations.

For anesthesia of the pharynx, nose, and larynx this drug, according to Siefert, is not so well adapted, as the anesthesia may be insufficient or symptoms of irritation may be very severe. Profuse secondary hemorrhage was also noticed in one case following its use, but how this condition was brought about by this agent is not clear. According to reports of Hugenschmidt, Pinet, Viau, Bauer, Zander and Dillenz, extraction of teeth can be painlessly carried out by the injection of a 4 to 5 per cent. solution into the gums. Custer advised this agent for the Schleich infiltration method, and Schleich used the powder of this agent for anesthesia of freely exposed nerve trunks, and the surface of serous membranes as exposed hernial sacs.

A systematic investigation of the local action of tropacocain injected into the skin has given the following results: The injection of tropacocain dissolved in 0.8 to 0.9 per cent. salt solution is absolutely painless when used in solutions up to 2 per cent. Stronger solutions cause irritation of short duration just as solutions of cocain. Pure watery solutions of 0.08 per cent. and less produce pain owing to the tumefaction from the water. The freezing-point of watery solutions of tropacocain are as follows:

3 per cent. solution, freezing-point	−0.395°
4 per cent. solution, freezing-point	−0.540°
5 per cent. solution, freezing-point	−0.645°

It will be seen from this table that the physiological concentration of this agent is about 4 per cent., that watery solutions of a lower concentration give rise to the physiological symptoms of tumefaction, while concentrated solutions produce symptoms of dehydration. It is therefore necessary in using weak solutions of tropacocain to add sufficient salt to give a solution of 0.6 to 0.9 per cent. The wheals produced by the endermatic injection of this solution become immediately anesthethic, and it has been determined that a solution of 0.01 per cent. tropacocain in 0.9 per cent. salt solution possesses marked anesthetic qualities. The wheals produced by the injection of this agent react differently than those produced by cocain. As a proof of this the author injected into the skin a 0.1 per cent. solution of cocain and a 0.1 per cent. solution of tropacocain in salt solution in such a manner that wheals of the same size are next to one another. Both become immediately anesthetic, but the duration of the anesthetic from the tropacocain is less than half as long as that from cocain. It will be found necessary to use a tropacocain solution of 5 to 8 times the strength of that of cocain in order to produce an anesthesia of the same duration. It can therefore be said that the action of tropacocain compared with cocain is much less intense. It has also been observed that a few minutes after the injection the wheal produced by tropacocain presents an entirely different appearance from that of cocain. The latter appears to have become smaller and flatter. The former is accompanied by itching and spreads irregularly in all directions, soon reaching double its original size, and raised above the surface of the surrounding skin. The extension of the anesthetic area does not seem to follow the enlargement of the wheal. The wheal disappears much later than that produced by cocain. Tropacocain, therefore, belongs to that group of substances which cause a secondary edema of the tissues into which they are injected. This edema does not seem to be much of a disadvantage inasmuch as it disappears very quickly. It has nothing in common with the edema and infiltration as described by dentists following injections of concentrated cocain, tropacocain, eucain, and other solutions. Concentrated solutions of tropacocain when injected into the tissues give rise to considerable action at some distance from the point of injection, and differ only from those of cocain in their shorter duration. If a 5 per cent. tropacocain solution be injected into the skin the tissues for a considerable distance around the border of the area infiltrated become insensitive for a short time.

Infiltration of the subcutaneous tissue with a 0.5 per cent. tropacocain solution causes anesthesia of the overlying skin. Tissue injury following the subcutaneous injection of solutions of tropacocain of weak and medium concentration have not been observed.

The injected solution is quickly absorbed without leaving any mark where injected. The blood contained in the area injected does not seem to be materially influenced.

The results of these experiments seem to show that tropacocain can be used for local anesthetic purposes when the duration of the anesthetia is of no moment. The inferiority of this agent as compared with cocain is shown when an extensive diffusive action is desired, as in anesthetizing mucous membranes by local applications. It must also be remembered that a much longer time and much more frequent application of the solution is necessary to produce the desired result. The local application of tropacocain, as a rule, produces an anesthesia of too fleeting a nature, and inasmuch as it has not the property of causing anemia, it is unsuitable for use in rhinology and laryngology. If, however, certain precautions are taken to prevent its rapid absorption, as, for instance the ligation of an extremity, then tropacocain becomes equally as efficient an anesthetic as cocain. This agent likewise becomes efficient for operations of short duration, if its use is combined with the cooling of the tissues. The general toxic action of tropacocain is very similar to that of cocain, producing in animals excitation of the entire central nervous system with severe cortical convulsions which, if not followed by death, causes paralysis. Pulse and respiration are increased in frequency, temperature is elevated, while the blood-pressure falls. The latter is in direct contrast to the action of cocain which causes the blood-pressure to increase owing to its power of contracting the bloodvessels. The experiences of Chadbourne are not convincing in reference to the action of this drug upon the vagus. Following the administration of fatal doses death occurs from paralysis of the respiratory centre. After intravenous injections, even in small doses, cardiac paralysis occurs before respiratory paralysis. The rapidly occurring but transitory action of tropacocain can be observed in its general toxic action. It is very remarkable to observe in rabbits and guinea-pigs how quickly these animals recover from an apparently moribund condition following the injection of tropacocain. After the administration of this anesthetic the animals are seized with the most severe convulsions, but in about ten minutes seem to have regained their normal condition.

The toxicity of tropacocain in experiments on both animals and man seems to be considerably less than that of cocain. These facts have likewise been verified by Chadbourne, Vamossy, von Pinet, Viau, Dillenz and Custer. Custer found that it was necessary to inject into rabbits 0.08 of tropacocain per kilo in 5 per cent. solution compared to 0.03 cocain per kilo in the same concentration to produce severe symptoms of poisoning, and he believes that with the use of very dilute solutions (0.1 to 0.2 per cent.) it is possible to inject a maximum dose of more than 0.5. Whether this is correct can only be determined by experiments on man. The author injected hundreds of patients with 0.5 per cent. tropacocain solution in quantities varying from 40 to

50 c.c. without observing the slightest general toxic action. This is conclusive proof that 0.2 in 0.5 to 1 per cent. solutions can be considered a perfectly harmless dose.

If weaker solutions be used this dose can be materially increased. Definite precautionary measures should always be observed for the prevention of general poisoning, the same as after the use of cocain. Too large a quantity should not be injected into the circulation at one time. Highly concentrated solutions of tropacocain should not be used for injection or for application to large absorbing surfaces. The advice of Reclus, to have the patient anesthetized with cocain assume a horizontal position, is not necessary in tropacocain anesthesia. Serious tropacocain poisoning has never been observed in man, but such slight secondary symptoms as dizziness, anemia, fainting, tremor of the extremities, pressure over the heart, and dryness of the throat have been frequently observed by dentists following the injection of 5 to 10 per cent. solutions.

Solutions of tropacocain can be readily sterilized by boiling without change and can be preserved in this sterile condition for an indefinite time without altering their stability. In weak, non-sterile solutions molds are often observed which may cause a partial disintegration of this alkaloid. This agent has been used almost entirely in lumbar anesthesia.

EUCAIN.

Eucain, so-called by Vinci (but later known as α-eucain), is an alkaloid which was synthetically prepared by Merling. Its chemical constitution and physiological action upon living animals very similar to that of cocain. This alkaloid, having the chemical name n-methyl-benzoyl-tetramethyloxy-piperidin-carboxylic-methyl ester, is only slightly soluble in water but readily soluble in alcohol, ether, chloroform, and benzol. Its hydrochloric acid salt crystallizes in brilliant leaves and plates, and contains one molecule of the water of crystallization as shown in the formula, $C_{19}H_{27}NO_4\ HCl\ H_2O$.

This salt is soluble up to 10 per cent. in water of the room temperature. The solutions can be sterilized by boiling and are stable. The general and local action is that of an intense protoplasmic poison. Its toxic action has been studied on animals by Vinci, and has been found similar to that of cocain. Large doses cause excitation of the central nervous system with tonic and clonic convulsions followed by paralysis, (if the animal does not die in the stage of convulsions). Death occurs from respiratory paralysis. This alkaloid seems to be somewhat less poisonous than cocain, but according to Vinci this difference is not very great. If a 5 per cent. eucain solution be dropped into the eye or injected subcutaneously intense local anesthesia will follow. These observations have been verified by many authorities, but those who have used eucain practically state that besides anesthesia this agent causes very severe irritation and hyperemia of the tissues, for which reason it is not a suitable substitute for cocain (Heinze and Reclus). Combinations of cocain and eucain (Hackenbruch) possess no material advantages. In fact eucain is very seldom used at present.

Of much greater value is another alkaloid, very similar to tropacocain, which was described by Vinci in 1897, being known as β-eucain, benzoyl-vinyl-diacetonal-karnin. The previously mentioned preparation of eucain was styled α-eucain. This nomenclature has caused a number of mistakes which we will shortly describe (Marcinowski). Free basic β-eucain, like cocain or α-eucain is almost insoluble in water but becomes readily soluble when converted into a salt by combining it with an acid, hydrochloric acid being used in the formation of this salt, which gives rise to the formula $C_{15}H_{21}NO_2$ HCl, a salt of much practical value. For the sake of brevity we will speak of this salt as β-eucain. It is a white crystalline powder which dissolves in water to about 3.5 per cent. at the room temperature. The solution is stable and can be sterilized by boiling without change.

Vinci observed that applications of a solution of β-eucain to the mucous membrane of the mouth caused anesthesia. If instilled into the eye rapid anesthesia of the cornea and conjunctiva occurred, whereas the pupil and accommodation were not affected. Applications of this agent always caused considerable hyperemia but not as marked as that following the use of α-eucain. Attempts were now made on all sides to replace cocain by β-eucain wherever local anesthesia was desired, as in ophthalmology (Silex), urology (Wossidlo, Legueu), in laryngology and rhinology, and also for injection into the gums in dental surgery (Dumont, Legrand, Keisel, Thiesing), and in general surgery (Braun, Heinze and Reclus). The properties of this agent for local use have been determined by the systematic investigation of Heinze and the author. The results following endermatic injections are almost identical with those of cocain. The injection of this alkaloid in indifferent solutions is absolutely painless, even 10 per cent. solutions (prepared by Worming) causing no symptoms of irritation. The lower limit of activity of this substance is similar to cocain, 0.005 solution producing definite disturbances of sensation following its endermatic injection.

When used in the same manner eucain anesthesia is usually of shorter duration than cocain anesthesia. If 0.1 per cent. cocain solution is injected into the skin of a person to be experimented upon, 0.15 per cent. β-eucain solution would be neccessary to produce anesthesia of like duration. Concentrated solutions (more than 1 per cent.) cause the tissues to become anesthetic for a variable distance beyond the area directly infiltrated. The extent of this diffusion is, however, very much less than after the use of cocain solution of the same strength. This anesthetic is much less efficient, and acts more slowly than cocain solutions when applied to mucous membranes and nerve trunks.

In osmotically indifferent and fairly concentrated solutions β-eucain does not cause tissue injury on injection. Wheals disappear quickly without leaving an infiltrate, but concentrated solutions (10 per cent.) are not so well borne by the tissues, painful infiltrations usually remaining after injection. Concentrated solutions of cocain and tropacocain act in the same manner. The cause of these symptoms is not only from the substance injected, but also from the physical and dehydrating action of these concentrated solutions. Pure watery solutions of β-eucain are painless in dilutions as low as 0.04 per cent., the anesthetic preventing the pain of tumefaction.

The freezing-point of various solutions of β-eucain are as follows:

1 per cent. solution, freezing-point	−0.125°
2 per cent. solution, freezing-point	−0.245°
3 per cent. solution, freezing-point	−0.36 °
4 per cent. solution, freezing-point	−0.45 °

It will thus be seen that the physiological concentration of this agent is about 5 per cent.; more dilute solutions when used for injections require the addition of 0.6 to 0.7 per cent. of salt, to prevent the consequences of tumefaction. Injections of β-eucain solutions cause a mild grade of hyperemia in the tissues. The results of these experiments demonstrate that the local anesthetic property of solutions of β-eucain are in general similar to those of cocain solutions of slightly weaker concentration. This agent diffuses, however, much less extensively than cocain, but it can be made equal to the latter in this respect by slightly increasing its concentration. Solutions of 3.5 per cent. can be readily prepared with warm water, and the salt will not readily precipitate on cooling. The intense toxic action of this alkaloid upon protoplasm even in very dilute solutions must necessarily cause general symptoms of poisoning. This toxic action has been studied by Vinci in animals. He observed after the administration of large doses irritation of the central nervous system, evidenced by convulsions and exophthalmos, which were, however, much less severe than those following cocain and α-eucain. Central paralysis was also noted following these symptoms. Death occurred from respiratory paralysis, the heart continuing to beat for a considerable longer time. Besides this action Vinci noted paralysis of the peripheral motor nerves and the vagus similar to that following the use of curare. Respiration was increased in frequency and only during the stage of convulsions was dyspnea noted. During the stage of paralysis respiration became very superficial, and the pulse slow in consequence of irritation of the motor ganglion of the heart, the blood-pressure falling in consequence of vasomotor paralysis. The toxicity of this drug is far less than that of cocain. The fatal dose, according to Vinci, following subcutaneous or intraperitoneal injections is:

	β-eucain.	Cocain.
Rabbits	0 40 to 0 50	0.10 to 0.12 per kilo
Guinea-pigs	0.30 to 0.35	0.05 to 0.06 per kilo

Dolbeau, Schmidt, Dumont, and Legrand hold that the fatal dose of β-eucain for animals is 3 to 3¾ times larger than that of cocain. The anthor's tests coincide with these results, provided that the concentration of the cocain and β-eucain solutions are about the same. Concentrated β-eucain solutions are more toxic than dilute cocain solutions. The statements of Dolbeau that β-eucain injected intravenously is just as toxic as cocain have been found to be not quite correct. In the anthor's experiments the difference was materially in favor of β-eucain. Following the injection of 0.01 cocain in 1 per cent. solution into a vein in the ear of a rabbit weighing 1500 grams, very severe, almost fatal, toxic symptoms occurred; whereas the same quantity of β-eucain in like solution, injected intravenously into the ear of a rabbit of the same weight, produced no symptoms of poisoning. Just as in cocain poisoning the concentration of β-eucain solutions plays a most important part.

A rabbit weighing 2900 grams was injected under the skin of the back with 3 c.c. of a 10 per cent. β-eucain solution (about 0.1 per kilo); clonic convulsions were noted in about five minutes, followed by paralysis of the extremities; the animal lay on its belly with extended extremities; after one and one-half hours the animal was to all appearances again perfectly normal.

A rabbit weighing 2800 grams was injected under the skin of the back with 30 c.c. of a 1 per cent. β-eucain solution (more than 0.1 per kilo); a slight paralysis of the extremities was noted after about fifteen minutes that entirely disappeared after one and a half hours.

A rabbit weighing 2750 grams was injected under the skin of the back with 300 c.c. of 0.1 per cent. β-eucain solution (more than 0.1 per kilo). This injection was not followed by any toxic symptoms.

A rabbit weighing 2090 grams was injected subcutaneously with 100 c.c. of a 1 per cent. β-eucain solution (0.5 per kilo); convulsions followed in a short time, death ensuing ten minutes later.

A rabbit weighing 1530 grams was injected subcutaneously with 750 c.c. of 0.1 per cent. β-eucain solution. This injection was followed by mild symptoms of poisoning, with convulsions and paresis of the extremities. The animal appeared perfectly normal again in four hours.

To arrive at definite conclusions in regard to this drug, these experiments must be frequently repeated. Just as we observe with cocain, so also following the use of eucain in concentrated solutions, the animal may at one time show no evidences of poison while at another it may show mild or severe symptoms from the use of the same dose. Following the subcutaneous injection in a rabbit weighing 2120 grams of 0.3 per kilo of β-eucain in 10 per cent. solution, there was not the slightest evidence of subsequent poisoning. Eight days later this same dose was injected in the same animal and in the same way, producing very severe symptoms of poisoning. These differences of action from the same doses and of like concentration are undoubtedly due to uncontrollable variation in the rapidity of absorption of the agent. Eucain poisoning, just as cocain poisoning, can occur when relatively small doses are introduced into the circulation and will not occur with relatively large doses when they are prevented from entering the circulation.

The same rules must be observed in the use and dosage of β-eucain as were considered for cocain. The maximum dose of β-eucain for man, which of course will vary with dilute solutions, can only be determined by experiments on human beings. It is certainly much larger than the maximum dose of cocain which can be borne without general toxic symptoms. Results obtained after extensive experiments would indicate that a dose of 0.1 in 1 to 2 per cent. solutions would certainly not be considered a large dose and has been materially exceeded by some authorities. Frequently doses of 20 to 30 c.c. of a 0.5 per cent. solution (−0.1 to 0.15) have been given, and 300 c.c. of a 0.1 per cent. solution. The author has never seen a case of β-eucain poisoning in patients and considers the dose above mentioned harmless. The use of 30 c.c. of a 10 per cent. β-eucain solution (3 grams), as advised by Lohmann, cannot be sufficiently deprecated, not only on account of the quantity but on account of the danger to the tissues after using solutions of this concentration. It certainly is unnecessary for us to again pass through the experiences and injuries which were produced in the early days from cocain used in a similar manner.

There are no reports in the literature of poisoning from β-eucain except those following Bier's lumbar injections. The serious consequences following lumbar injections are certainly not entirely due to the absorption of the drug but rather to the local action by contact of the injected solution with the central nervous system. The negative reports from the literature do not indicate by any means that poisoning from eucain has not occurred. However, it is justifiable when using this agent to observe all necessary precautions. Marcinowski, to whom we are indebted for his interesting studies in regard to eucain, noticed mild symptoms of poisoning following the injection of a 5 per cent. β-eucain solution into his own thigh (dosage is not given).

The author can report a similar personal observation. For experimental purposes a nerve trunk of the forearm, probably the median nerve, was injected with 1 c.c. of 3 per cent. β-eucain solution (0.03). In about five minutes nausea, vertigo, and a peculiar weight and weakness of the extremities occurred which compelled him to lie down. These observations were similar to those of Marcinowski. In about fifteen minutes all these symptoms had disappeared. It is quite as unjustifiable to use concentrated solutions of β-eucain for injection into the tissues as concentrated solutions of cocain, and the operator must so perfect his technique that it will not be necessary to use highly concentrated solutions. It is never advisable to exceed a 2 per cent. β-eucain solution for injection. This solution should not be considered weak but rather a concentrated one.

To recapitulate: It can be said that the advantages of β-eucain over cocain are its undoubted milder toxic action, its stability, and the possibility of sterilizing by means of boiling. The disadvantages of this preparation are less intense anesthetic action, which in some procedures must be intensified by increasing the concentration of the solution, mild hyperemic action. Some authorities (Mikulicz) attempt to prevent this hyperemia by mixing eucain solutions with cocain.

A short time ago a new eucain salt was placed on the market, viz., eucainum aceticum. This latter preparation differs from the hydrochlorate salt in its greater solubility in water (33 per cent.). According to Cohn, its action on the eye differs but slightly from that of β-eucain solutions; at any rate, 2 per cent. solutions cause very uncomfortable irritation. The author tried this agent on healthy individuals and likewise found that it is more irritating than the hydrochloride of β-eucain. Whether the concentrated solution will be suitable for anesthesia of the mucous membranes appears doubtful. If the operator desires to have a β-eucain salt which is readily soluble in water, it would be best to use lactic acid β-eucain, which has recently been tried out. This salt does not differ materially either in its irritating action or anesthetic properties from the hydrochlorate.

HOLOCAIN.

Holocain was prepared in 1897 by Taeuber by combining molecular quantities of phenacetin and phenatidin. It belongs to the group of the amido compounds (p-diathoxyæphenyl-diphenyl-amidin). Its basic compounds are insoluble in water, whereas the white crystalline needles of the hydrochlorate are soluble up to 2.5 per cent. in this liquid. The solutions are extremely sensitive toward alkalies, for which reason they must be prepared in porcelain vessels. Solutions of this drug are stable and can be sterilized in porcelain vessels by boiling (Legrand). Up to the present this remedy has only been used in ophthalmology by Guttman, Hirschfeld, Denneffe, and others. Instillations of holocain solutions in the eye first cause severe burning followed by a useful anesthesia. Following the endermatic injection severe irritation precedes anesthesia. Holocain does not possess any advantage over cocain and β-eucain, and on account of its toxic action should be used with great care.

Severe convulsions have been produced in rabbits by the administration of 0.01 per kilo. Pouchet has discarded this agent owing to the variation of the product found on the market. Legrand states that this drug should be stricken from the list of local anesthetics.

ANESON.

In 1898, under the trade name *aneson* or *anesin*, 1 to 2 per cent. watery solutions of trichlorpseudobutylalcohol were placed on the market. It has also been known under the name of acetone chloroform or chloretone. According to Vamossy, acetone chloroform when administered in doses of from 0.5 to 1 gram is without unpleasant consequences. He also recommended this drug for local anesthesia. Impens, on the contrary, claims that it is a very dangerous hypnotic. Aneson is a clear colorless solution with a peculiar moldy odor all its own. Its freezing-point is −0.118°, which would of necessity require the addition of salt to prevent tumefaction following injection. Verified in part by communications from Israi, Grósz, Antal, Bilasko, Vamossy claims that aneson both when applied to mucous membranes and injected into the tissues causes a local anesthesia equal in intensity to a 2 to 2.5 per cent. cocain solution.

Heinze and the author have experimented with this solution and have found that when injected endermatically it causes very severe pain, and the anesthesia which is confined to the wheal lasts only a few minutes. An extension of the anesthesia beyond the border of the area infiltrated never occurs. We were also unable to detect any noticeable effect on the mucous membranes, and just as little effect on the nerve trunks, which refutes the communications of Moosbacher. In areas of the skin infiltrated with aneson the painful infiltrates remain. The activity of aneson is almost completely lost on boiling. We must, therefore, refute the statement of Vamossy that this agent corresponds to a 2 per cent. cocain solution in its local anesthetic action. In comparing this drug with cocain it will be found that 0.05 per cent. cocain solution will produce the same local anesthetic effect as aneson. Rubinstein and Sternberg reached the same conclusions when using this drug for purposes of infiltration. If 100 c.c. of aneson are injected subcutaneously into a rabbit weighing 2700 grams, the rabbit will pass into a sleep lasting twenty-four hours, a death-like sleep; pulse and respiration are for hours scarcely noticeable; the animal recovers gradually. 100 c.c. of 0.05 per cent. cocain solution never cause such general symptoms. Therefore, aneson, for local anesthetic purposes, should be placed in the obsolete class.

AKOIN.

Under the name of *akoin*, Trolldenier has included chemical compounds similar to holocain (alkyl-oxyphenyl-guanidine). The akoin of commerce is a hydrochloric acid salt of guanidine, its chemical name being di-p-anisyl-mono-p-phenetyl-guanidinchlorhydrat. Akoin is a white, odorless, crystalline powder of bitter taste, soluble in cold water up to 6 per cent., very readily soluble in alcohol. The solutions are strongly antiseptic. The experiments of Trolldenier, made upon animals, on his own person and other healthy persons, demonstrated that this substance produced intense anesthesia of long duration. A solution of 1 to 2000 produced anesthesia in the eye of a rabbit; the instillation of a 1 per cent. solution caused lack of sensation lasting about three-quarters of an hour; a 5 per cent. solution produced anesthesia lasting twenty-four hours. Irritation occurred when the solutions exceeded 1 per cent. A 1 per cent. solution was sufficient to produce a useful anesthesia in the eyes of horses and dogs, but was not so efficient when used in the eyes of human beings, the irritation being very severe. Endermatic injections made on human beings with a 0.05 per cent. solution in normal salt produced an anesthesia lasting thirty-five minutes. When the solution was increased to 0.1 per cent. anesthesia lasted forty minutes.

Shortly after the first reports by Trolldenier regarding the action of akoin the author carried out a series of experiments on the endermatic injection of this remedy in healthy individuals and found that it produced a skin anesthesia of unusual duration.

Concentration of the Solution in 0.8 Per Cent. Salt Solution and Duration of the Anesthesia.

5% to 1%	0.5%	0.2%	0.1%	0.05%	0.01%	0.005%	0.0025%
Several hrs.	2 hrs.	1 hr.	30 to 40 min.	20 to 26 min.	10 min.	6 min.	4 min.

The duration of akoin anesthesia is many times that of cocain solutions of like concentration. If akoin in 0.0005 per cent. is added to an indifferent salt solution disturbance of sensation can still be determined in the wheal. It will be seen that the lower limit of activity of this substance is considerably below that of cocain. In testing the sensation after the injection of this substance another material difference is noted from that of cocain. Although anesthesia occurs instantly in the skin at the point injected, it requires a half-minute or longer before anesthesia becomes complete in the infiltrated tissues. It will, therefore, be noted that the changes brought about in the nerve substance take place slower but are of much longer duration than following the local use of cocain. The injection of very weak akoin solutions gives rise to slight pain. Injury to the tissues has not been observed following the use of dilute solutions, but 0.5 per cent. solutions cause a painful infiltrate to remain at the point of injection; 5 per cent. solutions sometimes cause gangrene of the wheal.

The anesthesia resulting from the diffusion of this substance, as in its application to mucous membranes and in anesthesia of nerve trunks, is much less than that following the use of cocain solutions of the same concentration. Akoin is a severe poison and great care must be exercised in its use. Trolldenier fed large doses of this substance to animals without noting any toxic effect, for which reason he holds that large doses can be likewise injected in man, but experiments of this kind must be viewed with more or less skepticism.

Opposing these experiments are those of Thiesing, who found that the fatal subcutaneous dose of akoin for rabbits was much smaller than the fatal dose of cocain (0.15 cocain in 1 per cent. solution, opposed to 0.08 akoin in 1 per cent. solution).

The following is a brief record of the author's experiments with the drug on rabbits:

1. A rabbit, weighing 1220 grams; subcutaneous injection under skin of the back of 6 c.c. of a 2 per cent. akoin solution (=0.1 per kilo); after ten minutes paresis of the forelegs, followed by paresis of the hind legs. Complete paralysis and difficult respiration followed rapidly. These symptoms continued four hours with apparently no interference with the consciousness of the animal. The animal returned quickly to normal.

2. Rabbit, weighing 1070 grams; subcutaneous injection into the skin of the back of 2.5 c.c. of a 2 per cent. akoin solution (=0.05 per kilo); in about twenty minutes symptoms same as above, but less intense, lasting one hour.

3. Rabbit, weighing 2150 grams; subcutaneous injection into the skin of the back of 13 c.c. of a 2 per cent. akoin solution (=0.12 per kilo); convulsions of short duration followed by paralysis; animal was alive twenty-four hours later, completely paralyzed, and was killed with chloroform.

4. Rabbit, weighing 1270 grams; subcutaneous injection into the skin of the back of 160 c.c. of a 0.1 per cent. akoin in salt solution (=0.12 per kilo); twenty minutes later severe symptoms of poisoning, with paralysis of the extremities. The animal was restored to normal in about six hours.

5. Rabbit, weighing 1800 grams; subcutaneous injection into the skin of the back of 270 c.c. of a 0.1 per cent. akoin in salt solution (=0.15 per kilo); very severe poisoning with paralysis of all the muscles of the body; death occurred in two hours from respiratory paralysis.

6. Rabbit, weighing 1300 grams; subcutaneous injection into the skin of the back of 200 c.c. of a 0.1 per cent. akoin in salt solution (=0.16 per kilo); paresis of the extremities in twenty minutes; in two hours total paralysis; no effect on consciousness. Animal was alive twenty hours later but completely paralyzed and had to be killed.

7. Rabbit, weighing 1590 grams; subcutaneous injection into the skin of the back of 13 c.c. of a 0.2 per cent. akoin solution (=0.164 per kilo); after ten minutes unable to coördinate the movement of the extremities; difficult respiration, followed in fifteen minutes by convulsions of short duration, then paralysis with apparently no change of consciousness. In twenty minutes death from respiratory paralysis.

8. Rabbit, weighing 3040 grams; subcutaneous injection into the skin of the back

of a 2 per cent. akoin solution (=0.164 per kilo); death followed in two hours with symptoms as above.

9–10. Dose of 0.2 and 0.7 per kilo in 2 per cent. solution was followed in a few minutes by death.

Exact pharmacological experiments with akoin have not been carried out, and lacking their reports all that can be said is that this agent causes a peripheral paralysis similar to that following the use of curare or eucain, at least the above-mentioned experiments seem to point this way. The symptoms of general akoin poisoning, as has already been noted in connection with its local action, are very stable and of considerable intensity. Medium-sized doses which do not cause immediate death of the animal give rise to a miserable condition which continues unchanged for twenty to twenty-four hours and necessitates the killing of the animal. In this it differs from the effects of cocain, eucain, and tropacocain poisoning, as following the use of these latter drugs the symptoms disappear very quickly. Another point of interest is the fact that the same dose of this agent in either concentrated or dilute solution acts the same, thus differing from cocain solutions.

The cause of these symptoms seems to be clear. The prolonged duration of the effects of the poison on the organs seems to produce the same effect as when a similar dose of other poisons is rapidly absorbed, thus giving rise to a cumulative action of the drug. The experiments have also shown that the toxic action of akoin is exceptionally severe, certainly not less than that following the use of cocain. In consideration of the miserable, long-drawn-out symptoms of akoin poisoning from which the animals cannot recover yet take so long to die, it appears that cocain is by far the least dangerous agent. It is advisable not to exceed the maximum dose of 0.025, as suggested by Thiesing.

Practical use of akoin was first made by Darier. He found that subconjunctival injections of cyanide of mercury, which were usually very painful, could be painlessly made if small doses of a 1 per cent. akoin solution were added to the solution. Cocain was unsuitable for this purpose owing to the short duration of its action. The value of akoin in subconjunctival injections has been verified by many ophthalmologists, (Guibert, Carter, Hirsch, Etiévant). The dentists Senn, Nipperdey, Bab, and Thiesing advised the subgingival injections of a 0.5 to 2 per cent. akoin solution for the painless extraction of teeth. Bab advised combining this solution with that of cocain, claiming that the action of a 0.5 per cent. akoin and 0.5 per cent. cocain solution was as effective as a 5 per cent. solution. Spindler praises the long-continued action of a 0.1 per cent. akoin solution for Schleich's infiltration anesthesia. The author has also used solutions of 0.05 to 0.1 per cent. akoin with 0.1 per cent. β-eucain combined with the requisite amount of salt in various major operations requiring considerable time for their performance.

The β-eucain was added to these solutions for the purpose of preventing the pain following injections of akoin solution. It is undoubtedly an advantage to use an agent for purposes of infiltration which will produce anesthesia lasting several hours. The use of this solution has been of particular value in hemorrhoid operations in which cocain and eucain solutions have often been insufficient. As much as 0.05 of akoin has been used at one dose without injury. It is inadvisable to use solutions for injection into the tissues of more than 0.25 to 0.5 per cent. of akoin, as they will without doubt cause injury to the tissues. In most cases sufficient anesthetic effect can be obtained from other agents without this danger.

Just as with holocain, solutions of akoin are extremely sensitive to even traces of alkalies as, for instance, that contained in glass, for which reason certain precautionary measures must be observed in preparing these solutions. Only distilled water should be used and solutions should be made in porcelain vessels either with cold or lukewarm water, the necessary quantity of salt being added last of all. The finished solution can be sterilized by boiling without deterioration, and can be kept in dark bottles previously boiled in hydrochloric acid and thoroughly washed with distilled water. It is perhaps better to keep watery solutions of akoin in strengths varying from 1 to 2 per cent., diluting them just before use. In the preparation of eucain-akoin solution take 25 parts of akoin to 100 parts of absolute alcohol and add 6 drops of this solution to about 0.05 to a 0.1 per cent. eucain solution just before use.

In the preparation of concentrated akoin solutions (1 per cent. or more) these alcoholic solutions naturally cannot be used, as the diluted solution will contain too much alcohol. Syringes and needles which have been previously boiled in soda solutions must be carefully washed with water before use. Since the introduction of suprarenin, the author has not used this solution for local anesthesia, as it is preferable to use solutions of cocain and suprarenin for long-continued anesthesia.

ANESTHETICS OF THE ORTHOFORM GROUP.

(*A*) **Orthoform.**—It has been an open question for some time whether it was necessary to use the complete cocain molecule for the production of local anesthesia or if parts of this molecule possessed similar action. Working along these lines Filehne used the alkaloid ecgonin, obtained from cocain by the removal of its benzoic acid, and found it to be absolutely inactive. He also tried to combine the benzol group with certain alkaloids not bearing any relation to cocain, attempting thereby to obtain the anesthetic properties of the latter. He concluded from these experiments that the anesthetic properties of an alkaloid were absolutely dependent upon combining the benzol group with them. Ehrlich is of the opinion that anesthetic action is only associated with certain bodies of the cocain group and only those in which the ecgonin ether has taken up certain acid radicals which might be termed anesthesiphorous.

Stimulated by these experiments Einhorn and Heinz concluded from their investigations that local anesthesia was brought about by the characteristic action of all aromatic amidoöxyesters. Of all these substances that known as orthoform possessed anesthetic properties in the highest degree (p-amido-m-oxybenzoicacidmethylester). This substance consists of a white powder slightly soluble in water, a property which is of decided advantage in the application to wounds, ulcers, burns, rhagades, excoriations, etc., as a useful anesthetic. It produces an anesthesia of indefinite duration, inasmuch as it is insoluble in the body fluids, at the place of application; it likewise possesses strong antiseptic qualities.

Orthoform exerts its anesthetic qualities only when in contact with exposed nerve ends, and remains active for several hours or days. Owing to its slight solubility it cannot penetrate the intact skin or mucous membrane. This agent is apparently only slightly poisonous. Heinz was able to inject 4 to 6 grams and administer the same quantity internally without any injurious action. Soulier and Guinard found the lethal dose for dogs when internally administered to be 1.0 per kilo, when placed within the peritoneal cavity 0.25 per kilo. The toxic symptoms from this drug are very similar to those of cocain.

As a local anesthetic in surgery, orthoform is of practical use owing to its slight solubility and the fact that it readily undergoes decomposition (Heinze). It has been recommended by Klaussner and Neumeyer as a pain-relieving application either in powder form or as a salve for open wounds, burns, ulcers of the stomach, for the relief of pain following extraction of teeth, for pain due to pulpitis, in painful ulcerations of the leg, decubitus, and carcinomatous ulcers. It has been used for long periods of time and in large quantities without injury. Various secondary effects have, however, been noted after the prolonged use of this substance at the point of application, such as erysipelatous reddening of the skin, swelling, vesiculation, local gangrene, eczema, the latter at times spreading over the entire body (Asam, Brocq, Wunderlich, Miodowski, Stubenrauch, Friedländer, Graul).

Friedländer collected 18 cases in which general symptoms, such as vertigo and vomiting, occurred after the use of orthoform. There have also been unpleasant secondary effects such as have been described following the use of this drug in the treatment of leg ulcers, for which reason this remedy should be used with caution, and before continuing its use it must be tried on each individual patient. It should never be used in cases of cracked nipples in nursing women on account of injury to the baby (Pouchet). This same author also cautions against the use of this remedy in combination with silver nitrate, owing to its strong reducing qualities, nitric acid being set free.

(*B*) **New Orthoform.**—This remedy is known under the high sounding title of m-amido-p-oxybenzoicacidmethylester, consisting of a fine powder, cheaper than orthoform, but having the same action and secondary effects as this preparation.

(*C*) **Nirvanin.**—Owing to the difficult solubility of basic orthoform and the strong irritating properties from its acid reaction, this remedy was not suitable for local anesthesia for which reason Einhorn and Heinze attempted to replace the amido atom group of amidoester and oxyamidoester, believing that this portion of the molecule was of secondary importance to other groups of atoms. They found in the hydrochloride of diethylglycocoll-p-amido-o-oxybenzoicacidmethylester a salt readily soluble in water, possessing local anesthetic qualities, solutions of which were neutral in reaction and had antiseptic properties. This substance was given the name of nirvanin and consists of a white crystalline powder, solutions of which are stable and can be sterilized by boiling.

Experiments with nirvanin in 0.8 per cent. salt solutions when injected endermatically give the following results: The injection is painful but is quickly followed by anesthesia of the wheal. The lower limit of activity of a solution is about 0.05 per cent. and can cause in this dilution a distinct diminution of sensation. This is about ten times the concentration of the weakest cocaine solution which would be active. It was also found that to produce anesthesia of the same duration it was necessary to use about ten times the concentration of a nirvanin solution as was necessary for the cocain solution; for example, if two wheals are injected next to one another in the skin of a person to be experimented upon, one with a 0.1 per cent. cocain solution, the other with a 1 per cent. nirvanin solution, the duration of anesthesia in both is about the same.

Anesthesia by diffusion beyond the borders of the point of injection is not distinctly shown, even after the use of a 5 per cent. solution; at any rate it is much less than the diffusion anesthesia following the use of 0.5 cocain solution. Injury to the tissues has not been observed following the use of nirvanin solutions, it merely causing a slight hyperemia.

The experiments following the practical use of solutions of nirvanin establish the following facts and results: Anesthetic properties of a 5 per cent. nirvanin solution are too slight to replace cocain solutions as a local application for mucous membranes. They are not suitable for use in the eye owing to their irritating properties. Nirvanin solutions of 0.25 to 1 per cent. can be used for local anesthetic purposes. According to Luxenburger solutions of 2 per cent. nirvanin are suitable for the blocking of nerve trunks. The author's experiments and investigations coincide with those of Hoelscher. He found that the activity of nirvanin solutions when injected into nerve trunks cannot be compared to cocain solutions of similar concentration. Nirvanin solutions of 2 to 5 per cent. act more slowly than 0.2 to 0.5

per cent. cocain solutions and require waiting a considerable time for interruption of nerve conduction, even when an extremity is ligated. Weaker solutions are not at all active. The pain associated with the injection of nirvanin is extremely unpleasant. Nirvanin solutions of 5 per cent. have been recommended for subgingival injections and extraction of teeth. Rothenberger has used it in 164 cases, and after waiting three to five minutes was able to extract teeth without pain in 155 of these cases. Stubenrauch discarded the 5 per cent. solution owing to the pain following injection, and was able to make teeth sufficiently anesthetic for extraction by injecting a 2 per cent. solution. In cases where the alveolar process was very thick or where periostitis was present this agent was absolutely ineffective.

In regard to the toxic action of nirvanin the following has been noted: Luxenburger found that general toxic symptoms occurred following the use of 0.22 per kilo of this substance in rabbits. Joanin claimed that the toxicity of cocain compared to that of nirvanin is as 1 to 7.5. Didrichson observed a cumulative action of this drug and found that its toxic effects did not bear any relation to body weight. Large animals were affected by small doses and *vice versa*. Small animals were often able to withstand very large doses.

The toxic symptoms are similar to all the other drugs previously mentioned, consisting of excitation followed by paralysis. Large doses produced very severe convulsions. Einhorn and Heinze consider 0.5 as the maximum dose in man. Luxenburger considers 0.55 as the maximum. Inasmuch as the dosage for local anesthesia is ten times that of cocain, the advantages of this remedy must be considered very doubtful. Luxenburger and others have used 0.5 nirvanin in patients without noting any secondary effects. Floeckinger observes after a dose of 0.5 vertigo and nausea, which were promptly relieved by the use of 2 mg. of strychnin. Dorn reports a case in which, following the injection of 0.75 c.c. of a 5 per cent. nirvanin solution, extensor convulsions, headache, vertigo, and ringing in the ears occurred. The above mentioned experiments seem to indicate that nirvanin will not have much of a future.

Anesthesin and Subcutin (Ritsert).—Another product of the orthoform group has been devised by Ritsert and is sold under the trade name of *anesthesin*. It is a fine, white, crystalline, non-hygroscopic powder which, when placed on the tongue, gives rise to a sensation of numbness. It is soluble with difficulty in water, readily soluble in alcohol and the fatty oils, and can be used as a salve without deteriorating. This agent, according to Binz and Kobert, is non-toxic and according to the reports of von Noorden and Lengemann can be used for anesthetic purposes in the same manner as orthoform, relieving pain for a considerable period without the secondary effects observed following the use of orthoform. Von Noorden recommends this drug in cases of nervous hyperesthesia of the stomach and ulcus ventriculi. It should be taken ten to fifteen minutes before eating, 2.5 grams being considered the maximum daily dose. Anesthesin can also be used as an insufflation and inhalation in hyperesthesia of the larynx, in troches for sore throat and cough due to irritation of the pharynx, in suppositories for tenesmus and painful hemorrhoids, in salve (10 per cent. ointment with adeps lanæ), for pruritus, in diabetes, etc. Kassel praises the action of this remedy when used as an inhalation (anesthesin 20.0, menthol 10.0 to 20.0, olei olivarum 100.0) in hyperesthesia of the larynx. Lengemann, Henius and Becker recommend the drug for the relief of pain in erysipelas, burns, and painful granulations, the drug to be applied alone or in combination with dermatol. Injurious secondary effects have never been noticed.

Solutions of the hydrochloric salts of anesthesin in 0.25 per cent. strength were used by Dunbar and Rammstedt for infiltration and conduction anesthesia on the fingers with good results. Ritsert considered the most suitable preparation of anesthesin to be a combination of anesthesin and paraphenolsulfoacid which he called subcutin. This is a white crystalline powder, soluble in water to 1 per cent.; is stable and can be sterilized by boiling. These solutions are strongly acid in reaction. According to Becker 0.8 to 1 per cent. subcutin solutions are suitable for infiltration and conduction anesthesia of the fingers. Experiments show that by injecting 0.8 per cent. subcutin in 0.7 per cent. salt solution that the injections are not painful and the infiltrated tissues become immediately anesthetic, the duration of the anesthesia being somewhat longer than that following the use of 0.1 per cent. cocain solutions. It was, however, noted that the injections of subcutin produced irritation of the tissues, painful infiltrates always being found at the point of injection. These were occasionally associated with superficial vesiculation. Injecting 1.5 c.c. of subcutin solution around the base of the fourth finger, which was ligated, required twenty-five minutes for complete anesthesia. This injection was followed by very severe pain which prevented any further investigation in this regard. Subcutin should, therefore, be considered unsuitable for injections into the tissues.

Propæsin and Zykloform.—Propæsin is the propylester and zykloform the isobutylester of p-amidobenzoacid. Both substances consist of a white crystalline powder only slightly soluble in water. These substances have been used in powder form for dusting on painful ulcerations of all kinds, as a salve (15 per cent. propæsin salve according to Stuermer and Lueders, 5 to 10 per cent. zykloform according to Straus) for covering painful ulcerations and rhagades and internally for intestinal pain (propæsin 2 grams, zykloform 0.2 to 0.4). The unpleasant local effects observed with orthoform were not noticed following the use of these remedies.

STOVAIN.

Fourneau, of Paris, observed that a number of substances belonging to the amido alcohol group possessed local anesthetic properties. A derivative of this group known chemically as α-dimethylamin-β-benzoylpentanol-chlorhydrate was placed on the market by Billon under the name of stovain, and was used by the French, particularly Reclus, as a substitute for cocain.

Stovain crystallizes in small, white, glistening leaves, is readily soluble in water, and can be sterilized by boiling, but deteriorates at a temperature of 120°. The pharmacological properties of this drug were studied in experiments on animals by Billon and Pouchet. They found stovain to be poisonous to the central nervous system, the same as cocain, after the administration of toxic doses. In herbivorous animals general analgesia was noticed in a few cases with other nervous symptoms. In other cases, as in dogs and cats, these latter symptoms were more prominent, evidencing themselves by paralysis of the extremities, incoördination of movements, and circular movements. Central tonic and clonic convulsions resulted in respiratory paralysis and death either immediately or after a comatose state. The body temperature of guinea-pigs was subnormal, while in dogs and cats it was normal or elevated.

This drug acts as a stimulant to the heart and has a dilating effect on the blood-vessels as stated by Billon. According to Pouchet the dilatation of the bloodvessels and the lowering of the blood-pressure is soon followed by normal conditions. 4 per cent. solutions of stovain applied to freely exposed nerve trunks cause an interruption of conductivity, but not so complete as after the application of cocain (Pouche). Laewen has demonstrated that a 5 per cent. stovain solution applied to the freely exposed sciatic nerve of frogs, causes irreparable damage to the conductivity of the nerve, and even after the use of a 4 per cent. solution he was able to prove that a return of conductivity in the nerve trunk never occurs. The toxicity of this new agent is supposed to be two to three times less than that of cocain. Reclus is the only one who has had extensive experience in the practical use of this drug for injection into the tissues. He used a 0.5 to 1 per cent..solution for purposes of infiltration and states that 0.2 to 0.3 is without danger and can be used as a substitute for cocain. For anesthesia of the mucous membranes stovain up to the present time has not been extensively used. According to Lapersonne the instillation of 0.5 to 2.5 per cent. solutions into the conjunctival sac is painful and the resulting anesthesia is not so complete nor of so long duration as cocain anesthesia.

The author has tested the action of this drug upon himself and other healthy persons by injecting solutions into the cutis and subcutaneous tissues. The results were as follows: 0.1 per cent. solution with the addition of 0.8 per cent. salt, intracutaneous injection of the forearm; injection was painful. The wheal became immediately anesthetic; duration of anesthesia five or six minutes. Hyperemia followed at the point of injection. The duration of anesthesia of a neighboring wheal made with 0.1 per cent. cocain solution lasted fifteen minutes.

One per cent. solution with the addition of 0.6 per cent. salt. Injection was very painful; very marked and lasting hyperemia at the point of injection; duration of anesthesia eight minutes. Duration of anesthesia in the neighboring wheal made with 1 per cent. cocain solution was about twenty-four minutes. No marked evidences of tissue injury, but the disappearance of the wheal was not so free from reaction as that produced by cocain.

Five and 10 per cent. stovain solutions, subcutaneously injected. Injection extremely painful. The resulting wheal anesthesia did not disappear, and the entire wheal as far as the subcutaneous connective tissue became gangrenous.

The subcutaneous injection of 1 per cent. stovain solutions in the forearm and neighborhood of the radial nerve produced a distinct effect upon the peripheral branches of this nerve. Stovain is not to be compared in efficiency with cocain, eucain, or tropacocain solutions of the same strength. The injection of stovain solutions in a ligated finger produces the same results as cocain solutions of much weaker concentration. The finger, however, remains painful and swollen for several days; whereas the injection of cocain, tropacocain or β-eucain causes no reaction. Stovain, according to the author's investigations, even in 1 per cent. solutions, causes injury to the tissues. Sinclair observed gangrene in 4 cases following the use of a 2 per cent. solution. These results stamp this agent as unsuitable for local anesthesia, a conclusion with which Reclus agrees.

ALYPIN.

This drug recommended by Impens is very similar to stovain. Stovain is the hydrochloric acid salt of benzoylæthyldimethylaminopropanol, and alypin is the hydrochloric acid salt of benzolethyltetramethyldiaminopropanol, and is derived from the former by the substitution of $N(CH_3)_2$ for the hydroxyl radical. This substance consists of colorless crystals very readily soluble in water, forming neutral solutions which can be sterilized by boiling. In regard to the chemical and pharmacological properties of alypin reference is made to Impens' reports.

Experiments with Alypin.—1. 0.1 per cent. alypin solution with addition of 0.8 per cent. salt. Formation of wheal on the arm of a healthy person. Injection is painful, and the wheal becomes immediately anesthetic. Sensation returns in about eleven minutes. The wheal becomes slightly hyperemic immediately after injection. Following the injection a markedly hyperemic infiltrate remains for several hours.

2. Control experiments with 0.1 per cent. cocain solution with addition of 0.8 per cent. salt. Formation of a wheal next to the alypin wheal. Injection is painless and the wheal becomes immediately anesthetic. Sensation returns in about fifteen minutes. The wheal is anemic; there is no infiltration or hyperemia.

3. 1 per cent. alypin solution with 0.8 per cent. salt. The injection is painful, The anesthesia lasts about twenty minutes. At the point of injection a painful infiltrate remains for several days.

4. Control experiment with 1 per cent. cocain solution with addition of salt. Injection is painless, the anesthesia lasting about twenty-five minutes; the injected solution is absorbed without leaving any noticeable effect.

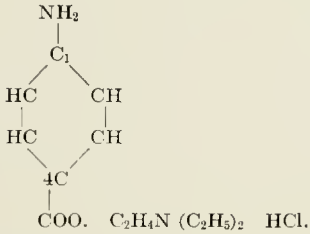
5. 5 per cent. alypin solution. Injection is very painful, the anesthesia which is quite extensive around the wheal lasts about thirty-seven minutes; at the point of injection the epidermis is raised in the form of small vesicles. A superficial layer of the cutis became gangrenous, for which reason the 10 per cent. solution was not tried for this purpose.

6. 1 per cent. alypin solution. Injection of 1 c.c. in the form of a transverse strip under the skin of the forearm. In about ten minutes there is a very pronounced effect upon the subcutaneous nerves from the solution resulting in a marked diminution and in places complete loss of sensation in their area of distribution. In about fifteen minutes sensation returns to normal.

It was noticed that this agent, like stovain, produced marked local anesthetic effects. The hyperemia following the injection was slight. The toxicity of this agent, according to Impens, is less than that of cocain. Unfortunately, the injection of alypin is painful, and the intracutaneous and subcutaneous injection is frequently accompanied by very noticeable tissue injury. The latter, however, is not so marked as following the injection of solutions of stovain. Laewen has demonstrated that nerve trunks poisoned with a 5 per cent. solution of alypin can be restored to normal by washing out this solution, which in the case of stovain is impossible. For these reasons the use of solutions of alypin for injections is contra-indicated, inasmuch as we have other agents without the local injurious effects. Alypin has been successfully used as an anesthetic for mucous membranes in rhinolaryngological practice (Seifert, Ruprecht), and also in urology (Joseph, Kraus, Lucke, Lohnstein, Garasch). Garasch in 1453 cases of alypin anesthesia observed severe poisoning following the injection of 5 c.c. of a 2 per cent. and also a 5 per cent. solution into the urethra. One and a half to two minutes after the injection dyspnea, nausea, vomiting, vertigo, mydriasis, hallucinations, and convulsions occurred, pulse and respiration could not be counted, and only after energetic efforts at resuscitation for eighteen to twenty-two minutes did the patient show evidence of returning vitality. These toxic symptoms are very likely to occur according to his experience in young debilitated persons. G. Ritter reports one death from alypin. A sixteen-year-old girl was given 1.5 gram adalin, thirty minutes later 1.5 cg. morphin preparatory to a thyroidectomy. The operative field was injected with 50 c.c. of a 2 per cent. alypin solution. Ten minutes later the patient became unconscious; convulsions, followed by respiratory and cardiac paralysis, resulted after a few hours in death. The question naturally arises: For what purpose was, and what were the indications, for the use of such quantities of a drug which had not been sufficiently tested?

NOVOCAIN.

Chemical Properties.[1]—The chemical properties of this drug were discovered by Einhorn. This preparation is a monochlorhydrate of p-aminobenzoyldiethylamino-ethanols with the graphic formula



The salt crystallizes from alcohol in the form of needles which melt at a temperature of 156°. It is soluble in equal quantities of water, producing a solution neutral in reaction. It is soluble in 30 parts of cold alcohol. From watery solutions, corroding alkaline carbonates of the free base are precipitated as colorless, sometimes crystalline, oily substances. By the addition of sodium bicarbonate clear watery solutions can be made. The free base crystallizes from dilute alcohol with two molecules of the water of crystallization from ether or ligroin it crystallizes in water free, shining prisms. The melting-point of the water-containing base is about 51°, that of the water-free base about 58 to 60°. With the general alkaloid reagents, as potassium iodide, calcium mercuryiodide, picric acid, this preparation even in very dilute solutions is precipitated. Watery solutions of novocain can be boiled without deterioration and can be kept in lightly-stoppered flasks for days without change of color. The physiological concentration is about 5.48 per cent.

The pharmacological experiments as carried out by Biberfeld have given the following results: In animals it was found that the preparation anesthetizes well and very promptly, 0.25 per cent. solutions being sufficient to cause an anesthesia of ten

[1] From the Hoechster Farbwerken.

minutes in a freely exposed nerve. When used locally, this drug has no secondary effects, and even after the use of very concentrated solutions symptoms of irritations were not observed. Powdered novocain can be sprinkled upon fresh wounds in delicate structures such as the cornea without irritation; whereas stovain applied in this manner immediately cauterizes the tissues. The general effect following the use of medium-sized doses is very slight. Doses of 0.15 to 0.2 per kilo when introduced subcutaneously in rabbits produce scarcely any noticeable change in the curves for blood-pressure and respiration on the revolving tambour. If novocain is injected intravenously, the blood-pressure sinks and the respiration becomes slow and superficial. The fall of blood-pressure is apparently due to the influence of the substance upon the vasomotor centres. The heart does not seem to be affected and likewise no peripheral action upon the vessels is noted. The toxic action of this drug is less than from any hitherto known anesthetic substance.

Fatal doses per kilo of body weight following subcutaneous injections are as follows:

	Cocain.	Stovain.	Novocain.
Rabbits	0.05 to 0.1	0.15 to 0.17	0.35 to 0.4
Dogs	0.05 to 0.07	0.15	0.25 is not fatal

Intravenous injections.

	Cocain.	Stovain.	Novocain.
Cats	0.018	0.025 to 0.05	0.15 not fatal

Laewen's experiments have shown that the function of a nerve trunk paralyzed by the application of a 5 per cent. novocain solution returns quickly to normal after the washing out of the medicament. The author's experiments have given the following results:

1. 0.1 per cent. isotonic novocain solution. Formation of wheal on forearm. Injection was painless. Wheal became immediately anesthetic. Anesthesia, as with tropacocain was of very short duration, after about three to five minutes sensation returned to normal. No hyperemia. The wheal disappeared without leaving any evidence of its existence.

2. 0.5 to 1 per cent. novocain solution. Injection painless; duration of anesthesia ten and fifteen minutes respectively. The wheals disappear without any injury to the tissues.

3. 5 to 10 per cent. novocain solution. Injection of 5 per cent. solution were painless, 10 per cent. solution caused very slight irritation; duration of anesthesia about seventeen to twenty-seven minutes very slight hyperemia at the point of injection; the wheals disappeared without any evidence of infiltration or sensitiveness.

4. 1 per cent. novocain solution. 1 c.c. was injected subcutaneously in the forearm in the region of the superficial radial nerve; the sensation of the skin immediately

over the point of injection was diminished shortly after the injection. There was no noticeable effect upon the peripheral branches of the nerve.

5. 0.5 per cent. novocain solution. Ligation of the fifth finger with a rubber band; injection of 1 c.c. of solution around the base of the finger in the subcutaneous connective tissue. In about 11 minutes the finger as far as the tip was completely anesthetized. Five minutes after the removal of the rubber band sensation returned. The finger experimented upon showed no secondary swelling or sensitiveness.

It will be noted from these results that we have to do with an agent having marked local anesthetic properties, not, however, having the same duration as many other similar substances. We find for the first time since the discovery of eucain that we have in novocain an anesthetic possessing scarcely any irritating properties. After the injection of 10 per cent. solutions of this substance endermatically it is found that they are absorbed without leaving any secondary effects. There is no peripheral effect on the bloodvessels; this has also been observed by Biberfeld. Ten per cent. solutions cause very slight irritation with slight hyperemia, just as any other concentrated hyperosmotic salt solution will produce purely by its physical properties. In the light of these experiments it would be said, very properly, that novocain, owing to the rapid disappearance of its anesthetic effects, could not compete with cocain. Laewen has similarly expressed himself. Experience and experiments have, however, shown that by doubling the dose of novocain, so as to make it as effective as cocain, and at the same time by adding certain substances, which will be described in the next chapter (suprarenin), novocain has become an ideal anesthetic for injection into the tissues and has made the use of cocain unnecessary. This agent has been introduced into England by Arnold, Struthers, and LeBrocq; in America by McArthur, Schley, and others; in Russia by Spisharny. In France the school of Reclus has given up stovain and taken up novocain.

In a recent communication regarding his experiments Piquand, a pupil of Reclus, states: "Novocain at present seems to be the local anesthetic of choice. Its slight toxicity permits of the injection of large doses without danger, and the carrying out of complicated operations which were performed with difficulty or not at all with cocain. Though having marked anesthetic power, it is neither irritating nor does it have any dilating effect upon the bloodvessels. The only disadvantage of novocain as an anesthetic is its short duration, which, however, can be rectified by the addition of small doses of adrenalin, causing the anesthesia to become more pronounced and of longer duration without adding to the toxicity of the drug."

Piquand also verified experiments regarding the use of novocain and suprarenin made in 1905 by the author and many others. The field of local anesthesia has been materially enlarged and its possibilities in surgery have been greatly extended. For the anesthesia of mucous membranes novocain is not so well suited as it penetrates this structure with much more difficulty than cocain and some other substances.

It has already been mentioned in describing the work of Gros that the bases of anesthetic substances are much more active than their salts, and the activity of the salts is greater, the weaker the acid contained in them. In the light of these experiments, Laewen conducted practical experiments and concluded that novocain bicarbonate solutions produce a more rapid anesthesia and conduction anesthesia of longer duration than novocain hydrochloride. The preparations of novocain phosphates and novocain borates as used by Gros in animal experiments were found to have very strong anesthetic properties, but owing to the injury to the tissues it was impossible to use these substances. It is impossible to state the maximum dose of novocain any more than we were able to state the maximum dose of cocain, eucain, and other similar agents. The toxicity of this drug as with many others depends largely upon the concentration of the solution and the method of its use.

In surgical practice the 0.5 per cent. and 2 per cent. solutions are the only ones used, as a rule. The solutions in combination with suprarenin as recommended for use by many authorities are the following:

Nast-Kolb injected about 50 c.c. of a 1 per cent. solution, von Lichtenberg 50 to 60 c.c., Axhausen has used 170 c.c. and has even gone as high as 200 c.c. (2.0 novocain), Chaput 110 c.c. Borchardt has used 150 c.c. of a 0.5 per cent. solution, Hesse 250 c.c. Since learning the harmlessness of this agent we have been using more of the solution, instilling daily from 100 to 200 c.c. of a 0.5 per cent. solution in connection with small quantities of a 1 per cent. solution, and repeatedly going as high as 250 c.c. (1.25 gram).

Secondary effects from these doses except occasional vomiting have not been observed. However, the fact that novocain is a poison must not be forgotten. Regarding the use of more highly concentrated novocain solutions, Krecke has injected subcutaneously 2 c.c. of a 20 per cent. solution without injury. Liebl in experiments upon himself injected 0.75 c.c. of a 10 per cent. solution into his thigh, in five minutes very mild symptoms occurred, consisting of a sudden peculiar warmth over the entire body, particularly in the region of the liver, slight nausea and vomiting with general unrest; there was no change in the pulse or color of the face. Two minutes later slight deafness was noted in the left ear; accommodation of both sides, but particularly that of the left, was only possible with much effort; double vision occurred; thirteen minutes after the injection there was a slight sticking headache of the left side. Seven minutes later paresthesia in the area of the radial nerve ensued, followed in about one-half hour by a return to normal. Solutions of this strength must not to be used in surgery.

Laewen and others have observed typical novocain poisoning following the injection of 20 to 25 c.c. of a 2 per cent. novocain solution into the sacral canal. The symptoms consisted of nausea, sweating, anemia of the face, rapid pulse, frequent respiration, repeated vomiting, a feeling of oppression and a haze in front of the eyes. We have never noticed any disturbance following the subcutaneous injection of 2 per cent. solution. These disturbances from sacral injections can be avoided by a slow injection of the solution (Laewen, von Gaza). The slight toxicity of novocain can be best illustrated by the experiment of Laewen on the nerve trunks of the lower extremities. Laewen has injected as much as 2.1 grams novocain; in one case the patient received 20 c.c. of a 4 per cent. solution, in another 30 c.c. of 2 per cent. solution. He has also injected as much as 50 c.c. of a 1 per cent. solution or larger quantities of 0.5 per cent. solution. The injections were distributed over a period of time, varying from ten to fifteen minutes. In only a few cases were toxic symptoms noticed.

Dentists have noted symptoms of various kinds in hysterical and nervous persons, as, for instance, sensory paralysis of long duration, and prolonged periods of sleep, which were supposed to be due to the toxic effect of novocain. Fischer has critically reported on these results. Moeller has described a death occurring in the practice of a dentist, Balzer, which was supposed to be due to novocain. A girl, aged twenty-three years, with periostitis of the lower jaw. Injection of 3 c.c. of a 2 per cent. novocain solution with the addition of suprarenin. Following the extraction of the tooth patient did not feel well; she rested an hour and a half, then stood up and talked excitedly. After an hour and a half she again lay down complaining of dizziness; six hours after injection her condition became worse; eight hours after the injection the patient died in coma, with symptoms of cardiac weakness. Fischer believes that this was a case of acute sepsis, but it could not be definitely proved. The author (with Moeller) believes that without an autopsy, which was not made in this case, that it was impossible to arrive at definite conclusions, but he stated that it was difficult to conceive of a death following the use of so small a quantity of novocain, since this agent was used in surgery in fairly large doses without serious consequences. Two very remarkable observations are reported by Claus. In the first case a cotton tampon containing six drops of a 10 per cent. novocain solution and six drops of adrenalin was placed in the nose of a young woman. The tampon was removed in about twenty minutes and the antrum was washed out. Almost immediately after this procedure the patient became cyanotic and died of paralysis of the heart. There was no diseased condition found in any of the organs at autopsy.

In a second case a woman, aged thirty-six years, had inserted into the lower and middle portion of the nasal tract a tampon containing 10 per cent. novocain and suprarenin solution. Besides this there was a local application of a 10 per cent. cocain solution applied to the mucous membrane of the nose. Following the anesthesia the antrum was punctured and inflated; the patient collapsed and died the same evening. Autopsy showed numerous hemorrhages into the heart muscle and into the gray cortex of the cerebrum and cerebellum. It is difficult to conceive how Claus can state that this was a case of acute novocain poisoning, inasmuch as the severe symptoms did not follow the application of this agent but rather occurred following the puncture of the antrum. Claus at the same time reports 2 cases of a similar kind which were operated upon without an anesthetic, in one of which serious symptoms of cyanosis and dyspnea occurred, and in the other apoplexy followed puncture of the antrum. At any rate these observations teach that the slightest operative procedure can be followed by dangerous complications which cannot be attributed to any one thing but must be explained by a combination of circumstances.

Other Anesthetics.—The anesthetic properties of *carbolic acid*, which belongs to the group of agents capable of penetrating the unbroken skin, has long been known. Pirrie advocated the use of carbolic acid compresses (carbolic acid 1, oil 6) for extensive burns, the pain being relieved in about ten minutes. Van der Weyde noted that carbolic acid was used in America for a long time for the relief of pain in carious teeth, and Rae reports that the pain of bee-stings could be immediately relieved by the hypodermic injection of carbolic acid (1 to 100). Bill and Smith were the first to recommend compresses and applications of carbolic acid to the skin for surgical purposes. Smith painted the skin of the forearm with 85 per cent. carbolic acid; this was followed in a few minutes by burning, after which the entire thickness of the skin could be cut without any sensation. This drug has also been used with success for the opening of superficial felons. It was observed in the hospital of the Rudolf Stiftung in Vienna that the injection of 1 to 3 per cent. carbolic acid gave better local anesthetic effects than injections of morphin. Caspari used a 2 per cent. solution of carbolic acid subcutaneously with very good results. Walser was able to produce very decided local anesthetic effects by the use of a spray of a 3 per cent. carbolic acid solution. Richardson recommended for local anesthesia ether sulphate 75.0, acid carbol. 0.3 in spray form, claiming to be able to produce a much more intense action than by the use of pure sulphuric ether. Schleich also used on circumscribed areas of mucous membranes and on the freely exposed nerve trunks in operative wounds a 5 per cent. carbolic acid solution to a local anesthetic to cause anesthesia in these parts. Strongly irritating carbolic acid can hardly be considered today, inasmuch as we possess so many other more suitable drugs.

Besides the previously mentioned substances there are a number of other drugs to which anesthetic properties are ascribed. Mays found that with brucin, an alkaloid similar to strychnine, the cornea could be made insensitive following the application of 5 to 20 per cent. solution. Seiss was able to verify these observations and used this drug in 5 per cent. solutions in furuncles of the auditory canal, in suppurative processes of the middle ear for the purpose of introducing instruments into the ear. Further observations in regard to this remedy are not at hand.

Stenocarpin or *gleditschin*, an alkaloid supposed to be derived from the gleditschia triacanthus, according to the investigations of Goodmann and Claiborne acts as a mydriatic and local anesthetic when applied to the eye. Novy, investigating this drug, proved it to be an "industrial humbug," and that the supposed 2 per cent. gleditschin solution was a mixture of cocain chlorhydrate, atropin sulphate, and salicylic acid. The presence of the alkaloid gleditschin was not denied.

Local anesthetic properties were also observed by Steinach and Panas with *strophanthin, erythrophlein, helleborin, convallarin, adonidin, dionin, peronin,* and many other substances which are more or less impractical owing to their local irritating qualities and the damage to the tissues, and, in case of some of them, to their general toxic symptoms. Erythrolphlæin was tested practically in 1888 and caused Liebreich to give expression to the paradox, "anesthetica dolorosa." Guaiacol was recommended by L. Championnière as a local anesthetic, but owing to its severe irritating properties and the fact that it causes gangrene of the tissues, it is unsuitable for local anesthesia (Reclus).

Antipyrin solutions, which according to the investigations of Heinze are not suitable for injection into the tissues, were used by Lydston for anesthetizing the mucous membrane of the bladder and urethra (10 per cent. antipyrin with addition of 1 per cent. carbolic acid). Kocher used for anesthesia of the larynx a solution of 5 per cent. cocain with 5 per cent. antipyrin and 1 per cent. carbolic acid. Ephraim advised the use of 2 per cent. antipyrin and 1 per cent. solution of chinin bimuriatic carbamid for anesthesia of the mucous membrane of the upper air passages.

In more recent times, Dalma prepared an alkaloid from the Indian plant *gasubasu* and named it nerrozidin, which was supposed to possess very marked local anesthetic properties. Magnani found that the alkaloid *yohimbin,* derived from yohimbehe-bark, produced anesthesia of the cornea and conjunctiva when instilled into the eye. Loewy and Moeller investigated this remedy more closely, and found that a 1 per cent. solution interrupted the conductivity of motor and sensory nerve tracts (sciatic and vagus). Just as with cocain the sensory nerves were interrupted before the motor nerves. The action of this drug is transitory and the return to normal takes place rapidly. Marked irritation following the use of this remedy was not observed. According to Oberwarth, 0.05 per kilo injected subcutaneously caused death in rabbits, and inasmuch as severe symptoms are produced in man by the use of 5 mg. of this drug, it must be used with great caution. This drug owes its value to its supposed action on the male genital organs, causing hyperemia and prolonged erections.

The value of the various substitutes for cocain can be judged from the following résumé. The requirements of local anesthetics are as follows: 1. The substance must be less toxic than cocain in proportion to its local anesthetic power. The determination of a lessened toxicity is not sufficient, for if its anesthetic property be less than cocain proportionately larger doses will be necessary to attain the same results as with the latter drug; all known substitutes, with the exception of akoin, fulfil these requirements.

2. The agent must not cause the slightest irritation or tissue injury but must, like cocain, be absorbed from the place of application without any secondary effects such as severe hyperemia, inflammation, painful infiltrates, or necrosis. Only when these conditions are fulfilled can we assume that the healing of wounds will not be interfered with. The use of strongly acid or alkaline reacting substances is not permissible, inasmuch as they cause local tissue injury. On account of this important requirement many of the newer anesthetics have failed in their purposes. The only local anesthetics not causing tissue injury besides cocain are tropacocain, eucain, and novocain. Several others, such as alypin, cause so little damage to the tissues that their use is still open to question (superficial application to mucous membrane).

3. The agent must be soluble in water and its solutions stable and possible of sterilization by boiling. These requirements are met by all previously mentioned substances, except cocain, which only in part meets the conditions.

4. It must be possible to combine the agent with suprarenin, as will be described in the next chapter. Cocain, alypin, and novocain meet this requirement, but all other agents interfere to some extent with the action of suprarenin.

5. For particular places of application, as, for instance, mucous membranes, the anesthetic must be able to penetrate rapidly, its anesthetic properties being dependent upon this quality.

Novocain and alypin are the two substances which have made the use of cocain in surgery almost obsolete. Eucain has been superseded by novocain, and the use of tropacocain and stovain is now almost entirely limited to lumbar anesthesia. The other substances had best not be used as anesthetics for operative work, inasmuch as they all have disadvantages without possessing any advantages over those just named.

CHAPTER VIII.

FURTHER AIDS TO LOCAL ANESTHESIA. THE INFLUENCE OF THE VITALITY OF THE TISSUES UPON THE LOCAL AND TOXIC ACTION OF LOCAL ANESTHETIC AGENTS.

Local anesthetic substances acting upon living tissues, in which the vitality—that is, chemical and physical changes—is artificially interfered with, and the circulation is disturbed, cause a much more intense local anesthesia than in tissues with undisturbed, active metabolism and normal circulation. This increase of local action is brought about: (1) By delaying the absorption of the poison from the point of application, thus allowing much longer time for local action. (2) By inhibiting all of those processes which the living tissues exert against a foreign substance but only to an extent that will permit the tissues to return to normal after exerting their local effect. With the increase in intensity of the local action there must be an accompanying diminution in the general toxicity from the substance because (*a*) the absorption of the poison is delayed; because (*b*) much of the poison is destroyed locally and therefore does not enter the circulation. The knowledge of substances which produce an artificial diminution or suspension of vitality and which cause a diminution of the parenchymatous absorption is of much importance to local anesthesia.

To a certain extent the dilute solutions of Schleich used for infiltration of the tissues belong to this class. By means of these dilute solutions the quantity of the anesthetic can be evenly divided over a considerable area and thus be more slowly absorbed, permitting the tissues to come in better contact with the agent than if a similar quantity had been injected in more concentrated solution. The dilution of the solution decreases both the toxic and fatal dose of the anesthetic. It will, therefore, be seen that the dilution of the solution increases the local effect and diminishes the toxic action of the substance.

The rapidity of absorption can be diminished and the local effect increased, together with diminished toxicity, if the anesthetic is dissolved in oil instead of water. The absorption of solutions in oil, which takes place through the lymphatics, is much slower than watery solutions, which are taken up directly by the circulation. Legrand and Hartwig recommend that gelatin be added to the anesthetic solutions used for injection. This has likewise been advised by Klapp to delay absorption. Contrary to these recommendations the author has failed to note an increase in the local effect from cocain by the addition of gelatin. The solutions were of course carefully sterilized, which, according to Klapp, so alters the gelatin that its property of delaying absorption is lost. On this account the practical application of this method cannot be considered. We possess, however, three other important aids to local anesthesia which can be considered in this connection: The hindrance or interruption of the blood-stream by means of ligating the extremities, the use of a substance causing a contraction of the bloodvessels (suprarenin), and the cooling of the tissues by means of the ether or ethyl chloride spray after the injection of the local anesthetic. We will consider these methods in the order named.

THE EFFECTS OF MECHANICAL INTERRUPTION OF THE CIRCULATION ON LOCAL AND GENERAL POISONING.

If a small quantity of a watery solution of coloring matter, such as eosin, is injected into the cutis of the forearm of the person to be experimented upon in such a manner as to produce a wheal, it will be noticed in the beginning that the wheal alone is colored; in a few minutes the extension of the coloring will be noted in a variable area of skin around the wheal, depending upon the concentration of the color solution used. The coloring matter has been diffused and has caused a local reaction that can be noted from the coloring of the tissues. On the other arm of the same person the same quantity of the color solution is injected in the form of a wheal, but immediately before or shortly after the injection the upper arm is constricted with a rubber band. It will be noted that the visible coloring of the skin area in the ligated arm is decidedly larger than in the one which has not been ligated; the color solution has extended into the surrounding area to a great extent and in large quantities. There must have been a hyperabsorption of the color solution at the point of application, and there must necessarily have been less absorbed into the general circulation.

If now a 1 per cent. cocain solution is injected into the skin of the forearm in like manner, an anesthetic wheal will remain for a variable length of time. If the arm is ligated before or immediately after injection, anesthesia of the skin will be distributed in a considerable area beyond the wheal, a result only possible in unligated extremities by using a very concentrated solution of cocain. From these results it will be noted that the anesthetic action of cocain has been increased. This can only be explained by assuming that hyperabsorption has taken place at the point of injection. The anesthetized tissues remain in this condition as long as the circulation is interrupted and even some little time after the removal of the rubber band. Only after the return of the circulation do reparative changes begin which are necessary for a return of the tissues to normal. As has already been noted, it is probable that a disintegration of the cocain has taken place. Since the work of Corning (in 1885), the Esmarch bandage for ligating extremities and thereby increasing the local action of cocain has come into general use as an important aid to local anesthesia. The tight bandaging of an extremity, continued for a long time, by interfering with the metabolism of the part and by the compression of nerve trunks, must necessarily aid in diminishing sensation.

With the increased local action and delay of absorption of cocain on account of the ligature, a lessening of toxicity must necessarily occur.

If 0.1 per kilo of a 10 per cent. cocain solution is injected into the hind legs of two rabbits of the same weight, after first ligating the leg of one of the rabbits with a rubber band, the rabbit with the unligated leg, as a rule, dies in severe convulsions in a few minutes, while the rabbit with the ligated leg shows no evidence of poisoning. If the band be released after half an hour mild symptoms of poisoning occur, which, however, do not cause the death of the animal. In fact, in some cases the animal remains perfectly normal. This typical course, which was known to Kummer and Kohlhardt, led the latter, upon the advice of Czylhartz and Donath, to carry out experiments of this kind in animals poisoned with strychnin. He also noted that the general toxicity following the injection of usually fatal doses of cocain was diminished or entirely prevented by the ligation of the leg of a rabbit, the intensity depending upon the length of time the leg was ligated. If the ligature remained in place for an hour or longer all symptoms of poisoning were avoided. These observations are explained by the fact that, absorption being prevented, disintegration of the cocain occurred at the point of injection. It has been observed by Kleine that absorption following the tight ligating of a limb is not entirely prevented but only delayed.

We are indebted to Klapp for his valuable investigations regarding parenchymatous absorption. He used for this purpose a locally indifferent substance such as milk sugar, which, following its injection, rapidly appeared in the urine. He used this observation to determine the rapidity or delay of absorption. He was able to repeatedly demonstrate that active hyperemia increased the rapidity of absorption, whereas a slight passive hyperemia, such as is produced by the application of a rubber band to the extremities, or following simple elevation, caused a delay in the excretion of the injected milk sugar. Both of these means, either simple elevation or the application of a rubber bandage, caused a marked increase in activity of local anesthetic substances like cocain and similar drugs.

THE EFFECT OF INTENSE CHILLING OF THE TISSUES ON LOCAL AND GENERAL POISONING.

Another means for diminishing the local vitality of the tissues and delaying absorption is brought about by cooling with either the ether or ethyl chloride spray. By this means it is possible to increase the local activity of various drugs, which can be readily observed in connection with local anesthetic substances. In a previous chapter intense and long-continued anesthesia was described following the application of cocain in ethyl chloride. This was not due to the simple combination of cocain anesthesia with the anesthesia from cold, but to the increased local effect of cocain from the cooling of the tissues. This same effect can be noticed if a mucous membrane is frozen after a watery solution of cocain hydrochlorate is applied. The transitory anesthesia from cold disappears rapidly to be followed, however, by a very intense cocain anesthesia in a very few minutes. If it is desired to combine cocain with anesthesia from cold in a practical manner, the mucous membrane should first be chilled and then cocainized, or the cocain-ethyl chloride spray can be used. While waiting for the action of cocain to begin, a second chilling of the surface is carried out before operation. The action of cold can also be tested in the increasing local anesthetic effect upon the wheal.

Experiment 1.—Two wheals are injected with 0.5 per cent. cocain solution next to one another on the arm of the person to be experimented upon, both immediately becoming anesthetic. One of these wheals is then chilled until frozen, the second is undisturbed. In the latter wheal sensation returns in about eighteen minutes, and the anesthesia has been confined to the wheal. In the one which had been frozen the duration of anesthesia is about double that of the latter. Five minutes after the injection the anesthesia from cold disappears, the skin is hyperemic, and anesthesia is found to have extended for some distance beyond the point of injection, so that an area of about double the size of the original wheal becomes insensitive. After about ten minutes this secondary anesthesia disappears. Similar symptoms occur if the skin is frozen just before injection.

Experiment 2.—Two wheals not widely separated from one another on the arm of the person to be experimented upon are injected with 0.5 c.c. of a 0.5 per cent. cocain solution. The area about one of the wheals is frozen, the other being left undisturbed. In the case of the one in which the surrounding area has been frozen anesthesia persists for twenty minutes; in the second wheal this action does not occur.

Both of these experiments readily demonstrate that decided increase in the action of cocain is produced by the cooling of the tissues. Other local anesthetics show similar results. This method of increasing cocain activity by the joint use of ether or ethyl chloride sprays has been successful for some time in practice, as, for instance, in the extraction of teeth (Wiener, Schleich and others). The combination of cocain anesthesia with the ethyl chloride spray has been very extensively used by Schleich and Hackenbruch. It is important to remember that the anesthetic action of cold with cocain anesthesia permits the use of dilute solutions of cocain in tissues where an intense and long-continued anesthesia is necessary, which without cold could only be produced by using much stronger solutions. The knowledge gained from these facts should be of practical value in the development of the art of local anesthesia. If cooling of the tissues diminishes their vitality, thereby delaying absorption and increasing the local activity of various drugs, it must likewise diminish or prevent the general toxic action of these substances.

The fact that cooling delays parenchymatous absorption, whereas an increase in temperatrue increases it, was long known and in almost daily use by physicians. It has again been demonstrated in a very interesting manner by Klapp in his experiments with milk sugar. The effect of the chilling of the tissues on absorption and the general action of poisons was demonstrated by Kóssa following the reports of Claude Bernard and L. Brunton.

Kóssa injected into the ears of rabbits, which had been cooled to a temperature of +5° to +7°, potassium cyanide, strychnine, and picrotoxin in doses which, in the control animals, produced death, or very severe symptoms of poisoning. With continued cooling of the parts the injection did not produce the slightest symptom of poisoning and even after the cooling had been stopped for one and a half hours symptoms did not occur. These same results can be readily determined with solutions of cocain.

Experiment 3.—Rabbit, weighing 1450 grams; the skin of the back having been freed from hair was chilled with the ether spray, following which 0.15 (=0.05 per kilo) cocain in 10 per cent. solution, was injected and the cooling was continued at the point of injection by means of an ice-cap filled with ice and salt. Symptoms of poisoning did not occur. After one hour the cooling was stopped. Ten minutes later mild symptoms of poisoning occurred, such as excitement and paresis of the extremities. Convulsions and coma did not occur. The animal appeared perfectly normal in about fifteen minutes. A control animal injected in the same manner with 0.05 cocain per kilo but without chilling exhibited in five minutes the usual symptoms of acute cocain poisoning, with convulsions and coma. Death, however, did not occur.

Experiment 4.—A third rabbit, injected with 0.1 per kilo cocain in 30 per cent. solution, in an area of the back which had been freed from hair and cooled with the ice bag, showed severe symptoms of poisoning but did not die. These symptoms occurred about seventeen minutes after the injection, following which the cooling was stopped; severe convulsions and coma now occurred but the animal rapidly returned to normal. The injection of 0.1 cocain per kilo in 30 per cent. solution injected subcutaneously is, without these additional measures, an absolutely fatal dose.

These experiments can be continued to further advantage in the following manner: A rabbit is placed in a close-fitting box, a small hole being sawed in one side and the unshaven hind leg drawn out and fixed in this opening. The leg is surrounded with wet cotton and placed in a vessel containing ice.

Experiment 5.—Rabbit weighing 1800 grams; 10:30 o'clock freezing of the hind leg begun; 10:40 o'clock injection of 0.18 cocain in 20 per cent. solution subcutaneously in the middle of the upper leg, above the bandage holding the leg in place. The point of injection is cooled with the ether spray followed by covering the leg with wet cotton and ice. No symptoms of poisoning occur; 11:40 o'clock the cooling is stopped and the animal freed; 11:45 mild symptoms of poisoning, as excitement and paresis of the extremities, convulsions and coma do not occur; 12:05 o'clock animal is apparently normal.

Control experiment: rabbit, weighing 1900 grams; the animal is confined in like manner and 0.19 cocain in 20 per cent. solution injected. In five minutes severe convulsions occur, death following six minutes after the injection.

These experiments permit us to see that general toxic symptoms do not occur when the vitality of the tissues is damaged by cooling, owing to the delayed absorption of the cocain. Furthermore, the symptoms of poisoning are very much diminished as long as the cooling continues, and may be entirely absent if the cooling be continued for some time.

The cooling of the tissues upon the local toxic action of anesthetic substances is of much practical interest, but it must always be kept in mind that even with its use the same care as has already been mentioned must be observed.

THE EFFECT OF SUPRARENIN (ADRENALIN) ON LOCAL AND GENERAL POISONING.

From an entirely unexpected source surgery, and particularly local anesthesia, has been offered a drug the local application of which causes a contraction of the bloodvessels, rendering the tissues bloodless and diminishing their vitality, thereby causing an increase of the local action of drugs and a diminution of their general toxic action.

We have known since the early important work of Brown-Séquard that the removal of both suprarenal glands in animals caused death, or when this did not occur, it was supposed that the animal possessed an accessory suprarenal gland. The fresh or dried suprarenal glands of healthy animals contain a toxic body (Pellacani, 1879) having a peculiar pharmacological action when administered to animals or man, and as partly described by Vulpian in 1856, possesses definite chemical reactions. Solutions of this gland or the fresh gland itself rapidly become red or brown when exposed to the air. They become green upon the addition of ferric chloride, again becoming red with the addition of alkalies or the halogens, these reactions being similar to those for guiacol.

Attempts were made by many experimenters to isolate the active principle of the suprarenal gland, the experiments of Fuerth and Abel coming nearer the solution of this problem than any previous workers. They each prepared an extract of suprarenal which, though not identical, possessed the same physiological and chemical characteristic reactions. Fuerth called his preparation suprarenin and Abel called his epinephrin. In the year 1901, Takamine and Aldridge, independently of each other, succeeded in separating the active principle of this gland in crystalline form, the product being known as adrenalin.

Fuerth was able to demonstrate that his suprarenin was identical with adrenalin. Suprarenin was first placed upon the market in pure crystalline form by Parke, Davis & Co., of Detroit, Mich., under the name of adrenalin. It is now prepared by a large number of German and foreign pharmaceutical houses both in crystalline form and in the form of a 1 to 1000 solution and marketed under the various trade names of adrenalin, suprarenin, eudrenal, epirenan, paranephrin, tonogen, etc. The action of all these various preparations is identical, but we have chosen the one known as suprarenin for our work.

Pure basic suprarenin is a white or slightly red or brown crystalline powder possessing the properties of an alkaloid. It is soluble with difficulty in cold water, but readily soluble in hot water. It does not deteriorate at a temperature of 100°, and combines with the acids to form salts. In attempting to dissolve this substance in water the solutions are promptly colored red or brown owing to oxidation of the suprarenin by the oxygen of the air. Solutions remain clear and colorless in a vacuum. By the addition of hydrochloric acid to the solvent, solutions remain clear and uninfluenced by boiling (Braun). Suprarenin is extremely sensitive to the action of alkalies. Synthetic suprarenin has been prepared by the Hoechster-Farbwerke.

After the chemical constitution of suprarenin was determined by Aldrich, Pauly, Stolz, and Friedmann, the chemists Stolz and Flaecher of the Hoechster-Farbwerke were able to produce suprarenin-like substances from guaiacol. This substance possessed the same contractile power on the bloodvessels and the ability to raise bloodpressure as the organ preparations and showed the same pharmacological properties only in a lesser degree. The first pharmacological investigations of this product were carried out by Meyer, Loewi and von Biberfeld.

The hydrochloric acid methyl-amino-ethanol-guaiacol compared in chemical and physiological reactions very closely to those of the organic suprarenin, possessing, however, only about half the physiological activity of the organ preparation. There was another physical difference observed between these two preparations: the organ preparation rotating polarized light to the left, whereas the synthetic preparation was optically inactive, which according to chemical nomenclature is called racem-form. Flaecher was able to convert the optically inactive synthetic suprarenin into two components, one being optically dextrorotary (dextrogyre) and the other being levorotary (levogyre). The latter is similar to the organ suprarenin. These two components were designated D-suprarenin, and L-suprarenin. The latter product, synthetic L-suprarenin, is identical in its pharmacological reactions with organ suprarenin, as has been demonstrated by the investigations of Cushing, Abderhalden, Mueller, Thies, Slavu. The author has used for several years the synthetic preparation made by the Hoechster-Farbwerke which he has tested as to its power of contracting the bloodvessels and whether it could be used as a substitute for the organ suprarenin. It was found suitable, but larger doses were necessary than with the use of organ suprarenin. This preparation was not stable either alone or in combination with novocain, for which reason within a short time the organ suprarenin we again used. The investigation of the newer products was taken up with much misgiving, first using D-suprarenin, which showed so little contractile power on the bloodvessels that it was not suitable for operations; the L-suprarenin, however, which is marketed under the name of synthetic suprarenin, we have used for some time in the same form and the same dosage as the organ suprarenin and have been unable to determine any difference in its action from the latter preparation.

Double inguinal hernia operations have been used as a test for these drugs, one side being anesthetized with the usual novocain solution with the addition of organ suprarenin, the other side being anesthetized with a similar quantity of novocain to which was added the preparation to be tested. The operator was, therefore, in a position to prove the identity of action of L-suprarenin with organ suprarenin. These investigations, which were carried on for many years by German chemists, were of immense importance in a practical way, inasmuch as the cleanliness and constancy of action of a synthetic preparation is more certain than a preparation made from organs removed after slaughter.

The most noticeable effect following the use of the juice of the suprarenal gland or its extracts is a transitory rise of blood-pressure, infinitesimal doses being sufficient to bring this about (according to Moore and Purinton 0.000000245 to 0.000024 of the extract per kilo for dogs). The cause of this rise of blood-pressure is due to the direct stimulation of the heart (Gottlieb, Hedboom, Schaefer) and to the contraction of the arteries and capillaries of the body. The smooth muscle fibers of other organs are influenced in like manner. According to Jacoby, Boruttau, and Pal the peristalsis of the bowel following the intravenous administration of suprarenal extract is stopped. Lewandowski has shown that the intravenous or subcutaneous injection of suprarenal extract causes the contraction of the smooth muscle fibers of the skin, so that in the hedgehog the bristles rise up. The hair can also be seen to bristle following the use of this substance in cats. Schaefer has stated that extracts of suprarenal cause a contraction of the musculature of the uterus. In large doses this substance is a severe poison and causes the death of the animal experimented upon in a short time with paralytic symptoms and pronounced fall in blood-pressure, the latter being preceded by a rise in blood-pressure.

Cybulski caused death in rabbits after the intravenous injection of 1 c.c. of a 10 per cent. solution of the extract, but this dose could be borne without causing any disturbance if it was diluted ten to twenty times. The active substance can be found in the urine fifteen minutes after a subcutaneous injection (Cybulski, Bardier, and Frenkel), and following the administration of fatal doses Blum and Zuelzer found glycosuria constantly present.

The question whether the action of this substance on the smooth muscle fibers, particularly those of the bloodvessels, was of central or peripheral origin has been decided in favor of the latter. Biedl observed in excised organs, such as the kidney and extremities, through which physiological solutions containing suprarenal extract were passed, a contraction of the bloodvessels to such an extent that the flow from the veins ceased entirely. Hedboom and Schaefer observed the direct action of this substance upon the heart excised from a mammal; the organ began to pulsate after the application of suprarenal extracts. Bates, Dor, Darier, and Koenigstein noted the contraction of the bloodvessels of the conjunctiva following the instillation of the extract into the eye. This same observation was made in connection with other mucous membranes, and Velich observed the anemia-producing power following local application of suprarenal extracts to granulating wounds—eczema and burns—in both animals and man. From these results we must believe that the contraction of bloodvessels is of peripheral origin.

It is of interest to note that the bloodvessels of various organs react more or less intensely to the action of suprarenin. The action is very marked in the skin, less intense in the stomach, intestines, and bladder, and not at all upon the vessels of the lungs (Langley, Brodie, and Dixon). Its action on the coronary vessels does not cause contraction but rather dilatation (Langendorff). Laewen has proved that suprarenin is destroyed by the living bloodvessel walls so that poisoning of the body from this substance is overcome by this action.

The anemia-producing properties of suprarenal extracts have proved of much value in laryngological and rhinological operations for the purpose of allaying hemorrhage (Swain, Moure, Brindel, Harmer, Rode, Rosenberg). Following the application of 1 to 1000 to 1 to 5000 solutions of suprarenin to the mucous membrane of the nose or larynx turgescence is diminished at once, so that the cavities and accessory cavities become more accessible. The mucous membrane becomes gray and completely bloodless so that no bleeding occurs after cutting.

Lermoyez called this substance "Alkaloid der Esmarchschen Blutleere." These remarkable observations following the subcutaneous injections of suprarenal solutions have been further tested in healthy persons by experts and the effects have been studied in its almost daily use in operations. It was shown that tissues freely infiltrated according to Schleich's method with a 1 to 1,000,000 suprarenal solution became bloodless in a few minutes. There was also noticed an absence of parenchymatous bleeding on cutting these tissues, whereas the arterial and venous bleeding was markedly diminished. Following the injection of stronger suprarenal solutions arteries of larger caliber, as, for instance, the arteries of the finger, were closed completely by the contraction of their lumen. We are in position to cause a circumscribed anemia of the tissues of long duration by means of suprarenin which is not far behind that occasioned by the constriction of an Esmarch bandage. This action of suprarenin is one which has long been sought in surgery. It is now possible to carry out all operations, wherever necessary, without the loss of blood. This was formerly only possible on the extremities. The anemia can be produced with extremely small doses of suprarenin; 5 drops are sufficient of a 0.1 per cent. suprarenal solution to 100 c.c. of salt solution which contains this substance in a dilution of about 1 to 600,000. A fraction of a milligram of suprarenin is sufficient to make a large operative field bloodless, provided this agent is freely injected in very dilute solution and evenly divided in the tissues. It is not necessary to saturate the operative field with suprarenin solutions. The field will become much more bloodless if the area around the operative field is injected with suprarenin solution, thus cutting off its blood-supply, as it were. The technique of the injection is similar to that which will be described later for anesthetizing operative fields. B. Mueller recently described the value of suprarenin anemia in operations upon the parenchymatous organs such as the liver and kidney. His observations upon the human liver have been proved incorrect. This organ has been infiltrated repeatedly with suprarenal solutions in cholecystectomies and injuries to the liver without showing any difference in the bleeding. This is only what should be expected from the rigid non-contracting liver veins.

The blood-checking property of the juice of the suprarenal gland has long been known to those employed in slaughter-houses. It has been stated that in the slaughter-houses at Leipsic the butchers would frequently apply the juice squeezed from the suprarenal gland to wounds for the purpose of stopping hemorrhage.

Suprarenin is of importance in local anesthesia owing to its anemia-producing properties. Suprarenin is not an anesthetic, but local action of other drugs is made much more intense if combined with it. It has been frequently observed by ophthalmologists (Dor, Darier, Koenigstein, Lichtwitz, Landolt, and others) that cocain, holocain, atropin, eserin, and other drugs act much more intensely upon the conjunctiva of the eye if combined with suprarenal extract or if the latter had been previously instilled into the eye. Rhinologists and laryngologists (Swain, Bukofzer, Rode, and others) observed the same results, particularly following the use of cocain. The value of suprarenal extracts in local anesthesia for the extraction of teeth was observed by Carpenter, Peters, Minter, Battier, Nevrezé, and Moeller. As a result of the exhaustive studies made with suprarenin this substance has been proved a very valuable aid to anesthesia.

It was observed that the local anesthetic power of cocain solutions was enormously increased by the addition of very small quantities of suprarenin. Dilute cocain solutions with the added suprarenin acted much more intensely than concentrated solutions without this addition, and anesthesia was observed in tissues far beyond the point infiltrated. The conductivity of nerves was readily interrupted, this being observed even in those mixed nerves which were usually very resistant to the action of cocain. At the same time the duration of cocaine anesthesia was prolonged for hours. The extent of the anemia of the tissues and anesthesia are independent of one another. The first depends upon the suprarenin content while the latter depends upon the quantity of cocain in the solution.

Further experiments were undertaken to determine the effect of suprarenin upon β-eucain and tropacocain. It was observed that both eucain and tropacocain interfered with the action of the suprarenin in contracting bloodvessels. This was noticeable with tropacocain, as already mentioned by Rode. The addition of suprarenin to solutions of eucain does not cause an increase in the intensity of its action to the same extent as is noted with solutions of cocain. The addition of suprarenin to tropacocain solution is of very little value. The effect of these three agents upon the action of suprarenin is well shown in the curves drawn by Laewen.

Laewen, by means of a canula fastened in the aorta, flushed the vessels of the hind leg of an animal under constant pressure, the fluid dropping out of the vena cava. The rapidity of flow from the vessels under constant pressure was determined by counting the number of drops per minute.

Fig. 6 shows the results of these experiments. The abscissa gives the time in minutes, the ordinate the rapidity of flow (drops per minute). For the sake of clearness the normal number of drops is reduced to 100 per minute. The arrows indicate the time of beginning the flushing with the different experimental solutions.

Curve A. 0.002 mg. of suprarenin is added to 10 c.c. of indifferent solution (Ringer's solution with the addition of 1 per cent. gum). The number of drops sank rapidly from 100 to 11, which again reached the normal after flushing with Ringer's solution. An interesting observation was made when using pure cocain solutions for flushing, a fact which, however, had already been determined by Kobert, Brodie, and Dixon and this was that cocain solutions alone do not cause contraction of the bloodvessels when passing through them.

Curve B. Solution of 0.002 mg. suprarenin and 0.01 gram cocain in 10 c.c. of Ringer's solution. The rapidity of flow fell promptly from 100 to 3 drops, which rapidly approached the normal after flushing with indifferent solution.

Curve C. Solution of 0.002 mg. suprarenin and 0.01 gram of β-eucain in 10 c.c. of Ringer's solution. The rapidity of flow fell from 100 to 63 drops per minute.

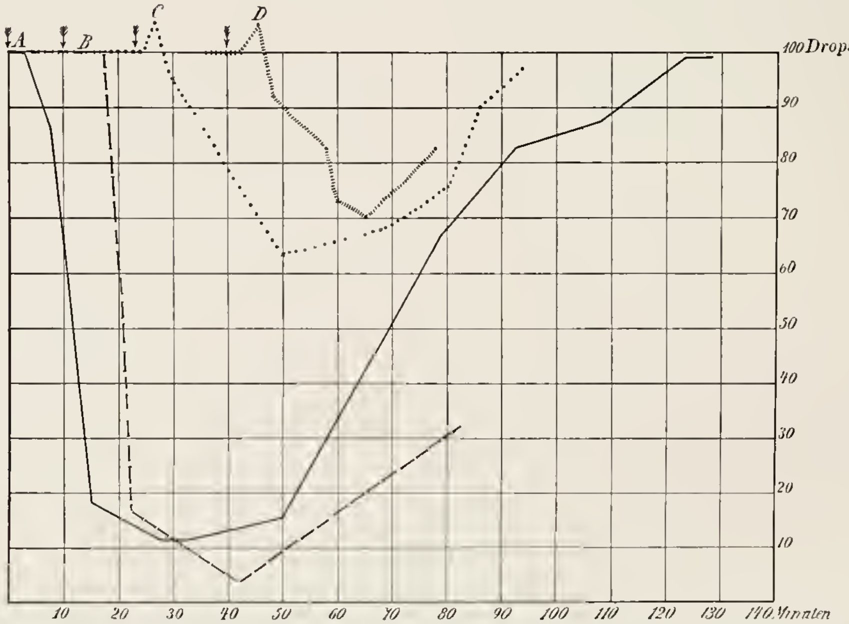


FIG. 6.—The influence of local anesthetics upon suprarenin in reference to its contractile power upon the bloodvessels (Laewen). *A*, suprarenin; *B*, suprarenin with cocain; *C*, suprarenin with eucain; *D*, suprarenin with tropacocain.

Curve D. Solution of 0.002 mg. suprarenin and 0.01 gram tropacocain in 10 c.c. of Ringer's solution. The rapidity of flow dropped from 100 to 70 drops per minute.

It can readily be seen from these experiments that cocain was the only one of the agents experimented with which did not interfere with the contractile power of suprarenin. The other anesthetics, such as holocain, akoin, nirvanin, and subcutin, in combination with suprarenin, were investigated by Recke. The anesthetic power of all these substances was increased by the addition of suprarenin, but not to the same extent as when the latter substance was added to a solution of cocain. Stovain anesthesia is only slightly increased by the addition of suprarenin. The newer substances, alypin and novocain, give brilliant results when combined with suprarenin. This can be readily seen by comparing the following experiments with those in the preceding chapter devoted to these drugs.

Experiment 1.—Five drops of a 1 to 1000 suprarenin solution were added to 100 c.c. of a 0.1 per cent. solution of alypin. A wheal injected into the skin was painful. Skin did not become hyperemic. The white wheal was in the centre of a white area several times the diameter of the original wheal. Anesthesia of the wheal lasted about two hours, when sensation gradually returned. Hyperemic infiltrates remained at the point of injection until the next day.

Experiment 2.—One drop of a 1 to 1000 suprarenin solution was added to 1 c.c. of 0.5 per cent. alypin in 0.8 per cent. salt solution and injected circularly in the subcutaneous tissues of the fourth finger. The injection was painful. After about ten minutes the entire finger as far as the tip became completely anesthetic. In about two hours sensation began to return and reached the normal in about three hours. The base of the finger remained infiltrated for several days, being red and painful. 0.5 per cent. solutions of cocain or eucain with like addition of suprarenin did not show these latter effects.

Experiment 3.—Five drops of a 1 to 1000 suprarenin solution were added to 100 c.c. of a 0.1 per cent. isotonic novocain solution. A wheal was formed on the forearm; the injection was painless; anemia very pronounced. Anesthesia lasted more than an hour, disappearing without leaving any effect.

Experiment 4.—Two drops of a 1 to 1000 suprarenin solution were added to 1 c.c. of a 1 per cent. novocain solution. A wheal formed on the forearm. Injection painless. Anesthesia around the wheal lasted about four hours. Action of the suprarenin very pronounced. After the disappearance of the suprarenin anemia some slight pain was felt at the point of injection, but no other reaction.

Experiment 5.—0.5 c.c. of the same novocain suprarenin solution was injected subcutaneously into the forearm. The skin over the point of injection as well as the parts supplied by the nerve trunks affected by the injection were insensitive for two and a half to three hours. The action of the suprarenin was very pronounced but disappeared without leaving any reaction.

Experiment 6.—One drop of a 1 to 1000 suprarenin solution was added to each cubic centimeter of a 0.5 per cent. novocain solution. The base of the fourth finger was circularly injected with 1 c.c. of this solution. In ten minutes the entire finger was both anemic and insensitive. After about ten minutes a return of sensation was noted in the tip of the finger. It required about one hour for complete return of sensation. There was no secondary pain or swelling of the finger.

From these experiments it becomes very evident that the anesthetic properties of both of these substances are enormously increased by the addition of suprarenin. This is of immense importance in the use of novocain, as the anesthetic power of this substance without the addition of suprarenin is too fleeting to be of practical value. There is no doubt that the influence of suprarenin in increasing the local anesthetic power of this substance is similar to that produced by ligating the extremities or cooling the tissues. These changes again are brought about by a diminution of the vitality of the tissues from the suprarenin anemia associated with delay in absorption of the drug.

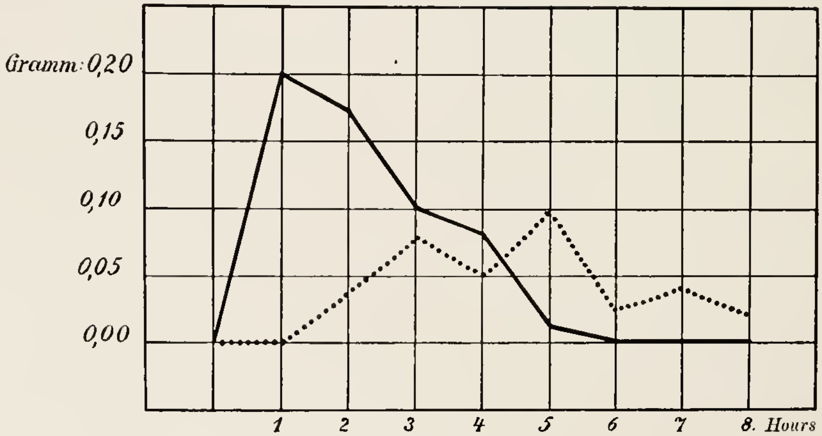


Fig. 7.—Elimination of sugar in the urine ——— without, ... with suprarenin. (Klapp.)

Klapp has graphically shown in the accompanying diagram the action of suprarenin even in very small doses upon the absorption from the tissues. He injected beneath the skin of the back of a dog 10 c.c. of a 6.5 per cent. solution of milk sugar, examining the urine hourly for evidences of sugar. Three days later the same quantity of this solution was injected with the addition of two drops of a 1 to 1000 adrenalin solution. The urine was examined in the same manner. In Fig. 7 the hours are indicated upon the horizontal line, whereas the vertical line indicates the quantity of sugar excreted in grams. The solid line shows the excretion before the addition of adrenalin. It will be noticed that the excretion of sugar begins immediately, reaching its maximum in about one hour, then falls slowly, stopping completely in about six hours. The entire quantity of sugar obtained in the urine was about 0.569 gram. The dotted line shows the result of the second experiment, where absorption was delayed by the addition of adrenalin. In the first hour no sugar was found in the urine, the excretion beginning only after two hours, reaching its maximum at the end of five hours, which was considerably less than in the first experiment. As long as eight hours after the injection sugar was found in the urine, the total quantity obtained being 0.343 gram.

From these experiments it can be readily seen that the local action of a substance is increased by the use of adrenalin. Owing to delayed parenchymatous absorption it was supposed that the simultaneous use of suprarenin and cocain would naturally diminish the toxic action of the latter drug. This is no doubt true, but the circumstances are of course different from those in the physical experiment. The use of cocain introduces two toxic substances into the body, and it can possibly happen that when both are absorbed the toxicity may be increased. This is, however, not the case. Moure and Brindel have observed in rhinolaryngological practice that the toxicity of cocain is markedly diminished by the use of suprarenin. It has also been demonstrated in suitable animal experiments that if the subcutaneous connective tissue be first injected with suprarenin and a definite time allowed to elapse for the maximum effect to take place, the toxic effect of cocain solutions injected into the anemic tissues was not only delayed but also diminished. These observations became more apparent in the experiments conducted by Doenitz, in which he compared the action of pure cocain solutions injected into the spinal canal of cats with that of cocain and suprarenin. On the contrary, Thiess has found that cocain and suprarenin when injected beneath the dura were more toxic than cocain alone.

The site for this last experiment is unfortunately chosen, as the spinal canal is not a suitable place for determining this question, inasmuch as the action of poisons in the canal is not only due to their absorption but also their direct action upon the central nervous system. Recently Sikemeyer in his experiments found that the central toxic action of cocain was delayed but not diminished by suprarenin.

The fact that suprarenin delays the absorption of cocain solution which has been injected is indisputable. Likewise the fact that cocain introduced slowly into the circulation is less toxic than when rapidly absorbed. This shows that suprarenin has a direct effect upon the toxic action of cocain under suitable experimental conditions. The practical value of the addition of suprarenin to cocain solutions does not lie in the fact that larger doses of cocain can be used, but that dilute solutions of the anesthetic substance can produce a more intense reaction of longer duration with the addition than without.

The value of suprarenin solution in local anesthesia is dependent alone upon its vasoconstrictor properties with the consequent anemia of the tissues. The remarkable increase of the local anesthetic power of a substance combined with suprarenin is similar in its action to the ligation of extremities. Esch has found that in animals in which the circulation has been interrupted the action of suprarenin causes a marked increase in the local action of cocain, alypin, and novocain, and he compares these results, which are in nowise dependent upon the anesthetic property of suprarenin, with the mordant used in dyeing.

Animal experimentation has demonstrated, just as we have observed before with cocain, that the toxic action of suprarenin when introduced intravenously into the unobstructed circulation is enormously increased over that introduced subcutaneously, as in the latter method absorption is hindered and a portion of the substance is not absorbed at all. According to Batelli, Taramasio, Bouchard, and Claude, 0.0001 to 0.0002 per kilo of suprarenin when introduced intravenously into rabbits or guinea-pigs causes death; whereas the fatal dose for subcutaneous injection is more variable, being between 0.002 and 0.02 per kilo, the fatal dose for guinea-pigs being 0.01 and for rabbits 0.02 per kilo. Batelli states that the intravenous injection of suprarenin is about forty times more toxic than that introduced subcutaneously. The reason for the lessened toxicity of this substance in subcutaneous injection is readily understood, if the delay of absorption due to the local action of this substance is taken into account.

Toxic symptoms following the injection of suprarenin in animals are evidenced by paralysis of the extremities with tonic and clonic convulsions, opisthotonus and mydriasis, frequent respiration, edema of the lungs, anemia of the viscera, and glycosuria. By means of repeated intravenous injections of small doses of suprarenin Josué, Loeper, Erb, and Kuelbs were able to produce in animals calcification of the aorta, coronary vessels and the heart.

The first experiments for the determination of the dosage to be injected subcutaneously were made by the author in 1902. He injected under the skin of the forearm 1 to 1000 solution of suprarenin in increasing doses. After the injection of 0.5 mg. (= 0.5 c.c.) general symptoms occurred. Five minutes after the injection he experienced a sense of oppression in the chest. It became necessary to breathe more rapidly and deeply. Palpitation followed, the pulse increasing from 64 to 94 per minute. At this point it was necessary to lie down. The symptoms disappeared completely in one and a half minutes; glycosuria did not occur. When the solution of adrenalin was diluted ten times with salt solution, 1 mg. could be injected without noting any symptoms. Doenitz made similar observations upon himself, being able to inject 1.5 mg. of adrenalin in 1 to 1000 solution. Thiess injected into two persons with healthy circulatory systems 1 mg. of adrenalin in a 1 to 2000 solution, in another case 0.2 mg. in a 1 to 10,000 solution and noted that the blood-pressure was increased 15 to 45 mm. of mercury. This occurred a few minutes after the injection and lasted three to eight minutes. No other general symptoms were observed. The experiences of recent years have proved that the dose of suprarenin when used for local anesthesia is of apparently no consequence. Inasmuch as the dose is so small and is injected in such dilute solution (1 to 100,000 to 1 to 200,000), general symptoms from this substance could not be expected. Physicians use suprarenin in combating symptoms of collapse in infectious diseases. The quantity used subcutaneously is as follows: Liebermeister and Kauer give 1 to 6 mg. daily; Kraus 6 mg. daily, in divided doses of 0.5 to 1 mg. Eckert gives 2 to 3 mg. every three or four hours. Kirchheim from his experiments claims that suprarenin is a perfectly harmless drug if given 1 mg. hourly or every four hours. In severe collapse 2 or 3 mg. at one dose; 24 mg. have been given in twenty-four hours—60 to 400 mg. of suprarenin in a 1 to 1000 solution being given in all. The quantity used in dilute solutions for local anesthesia must necessarily be harmless, and only clean, active preparations of the fresh solution should be used.

An unknown writer reported in the "Zentralblatt für Gynäkologie" under the title "Warnung vor Adrenalin," that in 1908 he experienced two sudden deaths from syncope in women just before the beginning of chloroform anesthesia. The injection of 0.0003 adrenalin in a 1 to 10,000 solution into the portio vaginalis was for the purpose of preventing hemorrhage. These cases were critically investigated by Fisch, Neu, Freund, and the author. They were declared to be typical chloroform deaths.

The concentration of suprarenin in anesthetic solutions is of much importance, as the intensity of the local action of suprarenin and the duration of the anemia of the tissues is dependent upon its concentration. Suprarenin is not a positive hemostatic. For this reason the concentration of suprarenin solutions should never be sufficient to cause a complete cessation of bleeding, such as occurs with the use of the Esmarch bandage. The medium-sized arteries must be permitted to bleed so that they can be ligated, and hemostasis even of the smallest bleeding-point must be secured by ligature, tampon, or a compression bandage, so that all possibility of secondary hemorrhage can be avoided. The care of wounds following this injection must be similar to that following use of the Esmarch band. If the action of suprarenin be too intense or long continued, gangrene of the tissues can occur, particularly if the nutrition of the part is already interfered with, as, for instance, in arteriosclerosis of the extremities, wounds, or plastic flaps. Siebert has collected cases of this kind. It should be the rule not to inject into tissues in which the vitality is already reduced, inasmuch as they recover very slowly, if at all, from the effect of this agent. In plastic flaps it is important to remember that no anesthetic should be injected into the flap or near the vessels supplying its pedicle.

With the observance of these rules and those to be mentioned in the later chapters of this book in reference to the special directions regarding the dosage and use of novocain-suprarenin solutions, no serious consequences need be feared. The limits of usefulness of local anesthesia have been materially increased since the introduction of suprarenin. Its results are more certain, the technique in many instances has been simplified, and danger from certain operations has been markedly reduced.

CHAPTER IX.

THE VARIOUS METHODS OF USING LOCAL ANESTHETIC DRUGS.

ANESTHESIA OF SUPERFICIAL SURFACES, AS MUCOUS, SEROUS AND SYNOVIAL MEMBRANES, AND WOUNDS.

The first practical use of cocain anesthesia as made by Köller consisted in the instillation of cocain solutions into the eye for the purpose of making the conjunctiva insensitive. Success in this instance led to the immediate application of eocain solutions for similar purposes to other mucous membranes. The mucosa of the bladder which, as is well known, is impenetrable to some substanees, can be anesthetized. The anesthesia is not dependent upon the power of absorption of this membrane, which usually plays a passive role, but upon the fact that small quantities of the anesthetic solution when placed upon its surface diffuse through the epithelium and in this way come in contact with the nerve endings in the submucous layers. The anesthesia, as a rule, does not extend beyond the submucosa. The application of cocain solutions is made by painting the surface, by means of cotton tampons saturated with the solution, by using fine sprays, by instillations into the eye, and by injections into the urethra and bladder.

The necessary concentration for suitable anesthesia depends upon the manner in which the solution can be applied to the mucous membrane. If the parts are anesthetized by painting, the application of tampons, or by means of the spray, very concentrated solutions (10 to 20 per eent.) will be necessary if it is expected to obtain a rapid anesthesia and one of sufficient duration. Instillations into the eye and injections into the urethra can be made with much weaker solutions, as the contact between the mucous membrane and the anesthetie is much more prolonged.

Anesthesia of the bladder can be made just as satisfactorily with weak solutions as with the more concentrated, if the former are allowed to remain in contact with the surface for a sufficient length of time.

Attention has already been directed to the fact that, to avoid eocain poisoning, no definite rules for dosage can be laid down, but the extent of surfaee and power of absorption of certain areas must be taken into consideration in determining the concentration of the solution to be used. Concentrated solutions should never be applied to large mucous surfaces; their use should be limited to circumscribed areas.

The use of suprarenin is of much value in anesthesia of the mucous membranes. It is possible with this addition to use highly concentrated cocain solutions in laryngology, rhinology, and urology without secondary effects hitherto impossible. Swain, and later Burkofzer, who were the first to introduce this agent in the practice of laryngology, directed attention to this valuable property of suprarenin, which they termed "Kokainsparer." According to Moure and Brindel a 3.5 per cent. cocain solution with the addition of suprarenin is sufficient for anesthesia of the larynx and nasal mucous membrane. Burkofzer and Rode stated that a 5 per cent. solution with the addition of suprarenin should be used. However, with either of these solutions an anesthesia of such intensity and duration will be obtained as has never previously been known. The substitution of other substances for cocain are discussed on pages 126 to 128. Regarding the chilling of mucous membranes as an aid to local anesthesia and the use of the ethyl chloride solutions containing basic cocain, see pages 96 and 131.

The local action of cocain when applied to other permeable membranes is similar to its action on mucous membranes. The peritoneum, the peritoneal covering of hernial sacs, and the tunica vaginalis can be made insensitive; the first by applying anesthetic solutions to the surface after opening the abdomen (Schleich recommends tropacocain in substance for this purpose). The latter can be anesthetized by injecting a quantity of the anesthetic solution into the scrotal sac. The use of cocain for this purpose is not necessary and should be avoided. If the scrotal sac is filled with a 0.5 to 1 per cent. novocain-suprarenin solution, the tunica will rapidly become insensitive.

Joint cavities can readily be made insensitive by injecting into them anesthetic solutions (Reclus, Lorenz, and von Hacker). This can be practically applied in the aspiration and washing of joint cavities in hydrarthrosis for the injection of iodine and iodoform in tuberculosis of the joints. Lorenz was able to forcibly correct a flat foot after injecting an anesthetic solution into the tarso-crural joint. We will later study anesthesia of the synovial membranes by injection into the joints as a means of making them insensitive for operation. Conway and Quénu have shown how readily a dislocated joint can be reduced following the intra-articular injection of anesthetic solutions.

Fresh, granulating wound surfaces and freely exposed nerve trunks can be anesthetized by the superficial application of an anesthetic agent. In the first case orthoform or some of the newer preparations—anesthesin, zycloform, or propäsin—can be used.

2. ELECTRIC CATAPHORESIS AS AN AID TO LOCAL ANESTHESIA.

The unbroken human skin is impenetrable to most substances in watery solutions. Drugs dissolved in alcohol, ether, or chloroform have slightly better powers of penetration (Parisot). Munk observed that drugs could be introduced into the system by means of the galvanic current. The positive electrode, saturated with a strychnin solution, applied to a rabbit causes death from strychnin poisoning in about five minutes. Potassium iodide and quinine have been introduced in man by this means. This method, known for some time under the name of cataphoresis, was tried in local anesthesia by Wagner and Herzog. Wagner placed the anode saturated with a cocain solution upon the skin and found that the latter became insensitive in a few minutes, the intensity of this action depending upon the concentration of the cocain solution and the strength of the current, which was always in inverse proportion to the diameter of the electrode.

With an electrode 2.5 cm. in diameter, a 5 per cent. cocain solution and a current of 5 ma., it required four to five minutes before the skin became anesthetic. By interrupting the circulation in an extremity, the duration of the anesthesia could be materially prolonged. Similar results were obtained by Herzog, Corning, and Peterson. This anesthesia was limited to the cutis and did not affect the deeper lying parts such as nerve trunks (Herzog). Corning was able to produce a deeper anesthesia by first abrading the skin with an instrument. Electrodes devised by Adamkiewicz, Stinzing, and Peterson are particularly suitable for cataphoresis and the testing of the anesthetic solutions. The electrode devised by Adamkiewicz is faulty or, as Peterson has stated, "constructed with inexcusable stupidity," inasmuch as the electric current does not pass through the fluid. The author conducted a number of experiments with cocain-suprarenin solutions but has not been able to determine that the method was of sufficient value to warrant its more extensive use. He has also attempted to produce a deeper anesthesia by means of the galvanic current applied to solutions of cocain injected subcutaneously. It can, therefore, be said that the practical application of cocain cataphoresis is of very little value. Corning and Peterson used this method in cases of hyperesthesia and neuralgia; Harris used it for ignipuncture. More recent investigations by Peterson have shown that minor operations can be carried out without pain by the use of a 10 to 20 per cent. cocain solution applied with the anode. Cataphoric applications of cocain solutions and cocain-guaiacol solutions have been used for some time in dentistry for the purpose of making dentine and extraction painless. The results of this procedure, notwithstanding the praise given it by many operators, have not been very brilliant (see monograph of Dorn). More recently Albrecht has used cocain cataphoresis with apparent success for anesthesia of the ear-drum.

3. INFILTRATION ANESTHESIA.

Infiltration anesthesia is a form of terminal anesthesia brought about by saturating the tissues with anesthetic solutions. By the use of suitable drugs the nerve elements lying in the infiltrated tissues become functionless. If the injected solutions contain large quantities of the anesthetic, the anesthesia is diffused for some distance beyond the infiltrated area. This secondary anesthesia is known as indirect infiltration anesthesia (see page 73). The action of the anesthetic is always due to its contact with the sensory nerve elements. The term "infiltration anesthesia" originated with Schleich; the method, however, as described by him differed from the older methods only in the use of more dilute cocain solutions.

Solutions of cocain were used originally almost entirely for infiltration anesthesia in connection with the so-called indirect infiltration anesthesia. Various "depots" of concentrated cocain solutions were injected into the tissues and by means of the Esmarch bandage the entire field of operation was made anesthetic. It has been previously mentioned on page 76, shortly after the introduction of cocain, that for cutting the tissues many surgeons held that it was necessary to completely infiltrate the tissues with cocain solutions if a reliable result was to be obtained. Roberts, in 1885, and later Reclus and Schleich, used infiltration of the skin in the form of a series of skin wheals in the entire proposed line of incision. The advancement in technical detail of infiltration anesthesia is due to Reclus and Schleich; their methods, at least in principle, cannot be separated from one another. The technique of Reclus and his pupils, Auber, Fillion, Legrand, Kendirdjy, and Piquand, have been known since their numerous experiments in 1889. This technique, in short, consisted in making injections into the skin with cocain solutions throughout the entire extent of the incision, and infiltrating in a similar manner all tissue layers to be cut. Reclus in 1893 used a 1 per cent. cocain solution for injection, later reducing this to 0.5 per cent. He did not depend upon the diffusion of the cocain solution, relying only upon direct infiltration. Reclus, from the very beginning of his method, did not confine its use to minor surgery but recommended it for various major operations, such as herniotomies, resection of the ribs, and many others.

According to his experience in more than 7000 cases the method was apparently without danger, provided the rules already mentioned on page 93 were observed, a dose of 0.2 not being feared. Ceci, who used a 0.5 per cent. cocain solution for infiltrating the skin, found anemia of the brain and psychical excitation in only 1 case out of 4054, no other symptoms of cocain poisoning were observed. For these reasons we cannot agree with the statement of Schleich that the danger from cocain anesthesia, used according to rule, is greater than that of chloroform anesthesia.

The infiltration method of Reclus was later introduced into Germany but not used to any great extent owing to the fact that for extensive operations comparatively large doses of cocain were necessary, and because Schleich had shown that more extensive anesthesia of the tissues could be obtained than heretofore by the use of very dilute solutions. It requires but little thought to separate this simple and important fact, to which we are indebted to Schleich, from numerous hypothetical embellishments suggested by this author. Schleich, about 1891, reported 224 operations, including herniotomies and laparotomies, performed with a 0.2 per cent. cocain solution in combination with the ether spray, a dosage of 0.04 cocain not being exceeded. He claimed that the cooling of the skin was only of importance in preventing pain from the insertion of the needle. We now know that cooling by means of the ether spray produces a marked increase in the action of cocain. In the monograph by Schleich, which appeared in 1894, the use of ether or ethyl chloride sprays was considered an essential part of infiltration anesthesia.

Schleich used 3 different cocain solutions for infiltrating the tissues:

No. 1	
Cocain muri.	0.2
Natri chlorati	0.2
Morphini muriat	0.02
Aquæ dest.	100 0
No. 2	
Cocain mur.	0.1
Natri chlorati	0.2
Morphini muriat	0.02
Aquæ dest.	100.0
No. 3	
Cocain mur.	0.01
Natri chlorati	0 2
Morphini muriat	0 005
Aquæ dest.	100.0

The No. 2 solution, containing 0.1 of cocain, was the one most frequently used (95 per cent. of all cases). Solution No. 1 was used for anesthetizing inflamed hyperemic tissues. Solution No. 3, containing 0.01 of cocain, was only used when the maximum dose had already been given with the other solutions, also for the infiltration of less sensitive nerves and tissues. According to Schleich it was very rarely necessary to use a 0.5 per cent cocain solution for infiltration of hyperesthetic areas. The above-mentioned solutions were prepared by Schleich from the following observations. He found in testing skin wheals that water with the addition of 0.2 per cent. salt caused anesthesia in the infiltrated tissues, whereas a 0.75 per cent. salt solution left sensation intact. He also observed that the action of very weak cocain solutions was much more complete when this agent was dissolved in water or in a 0.2 per cent.

salt solution than when physiological salt solution was used as a solvent. Because pure water produced a severe irritation upon injection he added 0.2 per cent. of salt to his solutions. In regard to the solutions which Schleich has termed "indifferent solutions," he has drawn the following conclusions: "Anesthesia is spread by means of the solution, it being a purely physical process, the chemical factors only coming in for consideration in relieving the pain of injection. Watery solutions above all others produce the best anesthesia."

Artificial edema itself acts as an anesthetic by causing pressure on the nerve substance, anemia of the tissues, and a difference in temperature between the body and the solution. (Schleich recommended the use of cold cocain solutions for injection.) In this connection Schleich himself observed that the infiltration of the tissues with physiological salt solution did not alter sensation. Heinze and the author have infiltrated the tissues to the point of distention with an indifferent isosmotic 0.9 per cent. salt solution, warm or cold, never obtaining a diminution of sensation but frequently a hyperesthesia. It can therefore be said that the artificial edema of the tissues not only does not produce anesthesia, but usually increases the excitability of the nerves. The forcible injection in a circumscribed area of about 0° degree solution can produce a local anesthetic effect by causing a local anemia and a diminution in the vitality of the tissues. This has already been referred to in Chapter VIII, in which the increased action of anesthetic solutions injected as just described was fully discussed. It appears very doubtful to the author's mind whether this method is of any great value; at any rate the action of the injections upon the tissues is not a physical one. The only physical effect to be noted in connection with the injection of Schleich's solution is a diminished sensation due to tissue swelling, the solution causing a certain degree of tumefaction anesthesia (see page 60). The intensity of the anesthesia depends upon the freezing-point of the solution. The freezing-point of solution No. 1 is −0.156°, No. 2 is −0.145°, and the third solution is similar to a 0.2 per cent. salt solution being −0.13°. In Fig. 4, page 59, the solutions are placed in their relative position on the curve. The injection of 0.2 per cent. salt solution into the cutis not only produces paresthesia, as suggested by Schleich, but the severe pain of tumefaction. This can be avoided by the addition of 0.04 per cent. of cocain, but not by solution No. 3, containing 0.01 per cent. of cocain.

These secondary effects must be less when using solutions Nos. 1 and 2, as their freezing-point, in consequence of the addition of cocain and morphin, are quite different from that of pure water. In contrast to the marked anesthetic power of a 0.1 per cent. and 0.2 per cent. cocain solution, the physical secondary effects are of the smallest practical importance, and it would be a most uncertain state of affairs if we were to attribute the anesthesia of the Schleich solution to its physical effects, and the Reclus infiltration anesthesia to the effect of cocain. All these solutions produce anesthesia owing to their cocain content, and the author has been able to determine experimentally that there is no difference in the anesthetic power of cocain, even as dilute as 0.02 per cent., whether dissolved in a 0.2 per cent. or in a 0.8 per cent. salt solution. Heinze and Legrand have not been able to determine the slightest difference in the anesthetic property of a No. 2 Schleich in a watery solution or 0.8 per cent. salt solution. The cocain anesthesia is so marked in the experiments as to interfere with the observance of any perceptible tumefaction anesthesia, and it is only when solutions of cocain are very dilute that it can be noticed. In watery cocain solutions of 0.01 per cent., cocain anesthesia cannot be noticed, the solution acting as a pronounced irritant and showing anesthetic properties similar to that of pure water. Solutions of 0.01 per cent. cocain in 0.8 per cent. salt solution produce a slight cocain anesthesia of short duration without irritation; solutions of 0.01 per cent. cocain in 0.2 per cent. salt solution or Schleich solution No. 3 show a slightly more intense anesthetic action. In the latter we see a combination of cocain and tumefaction anesthesia. The injection is painful and the cocain anesthesia cannot prevent the pain of tumefaction.

Schleich's physical hypothesis is dependent upon this practical but unimportant difference which can only be determined by the most experienced observer. Because watery solutions have a freezing-point similar to 0.2 per cent. salt solution they will cause a destruction of red- and white-blood corpuscles, or their injection into the tissues may cause a tumefaction necrosis. For this reason it is advisable only to use injections which have been made indifferent by the addition of 0.8 to 0.9 per cent. salt. In this way the desired anesthesia can be obtained without the practically unimportant physical effects of the Schleich solution. The use of salt solution for injections into the tissues will therefore exclude the physical and limit the anesthesia to the specific action of cocain.

In 1898 the author clearly stated that the addition of morphine to the local anesthetic was not of the slightest value in Schleich's solution, which statement has been verified by Heinze, Custer, and Gradenwitz. The diminution of after-pains, which Schleich attributes to the addition of morphin, can only be of central origin and are not due to any local effect of this substance. For this reason it is better to inject the morphin, if it is considered necessary, in another part of the body rather than immediately into the operative field; or it may be administered before operation, as has been recommended by many surgeons, so as to increase the duration and intensity of the local anesthetic or diminish the after-pains.

The use of 0.01 to 0.1 per cent. cocaine in 0.8 per cent. salt solution, the object of the latter being to prevent swelling of the tissues, acts in exactly the same manner as the Schleich solution with morphin. Hackenbruch, Gottstein, Legrand and others have recommended mixtures of eucain and cocain for the purpose of utilizing the less toxic effect of eucain and at the same time retaining the effect of cocain in contraction of the bloodvessels. Schleich also used mixtures of cocain and alypin. In reference to the other substitutes for cocain up to the time of the introduction of novocain, see the previous chapter.

The saturation of the tissues with anesthetic solutions is carried out in layers, according to the recommendation of Reclus and Schleich, and is made from without. The anesthesia is begun by the injection of successive wheals throughout the entire length of the proposed incision (see Chapter X), then just before cutting the skin the subcutaneous connective tissue is injected in the same direction. When using a 0.5 to 1 per cent. cocain solution, it should be given as sparingly as possible. When using the Schleich solution, the anesthetic zone is injected from two wheals at the ends of the proposed incision, and the subcutaneous connective tissue so saturated that the field of operation is raised above the surrounding surface of the skin in the shape of a huge boil. The skin and subcutaneous connective tissue can now be cut without pain. In some cases Schleich infiltrates for some distance beyond the subcutaneous connective tissue before beginning the operation. After infiltrating the subcutaneous connective tissue according to the method of Schleich the parts become edematous and the injected fluid flows in part from the cut surface. After incising the tissues, as above mentioned, the other layers are successively injected before cutting, using small quantities of 0.5 to 1 per cent. cocain solution or larger quantities of the dilute Schleich solution. Nerve trunks crossing the field of operation, particularly when using the Schleich solution, must be anesthetized in a manner which will be described later. The periosteum, according to Schleich, becomes rapidly insensitive if the subperiosteal tissue be infiltrated with dilute cocain or eucain solutions and can then be cut or separated from the bone. Periosteal injections are often difficult, sometimes impossible.

Bone can be cut without pain if the subperiosteal infiltration has been carefully performed and made sufficiently extensive. This only applies to bones with sensory nerve trunks, like the upper and lower jaw, as these nerves retain their sensation following the use of the Schleich solution. Direct mechanical infiltration of bone is impossible. Dzierzawsky has demonstrated that colored solutions injected beneath the periosteum penetrate the bone. This is certainly not due to mechanical infiltration but rather to a process of diffusion. To produce anesthesia of the nerve elements in th ebone it is necessary to use highly concentrated cocain solutions for injection beneath the periosteum. Dilute cocain solutions cause just as little effect in their distal action on bone as dilute color solutions. Mucous membranes are rendered insensitive by infiltration of the submucous connective tissue. In order to remove a tumor from the submucous tissues all of the surrounding tissue bordering the tumor must be made insensitive, or, as Reclus states, it must be surrounded by an atmosphere of cocain. According to Schleich, the skin over the entire extent of the proposed incision, be it straight, curved, or oval, must be infiltrated on all sides of the tumor with curved needles, so that the neighboring tissues become filled with dilute cocain solutions. Schleich anesthetizes the parts for opening an abscess or furuncle by first infiltrating the tissues, such as subcutaneous connective tissue, fascia, and muscle which are not inflamed but surround the inflammatory area, and last of all before incising the abscess the inflamed tissues themselves are infiltrated. The use of solutions very near the lowest border of activity of cocain has been advocated by surgeons universally for infiltration anesthesia and the way has been opened for the use of such solutions in abdominal operations.

These dilute solutions for infiltrating the tissues, according to Schleich, have their advantages and disadvantages. The advantage consists in the fact that much less cocain is used; the disadvantage being that the tissues are not rendered perfectly insensitive and the duration of the anesthesia is quite short, so that in operations of some length the skin becomes sensitive before their conclusion and must again be infiltrated.

The ability to anesthetize areas with very dilute solutions must be considered an advantage, but this infiltration, according to the method of Schleich, is not always possible and does not always produce complete anesthesia in the field of operation, many of the sensory tracts retaining their sensation. If the skin and subcutaneous connective tissue are cut immediately after infiltration with a 0.1 per cent. cocain or eucain solution, even though the tissues are swollen and edematous, the parts are not always completely anesthetic. Closer investigation will show that the nerves accompanying the bloodvessels in the thicker layers of the tissue remain painful to cutting, pressing, pulling, or grasping with instruments. This pain is described as slight by some patients, whereas others complain very bitterly. It is a mistake to draw conclusions from experiments on the skin, as other tissues, such as subcutaneous connective tissue, do not possess sensation but serve merely the purpose of transmitting the sensory nerve trunks. It is impossible to infiltrate all the tissues equally, as can be noted in the skin by injections into the subcutaneous connective tissue. The injected fluid follows the course of least resistance, filling the spaces between the tissues and penetrating the connective tissue containing bloodvessels and nerves just as little as it does the fascia and skin. It is only under pathological conditions of inflammation and chronic infiltration, where the skin and subcutaneous connective tissue assume a more or less similar consistency, that these parts can be infiltrated by injections into the subcutaneous connective tissue. After cutting the tissues the painful points can be touched with a 5 per cent. carbolic acid solution (Schleich), or again infiltrated with the anesthetic solution, but this, of course, should only be done if the patient has given expression of pain. The larger nerve trunks in the operative field, the position of which is determined from our anatomical knowledge, must be sought and properly treated. The muscles act similarly to the subcutaneous connective tissue, for which reason an even saturation with fluid is impossible. The solution is forced between the muscle fibers but does not penetrate the thick connective-tissue septa containing the bloodvessels and nerves. The cutting of muscles immediately after infiltration with very dilute cocain solutions is frequently painful. Von Friedländer, who has always expressed much enthusiasm for the infiltration of Schleich, stated that it was never possible for him to make an entire muscle insensitive.

The action of anesthetic solutions on nerve trunks passing through tissues which have been infiltrated can be explained by the writer's experiments upon the fingers. If the subcutaneous tissues at the base of a finger are infiltrated circularly, the sensory nerves will lose their conductivity as soon as the entire finger becomes insensitive. If this does not occur, the infiltrated subcutaneous connective tissue has not been made insensitive. It has been shown that the action of a 0.1 to 0.2 per cent. cocain solution is so slight that larger nerve trunks frequently are not made insensitive. It also requires considerable time before a nerve trunk passing through infiltrated tissues becomes insensitive. These conditions can be changed by increasing the concentration of the anesthetic solutions or by the use of a ligature around the extremity. The addition of suprarenin or chilling the parts renders anesthetic action much more rapid and interrupts the sensory tracts with much more certainty. The conductivity of nerves is never immediately interrupted, even with the use of 0.5 to 1 per cent. cocain solutions, with the addition of suprarenin or ligation of the extremity; so if the skin of the finger and its subcutaneous connective tissue have been infiltrated with 0.1 per cent. cocain solution the sensation of the subcutaneous connective tissue will be retained. For these reasons the old belief that the Schleich solution containing 0.01 per cent. of cocain was supposed to be useful for infiltrating tissues containing nerve tracts, is highly problematical. Tissues which become anesthetic following injections with these dilute solutions in all probability would not have required infiltration at all. In parts of the body which contain only the sensory nerve endings and no nerve trunks as, for instance, in the median line of the abdomen and neck, the dilute solutions of Schleich are very satisfactory, but if the tissues injected contain larger nerve trunks, it is a very uncertain and difficult procedure to hunt for each one of these nerves and inject them separately. Nevertheless, this is necessary for producing anesthesia in these areas.

These disadvantages may be partially overcome by the observance of certain rules, the first and most important of which is to wait after infiltration until anesthesia occurs. It is a mistake to attempt to cut tissues immediately after infiltration, as all tissues do not become immediately anesthetic, as we have observed. No matter where one injects, the action of the anesthetic requires time, and its maximum efficiency will only be attained after many minutes have passed. This circumstance as to time was not considered by either Reclus or Schleich in their technique. If the tissue layers are successively infiltrated, first infiltrating and then cutting, it is necessarily impossible to wait the requisite time for the action of the anesthetic; therefore, it is desirable to methodically infiltrate the tissue layers before beginning the operation, starting with the deepest and finishing with the most superficial layer, so that further injections during the operation will be rendered unnecessary (see Chapter IX). If this rule is followed, it will be seen that a separate infiltration, as for instance in the skin and periosteum, will never be necessary. It is also much better in most cases not to infiltrate the line of incision itself but the area surrounding the operative field which contains the nerves innervating the parts to be cut. The second rule is to use such substances as will cause a delay in the parenchymatous absorption of the local anesthesia. This is a preliminary measure which is very necessary for the success of the technique to be described, and is not only intended for small incisions but also for extensive operations requiring that infiltration be thoroughly reliable.

CONDUCTION ANESTHESIA.

The ability of cocain to interrupt the sensory and motor nerve trunks was demonstrated by Torsellini, Feinberg, Alms, Kochs, Witzel, Mosso, and Frank. The first observations of this kind made on man originated with Corning and Goldscheider, but were only of theoretical interest. After ligating the upper arm Corning injected into the trunk of the nervus cutaneus antebrachii lateralis 0.3 c.c. of a 4 per cent. cocain solution and immediately noticed anesthesia of the skin supplied by this nerve as far as the wrist. Goldscheider, without interrupting the circulation, was able to obtain anesthesia in the area of distribution of a nerve following the subcutaneous injection of strong solutions of cocain.

Anesthetic solutions can be used in various ways for anesthetizing nerve trunks. The injection can be made immediately beneath the fibrous sheath directly into the nerve trunk (endoneural injection). If the injected solution is not too weak, almost immediate interruption of conductivity occurs (Crile). This procedure is only possible when the nerve trunk has been freely exposed before operation. Very few nerve trunks are so situated and so palpable that they can be reached exactly with the needle through the unbroken skin. As a rule, it is only possible to inject the solutions in the neighborhood of the nerve trunks (perineural injections). The interruption of conduction by this procedure requires some little time, inasmuch as the nerve trunk is reached only by diffusion. Conduction anesthesia can also be produced by direct injections into the spinal canal, according to the method of Bier, or by injections into the epidural space of the sacrum, according to the method of Cathelin-Laewen. Intravenous and intra-arterial injections produce anesthesia not only by their action on the nerve ends but also on the nerve trunks.

Perineural Injections of Anesthetic Solutions.—The action of anesthetic solutions upon nerve trunks passing through tissues infiltrated with anesthetic solutions is indirect. The anesthetie must diffuse through the connective tissue layers surrounding the nerve trunks before the nerve substance is anesthetized. For these reasons it will be observed that sensory nerve tracts are much more readily and more quickly interrupted when the perineural injection is made in the area where the nerve branehes are very thin rather than in the neighborhood of the beginning of the nerve trunk. For instance, in the neighborhood of the spinal cord, where it will be found that much larger quantities of a more highly concentrated solution will be necessary for the interruption. This is due to the fact that the nerve trunk not only increases in thickness toward its proximal end but the thickness of its connective tissue covering is also increased. It will be noticed that the action of an anesthetie in the spinal canal is very prompt and pronounced, owing to the fact that the nerve trunks are not protected by this connective tissue covering. The interruption of nerve trunks by means of perineural injections is used very extensively for rendering their areas of distribution insensitive. Every infiltration of connective tissue layers containing nerve tracts produces not only infiltration anesthesia in the area injected, but also conduction anesthesia in the area of distribution of the nerves affected.

The simplest form of conduction anesthesia follows the injection of anesthetic solutions into the subcutaneous connective tissue. Inasmuch as the subcutaneous connective tissue contains the sensory nerve tracts for the overlying skin, this structure must of necessity be made insensitive, when the subcutaneous connective tissue is infiltrated with an anesthetic solution. It might be thought that the anesthesia of the skin is produced by diffusion of the injected anesthetic from the subcutaneous connective tissue, but this is probably not the case, as the small quantities of solution which would reach the skin in this way would make the parts less insensitive than a direct infiltration of the skin with the same solution. On the contrary, it will be noted that solutions injected into the subcutaneous connective tissues produce an anesthesia of the same intensity and duration as that following the intracutaneous infiltration of the same solution; in fact, this effect is produced beyond all doubt by interrupting the nerves supplying the skin. In like manner we speak of the innervation of the periosteum, which takes place not from the bone but from the tissues overlying it; therefore, if these tissues be infiltrated, both periosteum and bone will be made insensitive, and subperiosteal injections will be found as unnecessary as the direct infiltration of the skin.

Hackenbruch has described the so-called "circular analgesia," which consists in so circumscribing the operative field with the anesthetic solution that all nerve supply to this part will be interrupted. Hackenbruch used for this purpose 0.25 to 0.5 per cent. cocain and eucain solutions, but the addition of the newer aids to local anesthesia were necessary for progress with this procedure. Until the introduction of these substances his method of anesthesia was only applicable to the ligated extremities. Oberst used a similar method for anesthetizing the fingers and toes. If 0.5 to 1 per cent. cocain solution is injected beneath the skin of the base of the finger or toe which has been ligated, a complete transverse anesthesia of the entire finger or toe will follow in a few minutes. The infiltrated subcutaneous connective tissue of the finger contains many nerve tracts; the finer branches supplying the skin are rendered non-conductive; the larger branches supplying the other parts are affected by diffusion. The anesthesia proceeds in this way from the centre toward the periphery, the disappearance of sensation in the finger tip indicating that all nerve trunks in the subcutaneous connective tissue supplying the finger have been interrupted. In an operation upon a finger anesthetized in this manner, all nerve trunks are found insensitive. A transverse incision can be made in any segment of the finger without pain. This method was used in 1888 by Oberst, but was first described in 1890 by Pernice. It is possible that Kummer and others may have preceded these writers, but it was not until the author's reference to this subject in 1897, in connection with a similar report by Hackenbruch, that this method came into general use. The first practical application of the perineural injection of cocain for the purpose of blocking various nerve trunks at a distance from the operative field was performed by Hall and Halstedt. The first mentioned injected cocain into the infra-orbital nerve; the latter into the trunk of the inferior alveolar nerve for the purpose of extracting teeth without pain.

The ligation of an extremity is not absolutely essential for the anesthesia of nerve trunks, as has been shown in the reports of Krogius in 1894, but if this is not done, more highly concentrated cocain solutions will be necessary. In reference to this anesthesia Krogius reports as follows: If one injects beneath the skin of the dorsum or palmar surface of the hand or the foot transverse lines of a 2 per cent. cocain solution, the parts distal to this injection will become anesthetic, and if the four nerves supplying the fingers be anesthetized by the injection of 1 to 1.5 c.c. of a 2 per cent. cocaine solution, the fingers will become totally anesthetic in about ten minutes. It is possible to produce an analgesia of the ulnar side of the hand as far as the base of the fourth or fifth finger by means of an injection over the ulnar nerve where it passes through the groove on the inner condyle of the humerus. If an injection is made in the neighborhood of the supraorbital foramina analgesia of the entire mid-portion of the forehead will occur. Injections around the base of the penis will render the foreskin entirely insensitive. This method is of little practical use for operations upon the arms or legs, and has not been of any value in operations in the gluteal region. This analgesia reaches its maximum intensity and extent after from five to ten minutes and continues for a quarter of an hour or longer. The effect of the cocain is much more satisfactory if an Esmarch band is placed above the area injected. The above statements express the experiments of Krogius. The fact is, however, the ligation is not necessary if 0.02 cocain in 1 to 2 per cent. solution be injected into a finger in the method described, anesthesia occurring in the course of a few minutes without interrupting the circulation; but the use of the various aids to local anesthesia permit of a diminution in the dose of cocain and the concentration of its solutions and should be recommended as making action more certain and prolonging the duration of the anesthesia. A 0.1 to 0.2 per cent. cocain solution injected circularly beneath the skin of the basal phalanx of a finger will cause a complete break in the conductivity of the nerves. It is, however, necessary to wait considerably longer for this to occur than after the use of more concentrated solutions.

The above-mentioned communications of the author have been the means of stimulating much experimental work along these lines by such men as Honigmann, Manz, Arendt, Sudeck, Berndt, Gerhardt, Hoelscher, and Luxenburger. They have used the method of Oberst for operations upon the fingers and toes and have attempted to increase the extent of the conduction anesthesia on the hand and foot by applying the methods already described by Krogius. Manz, after ligating the upper arm, injected a 0.5 to 1 per cent. cocain solution into the radial, ulnar, and median nerves of the forearm, and after ligating the leg, he injected the peroneal and tibial nerve just above the ankle. After twenty to forty-five minutes the hand and foot became absolutely insensitive so that operations of any kind could be carried out on the hand and foot without pain. Similar experiments upon the hand and forearm have been reported by Berndt, Hoelscher, and Luxenburger. Berndt also described an amputation, according to the method of Gritti, which was performed without pain. Gottstein reports a Pirogoff amputation carried out by this method. Arendt and Hoelscher used this same method for operations upon the penis. Berndt and Hoelscher held it to be more advisable to use larger quantities of dilute cocain and eucain solutions (0.2 per cent Hoelscher, 0.05 per cent. Berndt) than smaller quantities of a 1 per cent. solution, as recommended by Pernice.

Manz claimed not to have had good results with solutions more dilute than 0.5 per cent. Berndt, believing that the edema of the tissues produced by the injection of an indifferent solution would produce anesthesia, injected physiological salt solutions for this purpose. Luxenburger advised the injection of 2 per cent. nirvanin solutions for anesthesia of nerve trunks. Hoelscher believed that nerve conductivity between the proximal and central parts of an extremity could be best interrupted by infiltrating all the tissues transversely with dilute solutions of cocain. Practically all observers are of the opinion that considerable time is necessary for the interruption of conductivity of the larger nerve trunks of an extremity except the fingers and toes, and that the ligation of the extremity cannot be dispensed with, even though its application causes very considerable discomfort and pain to the patient during its use. It is only in very thin extremities that the pressure of the bandage necessary to interrupt the circulation is so slight as not to cause pain.

Just how much of the anesthetic effect upon an extremity so treated is to be ascribed to the medicament injected, and how much to the compression of the nerve trunks from the bandage, Manz is unable to say; whereas Kofmann claims that the ligation is the most important part and the injection of the anesthetic solution is entirely unnecessary. The anemia of the tissues produced by ligation (see Chapter III) affects sensation so late that it can hardly be considered an active factor of the anesthesia; whereas the ligation itself, if made sufficiently tight, can produce an interruption of the conductivity of the nerve trunks. It can therefore be said that in many of the reported cases in which anesthesia is supposed to have been produced by the injection of very dilute solutions of cocain, or even of normal salt solution following the injection of this substance it was necessary to wait considerable time before anesthesia occurred. Anesthesia in these cases was not due to the injection of cocain but rather to the prolonged ligation of the extremity.

In 1903 the writer reported some results of experiments for producing conduction anesthesia—in fact, introduced the term "conduction anesthesia" to physiology and other related sciences. These experiments demonstrated that by means of the injection of cocain, in connection with the ligation of an extremity or the addition of suprarenin, the ulnar, radial, median, tibial, and peroneal nerves could be readily interrupted at certain points and that suprarenin could replace ligation. Following the interruption of conductivity, sensory and motor paralysis occurred; in the mixed nerves of the extremity vasomotor paralysis followed, so that the innervated area became hyperemic just as after the cutting of the nerves. According to the experiments of Heidenhain, the sensory nerves are usually affected before the motor nerves and the effects are also more lasting, so the former can be considered much more sensitive to the anesthetic than the motor nerves. The long subcutaneous nerves of the skin can readily be interrupted if a transverse strip of subcutaneous connective tissue is infiltrated according to the method of Krogius. On account of the overlapping of the innervated areas of one nerve with another, it will be necessary to anesthetize several nerve trunks in order to produce a practical and useful peripheral conduction anesthesia. Owing to vasomotor paralysis it may also be necessary to ligate an extremity in case mixed nerves are interrupted near the base of the extremity. If suprarenin has been added to the solution, it will not be necessary, while waiting for anesthesia to occur, to apply the ligature until just before beginning the operation. Absorption can, however, be still more delayed by the application of the compression bandage.

The use of suprarenin renders conduction anesthesia just as certain in other parts of the body as in an extremity. We have already spoken of the interruption of the supraorbital and occipital nerves, the cervical nerves where they pass from beneath the posterior edge of the sternocleidomastoid muscles, and also the superior laryngeal nerves in operations on the larynx. Halstedt has already described the interruption of the inferior alveolar and lingual nerves. Another advancement followed the introduction of novocain, whereby indefinite quantities of a stronger-acting anesthetic could be introduced without danger. All methods of conduction anesthesia were improved by the introduction of this drug, such as infiltration of tissue layers containing conducting nerve tracts, the circuminjection of operative fields, the blocking of nerve trunks, and better methods of operating in the areas supplied by the trigeminus, in operations upon the neck, operations upon the thorax, and in hernia in which conduction anesthesia by means of perineural injections is most important. More recently Laewen has introduced the precutaneous anesthesia of the sciatic and femoral nerve, and Hirschel and Kulenkampff a similar method for anesthetizing the brachial plexus. More definite information can be gained from the special chapters devoted to this subject. In general, however, it can be said that large individual nerve trunks are easily and certainly blocked by injection if their position can be determined by bony landmarks. Much more experience is necessary if these nerves are situated in the midst of soft parts. In the latter case the radiating peripheral sensations of paresthesia following the touching of the nerve trunks with the needle is the most certain method of determining the proper location of the needle, so as not to be dependent upon the statements of the patients. Perthes constructed a needle covered with an insulating material through which he passed a faradic current; as soon as the needle touched a mixed nerve contractions in the muscles supplied were readily observed.

Endoneural Injections of Anesthetic Solutions.—This method was first described by the American surgeons, Crile, Matas and Cushing. It consisted in introducing a needle into the several nerves supplying the operative field and injecting a small quantity of an anesthetic solution under the fibrous sheath or between the bundle fibers, in this manner thoroughly saturating the nerve and causing it to swell. By the use of proper solutions the conductivity of the nerve was instantly interrupted just as though it had been cut with a knife. For the carrying out of this procedure it is necessary in most cases to freely expose the nerve trunk under local anesthesia at some distance from the field of operation. Crile carried out extensive experiments upon animals in reference to the action of cocain and eucain when injected into nerve trunks and found that these drugs did not differ markedly from one another in their action. He performed amputation of the leg five times with this method (the first operation occurring in 1887); the sciatic nerve was exposed in the gluteal fold and the femoral nerve in the inguinal fold, and cocain or eucain solutions were injected into the nerve trunks. The patients, after consenting to operation, were not permitted to know what was taking place so that the psychical effect of the amputation could be prevented. The interruption of the nerve trunks lasted twenty-five to thirty minutes. Matas, to whom credit for the terms *endoneural* and *perineural* belongs, carried out this same procedure in operations upon the foot and leg; the popliteal and saphenous nerves were exposed and infiltrated with a cocain solution, whereupon complete anesthesia was produced from the knee down. Matas was able to centrally anesthetize the forearm and hand by infiltrating the freely exposed ulnar, median, and radial nerves, injecting into each of them 0.25 to 0.5 c.c. of a 1 per cent. cocain solution. The upper arm was then ligated, after which the operation was carried out and the wound sewed and dressed. Sensation returned about ten to fifteen minutes after the removal of the constricting band. Anesthesia of the brachial plexus was also attempted by Crile. Under infiltration anesthesia with a 0.1 per cent. cocain solution he exposed the brachial plexus and the subclavian artery at the posterior end of the sternocleidomastoid muscle and injected 0.5 per cent. cocain solution into each nerve trunk, using just sufficient of this solution to cause a small swelling of the nerve. The artery was temporarily clamped and the arm disarticulated at the shoulder-joint. The operation was painless with the exception of the posterior and outer skin incision. In a similar manner Crile performed amputation in the middle of the upper arm. He also performed a disarticulation of the upper arm with removal of the scapula, some general anesthetic being necessary, as was to be expected. Crile directed attention to the fact that the ulnar nerve at the elbow could very readily be injected with an anesthetic solution without previously dissecting it free, the interruption of conductivity following almost immediately after the injection. The peroneal nerve can be frequently injected at the bend of the knee. The trunk of the trigeminus can likewise be injected at the base of the skull as well as the Gasserian ganglion.

The necessity for freely exposing nerve trunks, as practised by Crile and Matas, so complicates anesthetic methods that this will only be done when there are definite contra-indications to the use of a general anesthetic. Crile mentions as a particular advantage of this method of anesthesia that, with an interruption of the conductivity of nerves from the field of operation, shock does not occur. Cushing and other American surgeons recommend the injection of the large nerve trunks before cutting them, even when an operation is carried out under general anesthesia, as, for instance, in disarticulations of the shoulder. The injection of anesthetic solutions into freely exposed nerve trunks is a sure and harmless method of anesthesia and will occasionally be found of use. This method would be very much simplified if it were possible to inject the nerve trunks exposed through the same incision as used for the operation itself. This method was made use of by Cushing in the operative treatment of inguinal hernia. By means of Schleich's infiltration anesthesia he freely exposed the inguinal canal and injected the ilioinguinal and spermatic nerves which lie under the fascia with a 1 per cent. cocain solution. As the result of this injection the hernial sac and its coverings, the spermatic cord, the testes, and a portion of the skin of the inguinal region became insensitive.

Lumbar and Sacral Anesthesia.—If an anesthetic solution be injected beneath the dura of the lumbar region by means of the lumbar puncture described by Quincke, the solution mixes with the cerebrospinal fluid and interrupts the conductivity of the nerve trunks of the cauda equina and the roots of the spinal nerves (Corning and Bier).

If by means of the sacral puncture described by Cathelin an anesthetic solution is injected into the epidural space of the spinal canal the anesthetic will act on the spinal nerves surrounded by the dura, passing from this point to the intervertebral foramina, causing their interruption (Laewen).

Both lumbar and sacral anesthesia, as will be readily seen, are forms of conduction anesthesia. Their technique and indications do not conflict with those of local anesthesia, as they have developed into particular anesthetic methods which in a narrower sense are opposed to local anesthesia, for which reason we will only mention these methods without entering into further detail.

VEIN ANESTHESIA.

In 1908 Bier devised a very effective method for bringing anesthetic solutions in contact with nerve substance. He injected a solution of novocain into one of the subcutaneous veins, freely exposed between two constricting rubber bandages, the space between which had been previously rendered bloodless. Experimental investigation had shown that the vein walls were particularly permeable to watery solutions. The injected solution permeated the entire section of the limb very quickly, producing between the two bandages a terminal anesthesia. This Bier called "direct vein anesthesia." The solution permeates this area, also those nerves passing to other parts of the limb, blocking them and giving rise to indirect vein anesthesia in the entire portion of the limb distal to the ligatures. The technique of vein anesthesia has been described in detail by both Bier and Haertel, and is as follows: The entire extremity is sterilized, elevated, and made bloodless by a rubber band carried from the toes or fingers to above the place where the injection is to be made. Immediately above this bandage a second rubber band is passed about the extremity. The first bandage is then removed for a distance of about a handbreadth and not more than three handbreadths from the upper bandage. At this point the second compression bandage is placed (Fig. 8). For peripheral portions of a limb direct anesthesia can be carried out with one constricting band which, however, should not be placed higher than the middle of the forearm or leg. Operations on infected tissues

Fig. 8.—Ligation for vein anesthesia.

should only be carried out by indirect vein anesthesia. For this purpose a compression band is placed above the infected area, and at this point the bandage for producing the anemia begins. The second compression bandage is then placed above the latter. Just under the upper constricting band one of the larger subcutaneous veins, such as the cephalic, basilic, median, or great saphenous, is freely exposed under infiltration anesthesia. In order to render the location of the veins certain it is advisable, before applying the bandage for producing the anemia, to mark the course and position of the vein, or expose the vein before applying the bandage. The author advises the latter method, so that the patient will not be allowed to suffer from the compression bandage remaining unnecessarily long upon the limb.

The syringe recommended by Bier (Fig. 9) is of 100 c.c. capacity, connected with a canula by means of a thick-walled rubber tube. The canula is provided with a cock so that it may be closed, and has two furrows at its end for the purpose of tying it into the vein. The canula is tied into the vein in the same manner as for salt infusions, except that it is tied into the peripheral and not the central end of the vein. Injections are made under even pressure, or, as occasionally happens, very strong pressure, until the vein valves are overcome, 0.5 per cent. novocain solution without suprarenin; 40 to 50 c.c. for the upper extremity and 70 to 100 c.c. for the lower extremity, depending upon the thickness of the limb. If during the injection some of the smaller branches are seen to spirt they must be immediately closed with hemostatic forceps. After completing the injection the canula is closed by means of the cock and the vein is ligated and cut, the small wound being closed by suture. Complete anesthesia will occur throughout the entire transverse section of the limb in about five minutes; indirect anesthesia as well as complete motor paralysis in the peripheral part of the limb follows in about five to fifteen minutes. At this time the peripheral constricting band can be removed in case it interferes with the performance of the operation.

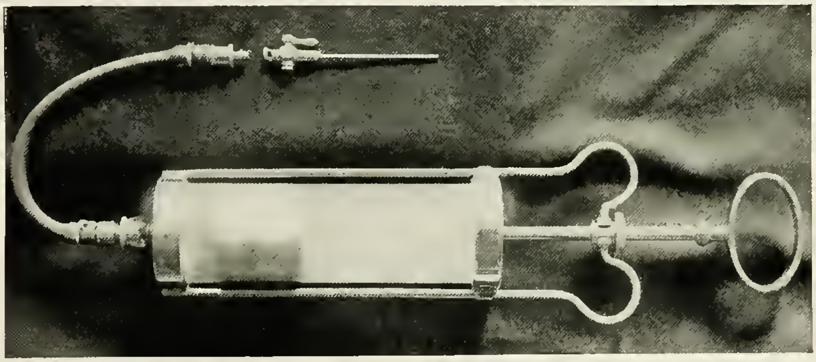


Fig. 9.—Syringe for vein anesthesia.

The anesthesia lasts as long as the upper constricting band is kept in place. As soon as it is removed, sensation returns in a few minutes. According to the observation of Bier, the addition of suprarenin to the novocain solution does not prolong vein anesthesia very materially, but it frequently prevents an even distribution of the injected solution throughout the transverse area, for which reason it should not be used.

Vein anesthesia should be used in suitable cases and is without danger. Poisoning from novocain need not be feared following its use. The cases most suitable for vein anesthesia are resection of joints and amputations from about the middle of the thigh or upper arm downward. This method should not be used when operating for diabetic gangrene (Bier). It is also a question whether this method should be used in septic infections, as it is possible to open a vein which is infected, even if some distance from the diseased area.

The upper constricting bandage causes severe pain after a short time. Perthes has devised a compressor which has relieved this somewhat. Momburg advises after anesthesia has set in that a second compression bandage be placed in the area of direct anesthesia and the bandage causing the pain removed. The rapid return of sensation following the removal of the bandage is very inconvenient in amputations, as the operation must have been previously completed, hemostasis being rendered very difficult. The literature on the subject of vein anesthesia is very scanty. Schlesinger believes it is possible to dispense with the artificial anemia by the injection of larger quantities of novocain solution. He punctures a congested vein with a thin trocar, places the constricting bandage, and injects. This method does not explain, however, the manner in which the pressure of the vein valves is overcome. Jerusalem, Mantelli, Hitzrot, Goldberg, and Petrow report successful results with this method. von Eiselsberg states in the discussion of the report of Jerusalem that he only used the vein anesthesia when other anesthetic methods were contra-indicated. The author holds this ingenious method of Bier to be a valuable addition to our anesthetic methods in performing aseptic operations upon the extremities when the usual local anesthetic methods are not possible. Bier himself limits this method of anesthesia to those cases in which local anesthesia is not possible.

ARTERIAL ANESTHESIA.

Alms and Maurel were the first to describe the anesthetic effects following the intra-arterial introduction of cocain with consequent paralysis of the muscles in the area supplied by the artery injected (see page 84).

Goyanes, a Spanish surgeon, reported in 1909 the practical application of arterial anesthesia, and stated in 1910 that he had performed amputations and resections in 23 cases with its use. In 20 of these cases complete anesthesia was obtained. Oppel performed many operations upon the hand and foot using the radial, dorsalis pedis, femoralis and brachialis as arteries of injection. The leg is made anemic and ligated; below the constricting ligature the artery is exposed and the anesthetic injected by means of a fine needle. Goyanes used for this purpose 50 to 100 c.c. of a ½ per cent. novocain-suprarenin solution. Smaller doses were found insufficient by Oppel. Goyanes recommended this method particularly for the upper extremity, using lumbar anesthesia for the lower extremity.

Hotz has recently controlled the experiments made for arterial anesthesia. He recommends that the artery be exposed under local anesthesia, and the leg made anemic just as in vein anesthesia and ligated above. A fine needle is then passed obliquely into the artery and a 0.5 to 1 per cent. novocain solution with suprarenin injected. For the brachial artery 20 to 25 c.c. are necessary. For the femoral artery 40 c.c. of a 0.5 per cent. novocain-suprarenin solution should be used. One or two minutes after the injection complete anesthesia occurs in the area supplied by the artery. Following the use of stronger novocain solutions (3 per cent.) severe pain occurs. After relieving the constricting bandage sensation returns immediately. In this manner 10 operations were performed on the hand, forearm, foot, and leg. In three lean patients it was found possible to inject the novocain solution into the femoral and brachial arteries without exposing them. In these cases the injection was rapidly made and the leg immediately ligated.

Injurious effects were never observed. This method, according to Hotz, does not enter into serious competition with inhalation or local anesthesia. It is of value in tubercular patients, in the aged with bronchitis and heart lesions, and other cases which are not suitable for general anesthesia.

That the extremity must be ligated above the anesthetized area and that sensation returns very quickly after releasing the constricting bandage, is a disadvantage that exists with arterial anesthesia just as with vein anesthesia. Arterial anesthesia possesses the added disadvantage over vein anesthesia in that it is much more difficult to find the artery than a superficial skin vein. This method should scarcely be given further consideration in anesthesia of the upper extremity, as plexus anesthesia is a much easier procedure.

The above-named authorities, as well as Girgolaw, claim that the intra-arterial introduction of an anesthetic is less toxic than that introduced intravenously, but this is of no practical importance, as the ligating of an extremity according to the method of Bier renders such danger impossible. Experiments which the writer made on animals in 1900 also contradict any such theory (see page 90). The toxicity of these methods depends upon the manner of injection. If cocain is injected into a previously ligated or clamped artery its toxic action is naturally much less than if this poison were injected into a vein with an uninterrupted circulation. If, however, the cocain is injected into the circulation of a vein previously ligated or clamped, as is done in Bier's vein anesthesia, the toxic action will naturally be much less than if injected directly into an unobstructed artery. Therefore, we can say with equal right that cocain injected intravenously is less toxic than when injected intra-arterially.

CHAPTER X.

THE VALUE, INDICATIONS, AND GENERAL TECHNIQUE OF LOCAL ANESTHESIA.

Local anesthesia is not of like value in all branches of surgery. In ophthalmology, laryngology, and rhinology it has been the most important means of anesthesia for some time past. In urology it is of much importance. In otology and gynecology, up to the present time, it has been of minor importance. With the introduction of suprarenin the importance of this method of anesthesia in dentistry has been record-breaking. Many dentists have stated that the introduction of this agent has been of the same importance to them as general anesthesia to the surgeon. The best evidence of the importance of local anesthesia in dentistry is the space given to this subject in the literature of the last few years. The value of local anesthesia in surgery was quite uncertain until the discovery of cocain. Then it rapidly reached its climax.

In the years following its discovery many different ways of using cocain were tried in surgery with varying results, such as infiltration anesthesia, conduction anesthesia, lumbar anesthesia. The beginning of the downfall of this method began with cocain poisoning, but interest was again renewed with improvements in technique by Reclus and Schleich. It seemed as though infiltration anesthesia was to be the most important method of anesthesia, as conduction anesthesia, even by the circum-injection method of Hackenbruch, gave practical results only on ligating an extremity. Infiltration anesthesia left much to be desired, and it would have been soon forgotten again had it not been for the introduction of suprarenin and the supplanting of cocain by less toxic agents. These changes, together with the improvement in technique in other directions, helped to place the method again on a sound footing. The new technique is characterized by injections around the operative field, the blocking of individual nerves, and, where possible, combining these methods with infiltration of the line of incision, as described by Reclus and Schleich. Ligation is not necessary at present with conduction anesthesia, for which reason this method can be used equally well in other parts of the body. Conduction and infiltration anesthesia are by far the most important means of producing local anesthesia. Anesthesia of superficial surfaces still has a limited field of usefulness. The most important feature is the possibility of injecting into the body as much of a solution as desired, producing a local anesthesia of such intensity and duration as has never before been known. This fact alone placed anesthesia in the foreground in surgery and assured its further progress. Improvements in technique with the older agents would not have brought about this change. The introduction of novocain and suprarenin were just as important for local anesthesia as the discovery of cocain.

Up to the present time the field of local anesthesia was limited to minor or so-called ambulatory surgery. Very few surgeons performed any of the classical operations of major surgery with the aid of local anesthesia; but of late years, thanks to the improved and simplified technique, this method has gained many adherents, as signified by communications from Roith, Nast-Kolb, Bier, Madelung, Axhausen, Hesse, and others. Statistics of various institutions demonstrate the extent to which it is used, not only in ambulatory cases but also in major surgery, as is graphically shown in the constantly rising curve (see table).

Local anesthesia possesses marked advantages over general and lumbar anesthesia. It is not associated with any danger to life, and the general condition of the patient as well as the surgical convalescence not disturbed, as is so often noted after general anesthesia. Ambulatory cases require no further attention and can be immediately discharged. We have learned of late how to produce local anesthesia of sufficient duration to carry the patient in comfort over the painful hours immediately following operation. The claim that postoperative pain is more severe after local than after general anesthesia has not been verified by experience. There are, of course, patients operated upon for various conditions who complain of severe pain no matter what the nature of the anesthetic. Local anesthesia does not increase these pains, but, on the contrary, lessens them until the return of sensation. A skilled anesthetist is naturally unnecessary; but it is important that someone should busy himself with the patient during a prolonged operation (moral anesthetist). A feature of local anesthesia not to be underrated is the bloodless operative field obtained, due to the suprarenin, an advantage of much value in certain operations.

Heidelberg Clinic (Narath, Wilms).

Year.	No. of operations.	General Anesthesia.	Local Anesthesia.	Lumbar.
1906	1917	1633 (85.0%)	218 (11.4%)	33 (1.7%)
1907	1936	1377 (71.0%)	426 (22.0%)	106 (5.5%)
1908	2070	1460 (70.5%)	559 (27.0%)	20 (1.0%)
1910	2303	1583 (68.7%)	632 (27 4%)	2
1911	2532	1063 (42 0%)	1375 (54.2%)	10

Hospital of Stettin (Hesse).

1908	1762	1364 (77.3%)	199 (11.3%)	15 (0.8%)
1909	1940	1294 (66.7%)	413 (21.3%)	26 (1.3%)

Hospital at Zwickau (Braun).

1908	1529	1078 (70.3%)	375 (24.8%)	4 (0.2%)
1909	1542	995 (64.5%)	489 (31.7%)	5 (0.3%)
1910	1811	1029 (56.8%)	727 (40.1%)	3 (0.1%)
1911	1898	987 (52.0%)	817 (43.0%)	9
1912	1866	903 (48.0%)	922 (49.0%)	5

Surgical Clinic of the Charity Hospital (Axhausen).

1910	1600		240 (15.0%)	

It has been charged that local anesthesia takes too much time. This is certainly a mistake, as the anesthetizing of the operative field requires less time than a general anesthetic. The claim that local anesthesia interferes with the exact performance of the operation will be noted only in the early attempts of the inexperienced; as a rule the reverse is true. The operator using this method must be qualified to know its technique, indications, and limitations, in this regard sharing the technical experience of surgery in general. Poor and insufficient local anesthesia, of course, will occur even to the most experienced, just as we have poor general anesthesia. The former brings no ill effects, while the latter may have serious consequences.

Where possible, local anesthesia should be the method of choice in operations not requiring too large a quantity of the anesthetic—when the field of operation can be rendered completely insensitive; when the operator knows the technique and limitations of the method; and when the psychical condition of the patient will permit of operation without the loss of consciousness produced by general anesthesia.

Regarding this last requirement it might be said that the importance of psychical contra-indications was much overrated during the developmental period of the method by the surgeons. Now, it is of minor concern. As soon as the patient finds that there really is no pain during the operation he quiets down at once, even in lengthy and serious operations. The knowledge that local anesthesia is possible is becoming more widely known, and excitable patients and well-bred children, with the proper preparation and other minor expedients, as will be described later, become readily converted to this method of operating.

A combination of local and general anesthesia may, for various reasons, become necessary, as, for instance, when local anesthesia is discovered to be imperfect. The greater the practice and experience of the operator the less often is such an occurrence noted. In some cases a combination with general anesthesia may have been decided upon beforehand. A superficial ether or ethyl chloride anesthesia may be required just at the beginning of the operation for the purpose of quieting the patient or causing a certain degree of mental confusion. There are operations which can be done in large part under local anesthesia, while certain phases may require the first stage of general anesthesia for their completion. Lengthy abdominal or stomach operations in weak persons can be carried out in this way with much less danger to the patient than if the entire operation had been performed under general anesthesia.

Kroenig tells how patients can be prepared for lumbar anesthesia with the aid of morphin, scopolamin, veronal, etc., which are used successfully in local anesthesia. Most patients, of course, do not require these aids, which have certainly no place in minor surgery. They are necessary, however, in excitable and anxious patients, particularly in operations which, according to their nature, unusual length of time, and their imperativeness, require uncomfortable positions on the table, taxing both the courage and patience of the patient; also in operations which, as known from experience, cannot be completed without general anesthesia. It is not by mere coincidence that gynecologists, almost without exception, advise the use of narcotic drugs in the preparation of patients, even when inhalation anesthesia is not to be used. Narcotic drugs in genital operations in women are very necessary. On the other hand, some women require no preparation in hemorrhoid operations. The author confines himself, when possible, to the use of morphin in doses of 0.01 to 0.02 according to the constitution of the patient. Scopolamin-morphin sleep is very valuable in the preparation of a patient, but we encounter difficulties in arriving at the proper dosage. The usual dose of scopolamin (0.0005) and morphin (0.01) is often too small and has the same effect as morphin alone, while in elderly persons this dose may be too large. The graduated doses of these agents, as advised by Kroenig, can hardly be carried out in hospital practice without decidedly increasing the personnel.

The prevailing opinion that children are not suitable patients for local anesthesia is, as Kredel states, no longer tenable. Some children are easily influenced, and readily permit the injection, particularly if chocolate or other sweets are offered. We operate for empyema, also for herniæ as does Kredel, in children as young as four years of age, mostly under local anesthesia. The old methods of local anesthesia were unsuitable for children, and also for anxious and sensitive persons, on account of their uncertainty. Frequently during the operation it became necessary to renew the injection first in one place then in another, owing to an insufficient anesthesia. Kredel suggests a most clever way of preparing nursing babies for local anesthesia. The baby is first allowed to become hungry, then, at the beginning of the injection, it is given a bottle, after which it does not concern itself with what goes on.

The modern operating-table is very comfortable for the operator, but for the patient operated upon under local anesthesia there is much to be desired. When, therefore, a particular position, such as a Trendelenburg or reverse Trendelenburg, is not necessary, the patient should rest on a mattress placed upon a smooth table and covered with sterile rubber cloth and sheets, and thus made comfortable for the ordeal.

INSTRUMENTARIUM.

The instruments necessary for local anesthesia, especially for infiltration and conduction anesthesia, consist of syringes, needles, and receptacles for the anesthetic to be employed. Syringes of 2.5, 5 and 10 c.c. are necessary, and must stand boiling. They should not be short and thick, but rather long and thin, so that the diameter of the piston is small and compact. The pressure of fluid in the needle is considerably greater the smaller the diameter of the piston. This is of much importance in injecting into dense tissues. The syringe should be well adapted to the hand and should have an attachment for making counter-pressure, such as a cross bar or rings; or, what the writer believes best, a groove that will fit the second and third fingers. The "Record" syringe, made in Germany, consists of a glass cylinder with metal piston. It does not fulfil all the requirements mentioned, as it is too short and thick and has no arrangement for making counter-pressure. Hammer, in his criticism of this syringe, claims it requires too much attention. The piston must be removed when boiled, and, in spite of the best of care, the glass cylinders will occasionally break either during the boiling or cooling. On account of the great cost consequent on breakage, Hammer and the writer have given up the glass syringe for the all-metal one. Metal syringes are much better than in former years, and the operator soon grows accustomed to not being able to see the fluid.

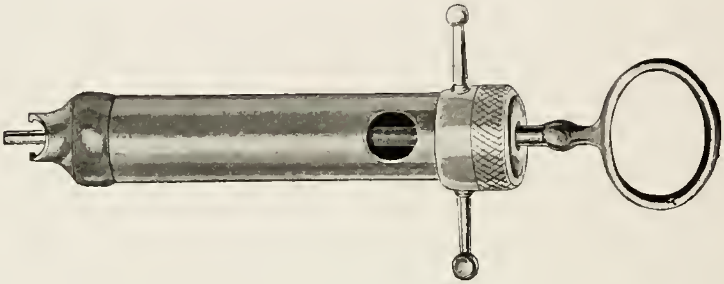


Fig. 10.—The Hammer syringe.

Hammer has constructed an all-metal syringe in which the solution to be injected is poured in from a side opening in front of the fully extended piston (Fig. 10). The fault of this syringe is that in order to fill it the needle which is fixed to the syringe must be withdrawn. It is very important that the needle should remain in the tissues, and, therefore, most essential that the syringe and needle should be detachable. This feature far outweighs the slight trouble of occasionally separating the instrument. Figs. 11 and 12 show good syringes.

Injections made under the skin and parallel with its surface are sometimes difficult to carry out if the needle is attached in the long axis of the syringe, owing to the conformation of the body. For this reason Hackenbruch constructed a syringe with the needle fixed at right angles. This arrangement, however, has the great drawback that it is difficult to feel the point of the needle, the location of which constitutes really the whole secret of local anesthesia. This difficulty is overcome by the needleholder presently to be described, in which the needle is attached at right angles to a cone-shaped end.

The needles must be as fine as their stability will permit, so that an injury such as the unintentional pricking of a bloodvessel will not be of serious consequence. We have always used needles made of steel. Platino-iridium needles are too costly, while nickel needles become dulled too quickly. The needle-points should

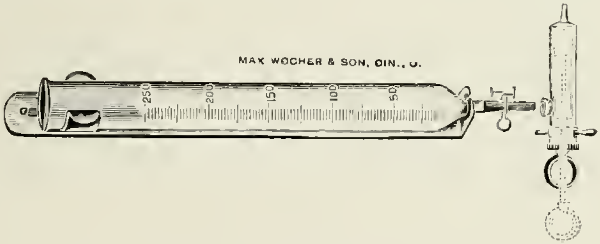


Fig. 11.—Shields' syringe.

have a short bevel and, of course, must fit the syringe perfectly. This should be tested by filling the syringe with water and attempting to inject with the point of the needle in a cork. There must not be any leakage between needle and syringe.

The needles which the author uses are shown actual size (Fig. 13). The fine short needle No. 1 is used only for the formation of wheals at the various points of injection, the longer needles being used for the completion of the injection. Half-curved angular needles are entirely unnecessary. The needleholder as shown (Fig. 14) is indispensable as a guide for the long needles when used in the trifacial, lumbar, and sacral

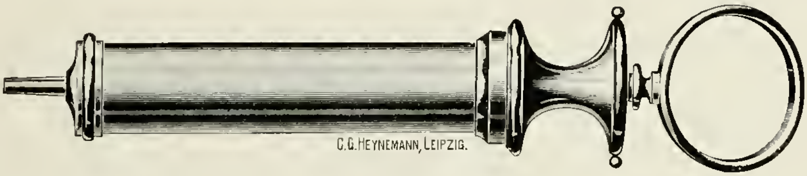
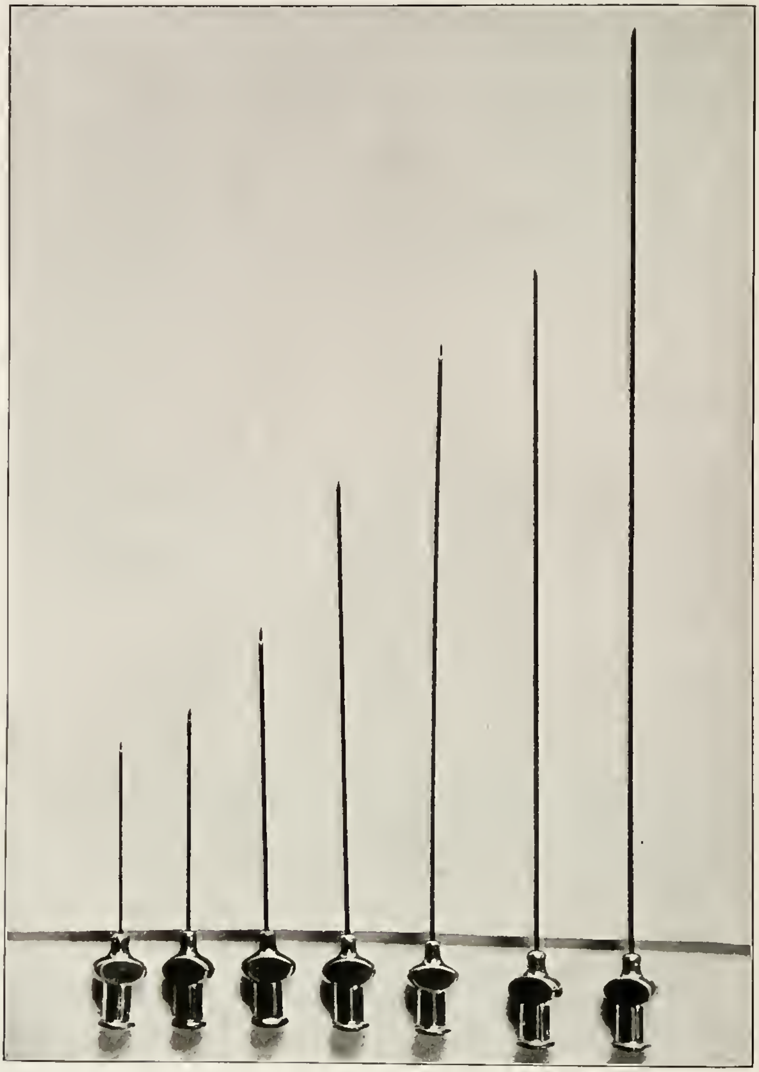


Fig. 12.—Braun's syringe.

injections. The needle is firmly held in the holder by means of two jaws operated by a screw. The slip-joint for attaching the syringe is made at an angle, which is an advantage over syringes with angular ends or angular attachments such as have been described by Hackenbruch. It is at times necessary to know beforehand the length

[1] The syringe (as shown in Fig. 11) is patterned after the Hammer syringe. It differs in having a slip joint which facilitates changing of the needle. The opening at the back part of the syringe is surrounded by a funnel-shaped collar, which renders the filling of the syringe easier. The syringe is made in two sizes of 5 and 10 c.c. capacity.—Editor.

of the needle to be used in the injection of certain parts of the body, for example, injections into the foramen rotundum and ovale. For this purpose a piece of cork is slipped over the needle and placed at a point previously measured on the needle to act



	1	2	3	4	5	6	7
Thickness .	0.5	0.5	0.6	0.7	0.7	0.7	0.9 mm
Length .	25	30	35	60	80	90	125 mm.

Fig. 13.—Diagram showing needles in natural size.

as a guide. The use of special needles with a graduated scale marked upon them is unnecessarily costly and at times inconvenient. A deviation from the usual form of needle has been devised by Schleich and consists of a cone-shaped end which is pressed

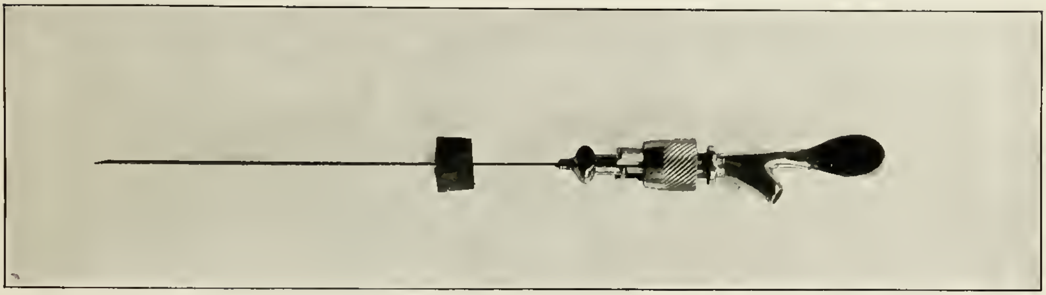


Fig. 14.—Needleholder, showing cork placed on the needle at a definite measured point.

into the end of the Schleich syringe (Fig. 15). This makes a very stable and tight connection, but cannot, however, be readily separated. The needles belonging to the syringe outfit of Schleich are too short. Complications, unpleasant for both patient and operator, sometimes result from breaking off and losing a needle in the tissues, and lawsuits often follow accidents of this kind. This mishap can occur with the most skilled, as it is impossible at times to prevent the needle from breaking where it joins the hub. This of course applies to needles which have not been damaged by rust. For this reason it should be the rule that a needle must never be pushed into the tissues as far as the hub; it will then be impossible to lose a broken needle in the tissues. Very long needles should be used in making injections into parts of the body difficult of access, as, for instance, injections carried out in the hidden recesses of the mouth, on the inner surface of the lower jaw, or the tuber maxillæ in dental operations. In operations at this depth, the needle should be of such length that it will not be necessary to have the syringe enter the mouth.

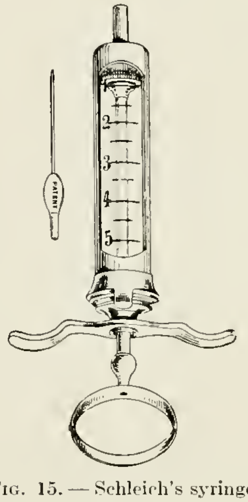


Fig. 15.—Schleich's syringe.

For the preparation of the various solutions, glass graduates of from 5 to 20 c.c. capacity, and porcelain measures of 150 to 250 c.c. capacity are necessary. The solutions can be used directly from these vessels. In the preparation of small quantities of the solutions watch glasses, as used for microscopic purposes, are very satisfactory.

Syringes and needles are sterilized by boiling in a soda solution. This must be thoroughly removed by subsequent washing in salt solution, as both novocain and suprarenin deteriorate in the presence of soda. After use, syringes and needles should be cleansed in alcohol and dried. Vessels and graduates should be sterilized

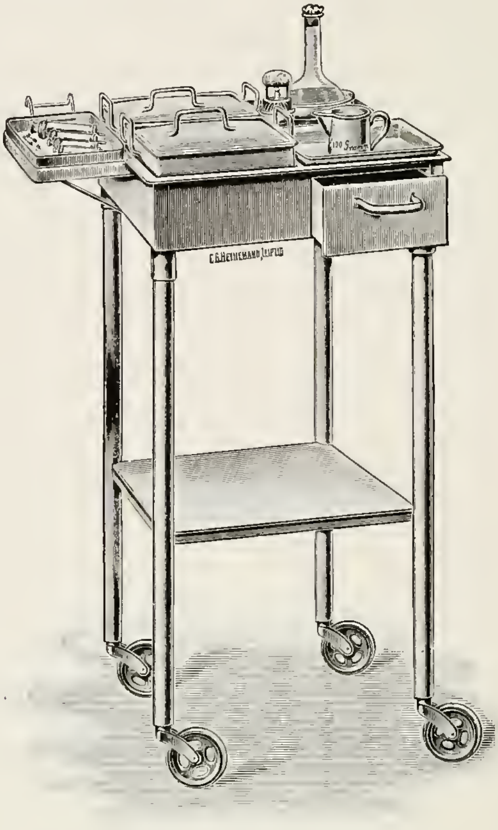


FIG. 16.—Table for local anesthetic apparatus.

by boiling, or may be kept in a 3 per cent. carbolic acid solution until used again. They should then be thoroughly washed in salt solution. Fig. 16 shows a well-arranged portable table for the equipment necessary in local anesthesia. This table provides for instrument trays in which syringes and needles can be boiled, an enameled iron basin for salt solution used in washing the soda from instruments, a similar basin for a carbolic solution in which graduates and other vessels are kept, a liter flask for salt solution and a spirit lamp.

The apparatus as shown (Fig. 17) consists of a glass-top table having suspended from an upright a 250 c.c. glass graduate with a tapering glass end-piece connected to the graduate with rubber tubing closed by a pinch-cock. An alcohol lamp with a small porcelain vessel for dissolving and boiling the tablets and one or two other glass graduates complete the outfit. The advantage of this apparatus consists in dispensing with one assistant, of rapidly and accurately filling the syringe, and knowing the exact quantity of the anesthetic solution which has been injected.

Fig. 17.—Shields' outfit for local anesthesia.

SOLUTIONS USED IN ANESTHESIA.

The solutions used for anesthesia should be isotonic as near as possible (see page 62), for which purpose a strong hypotonic physiological salt solution is used. To be exact, the strength of the salt solution should vary with the concentration of the anesthetic, but this is neither practical nor necessary. A 5.4 per cent. solution of novocain constitutes a physiological solution, for which reason a 4 per cent. novocain solution is best prepared by dissolving in water instead of salt solution. Salt must therefore never be added to hypertonic solutions. Cocain, at least in surgery, has become obsolete. For infiltration and conduction anesthesia novocain combined with suprarenin is the combination of drugs most recommended. Novocain can be sterilized by boiling, after which it will keep indefinitely. Suprarenin, on the contrary, is a very delicate drug, for which reason certain precautions are necessary in its use. The suprarenin of commerce is known by various trade names, viz.: adrenalin, suprarenin, paranephrin, tonogen, etc. In Germany the American product adrenalin and the suprarenin of German manufacture are most commonly used. The latter is synthetically prepared and is placed on the market in a solution of 1 to 1000, with the addition of hydrochloric acid and an antiseptic such as acetone, chloroform, thymol, etc., to insure its stability. In this form the solution can be sterilized by boiling, and, if kept in alkaline-free glass, remains unchanged for a considerable time. Compressed tablets containing 1 mg. of suprarenin can be obtained, and tablets are likewise on the maiket containing the anesthetic drug with the requisite amount of suprarenin. In dental practice glass ampoules are preferred by many, each ampoule containing a small quantity of the anesthetic and suprarenal substances in solution. Preparations dispensed in this way have little to recommend them. They are costly and not fitted for physicians' use. The writer personally prefers the tablet as used in the dispensing of all alkaloids employed in medicine; this applies to unstable drugs particularly, such as suprarenin. Suprarenin is not stable in solution, while in tablet form it remains unchanged indefinitely. Diluted solutions of suprarenin become red quickly when exposed to the air without, however, losing any of their effectiveness. After longer exposure these solutions turn brown and then are unfit for use. Lieble states, and with perfect right, that solutions made from the solid substance of suprarenin, particularly the tablets, are the most reliable. A chemist engaged in the manufacture of suprarenin writes: "The stability of suprarenin solutions is dependent upon many contingencies which cannot be avoided even with utmost care."

The sterility of the manufactured tablet cannot be depended upon even though the manufacturer claims the tablets are sterile. Hoffmann and Kutscher found bacteria in a number of tablets which they examined, and it is not a remote possibility that pathogenic bacteria could also be found. Inasmuch as the dry substance cannot be sterilized, it is necessary to sterilize solutions made from these tablets before use. Solutions prepared from synthetic suprarenin can be sterilized by boiling without injury.

Anesthetic solutions can be prepared in various ways. 1. The writer has had prepared by Hoechster-Farbwerke[1] tablets of novocain-suprarenin, so-called tablet A containing 0.125 novocain hydrochloride and 0.000125 of synthetic suprarenin in the form of a water-soluble salt, the tartrate being the one used at present. 1–2–4 of these tablets dissolved in 25 c.c. of physiological salt solution produce 0.5 to 1 to 2 per cent. solutions. The tablets necessary for an operation are placed in a small porcelain dish or sterile test-tube, covered with sufficient physiological salt solution and sterilized by boiling. This solution is then placed in a porcelain vessel and diluted with salt solution as desired, and used directly from this vessel.

2. Approximately 1 mg. of suprarenin is added to 200 c.c. of a 0.5 per cent. solution, 100 c.c. of a 1 per cent. solution, 50 c.c. of a 2 per cent. solution and 25 c.c. of a 4 per cent. solution. In institutions where large quantities of the anesthetic are required daily, the following procedure will be of value. A 4 per cent. novocain solution is sterilized and kept ready for use in cotton stoppered glass flasks. A tablet of 1 mg. suprarenin is dissolved as before mentioned and then boiled and added to 25 c.c. of the 4 per cent. novocain solution. This novocain suprarenin solution is now diluted with salt solution as desired.

3. At times it becomes necessary to prepare these solutions from a 1 to 1000 solution of suprarenin, for which purpose either the commercial preparation is used, which must be sterilized, or the solution is made from the suprarenin tablets and placed in a drop bottle. In preparing this solution 10 suprarenin tablets, each containing 1 mg., are added to 10 c.c. of distilled water to which 3 drops of dilute hydrochloric acid have been added; this is then boiled. Before using the drop bottle it is very necessary to know the number of drops per c.c., as without this precaution the strength of suprarenin would be most unreliable, as the number of drops per c.c. varies between 10 and 20, depending upon the bottle. When the correct number of drops is known this amonnt of the liquid is added to the requisite quantity of novocain solution. It is best in preparing these solutions to have a graphic formula to work by as the following:

16 gtt. suprarenin solution 1 to 1000 = 1 c.c. = 1 mg. suprarenin.
to be added to

200 c.c. 0.5%	Novocain solution.
100 c.c. 1.0%	
50 c.c. 2.0%	
25 c.c. 4.0%	

From this diagram it becomes at once apparent how many drops of the suprarenin solution are necessary for larger or smaller quantities of the novocain solution.

The use of tablets in the preparation of these solutions is the simplest and most

[1] Hoechster-Farbwerke prepares novocain and suprarenin in ampoule form, insuring sterility.

trustworthy procedure, and, outside of hospitals, the only method to be recommended. It would certainly not be justifiable to have alkaloid solutions prepared by the druggist and then kept on the shelf until ready for use. The 1 per cent. solution of novocain-suprarenin is suitable for nearly all purposes and should be recommended for general use, but for major operations it will often be advantageous to have solutions of different strengths. The 0.5 per cent. novocain-suprarenin solution is the one the author uses most frequently, whereas the 1 to 2 and 4 per cent. solutions are reserved for anesthesia of the larger nerve trunks, in cases where a rapid and peripheral anesthesia or a more intense suprarenin anemia is desired. Since Laewen has shown that the 4 per cent. novocain-suprarenin solution is harmless, even in large quantities, the author has been using this solution, and will describe it later in detail.

The dosage of novocain and suprarenin has already been discussed on pages 124 and 144. More than 1.25 novocain (250 c.c. of 0.5 per cent. solution, 125 c.c. of 1 per cent. solution) can be injected without toxic effect. In using the 2 to 4 per cent. solutions it is best not to exceed 0.8 of novocain, and if injections are made into dense vascular tissues like the gums, the fractional quantity of this dose should not be exceeded, although additional quantities of the 0.5 and 1 per cent. solution can be used without danger. In using strong solutions, always observe Laewen's rule to *inject slowly*.

As a rule the dosage of novocain need not be given much thought, provided no attempt is made to anesthetize too large an operative field. The progress of local anesthesia is based upon this fact. The reason why the dosage of suprarenin in local anesthesia is without consequence, and why the concentration of suprarenin in anesthetic solutions should not be exceeded, has already been discussed on page 145.

Solutions of alypin for anesthesia of mucous membranes can be prepared in the proper strength and necessary quantity from tablets containing alypin 0.2 and suprarenin 0.00033.

GENERAL TECHNIQUE OF INFILTRATION AND CONDUCTION ANESTHESIA.

Infiltration anesthesia and conduction anesthesia are theoretically entirely different procedures. In practice, however, they are not separated and must be considered together. Their development and relation to one another has already been described in Chapter IX, and in this chapter the influence of modern anesthetic agents on the technique of the methods is given in detail.

We no longer attempt to systematically infiltrate the layers of the tissues in the proposed line of incision, as described by Reclus and Schleich. We anesthetize by infiltration certain layers of the tissues alone, or in connection with the breaking of conduction of certain nerve trunks before their distribution in the operative field. It should be borne in mind that injections are not permissible in diseased tissues. In practice we seldom use the direct infiltration of the tissues, that is, infiltration anesthesia, but usually combine infiltration of the tissues with conduction anesthesia. It can be readily seen that a particular method of anesthesia is necessary for every operative field or part of the body. For the practical application of local anesthesia little is gained from the knowledge of the general technique of injection, but it is necessary to have a comprehensive knowledge of the sensory innervation of the operative field. For these reasons it is impossible to describe briefly the technique of infiltration and conduction anesthesia. In the surgical text-books of the future it will not be sufficient to place the subject of local anesthesia next to that of general anesthesia and dispose of it in a short résumé, with the mere mentioning of such historic names as Reclus, Schleich, Oberst, and Hackenbruch. The subject must be taken up fully and the technique for each operation given in detail.

Inasmuch as the injected agent does not immediately produce its maximum effect, either as to intensity or extent of anesthesia, except when the agent is injected endermatically, it is necessary to circumscribe the operative field by the requisite injections before beginning the operation. The injection of the deeper layers of the tissues should be made first, as the primary injection into the subcutaneous connective tissue would render the technique of the deeper injections more difficult. At the present time it is usually unnecessary to repeat injections during the operation, a distinct advantage in that valuable time is lost in waiting for the anesthetic to become effective when repetition is necessary.

Anesthesia by means of injection, as carried out by Reclus and Schleich, was an integral part of the operation. Today it is independent of the operation, in fact precedes it, and need not be performed by the operator or in the operating-room. Before beginning the injections, the skin of the operative field should be sterilized with benzine or iodin-benzine, or the points of entrance of the needle can merely be touched with the tincture of iodin. After completing the injection, the preparation of the operative field is undertaken, such as the disinfection of the skin, surrounding the operative field with sterile towels, and locating the assistants. During this preparation anesthesia has attained its maximum effect.

The hand must be trained in the skilful manipulation of the syringe, which, as shown in Fig. 18, is held by the thumb, index, and middle fingers of the right hand. The wrist should be free, and all lateral pressure should be avoided to prevent the breaking of the needle, which must never disappear completely from view in the tissues, as already mentioned on page 175.

For the first punctures of the skin fine and short needles should be used (No. 1,

Fig. 13). It is impractical and unnecessary to use ethyl chloride on the skin for the first needle punctures, as the skin is rendered hard and the insertion of the needle

Fig. 18.—Manner of holding syringe.

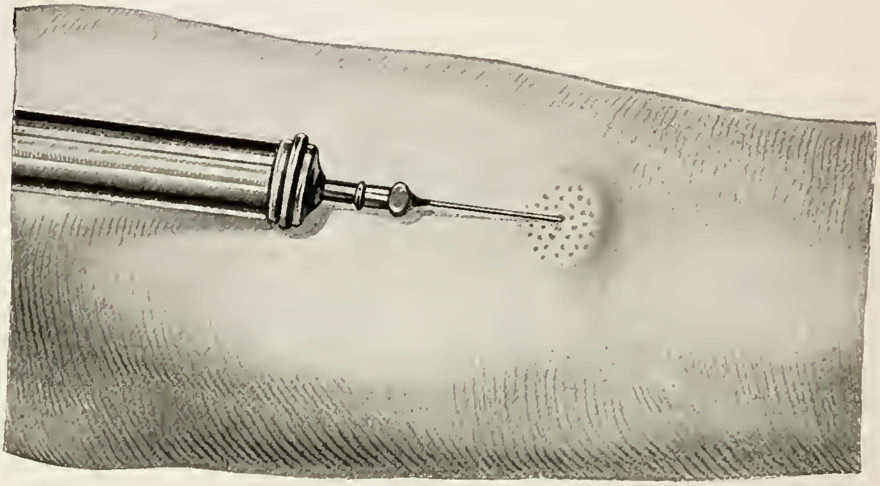


Fig. 19.—Formation of a skin wheal.

difficult; likewise the pain consequent upon freezing the skin is more severe than the pricking of a fine sharp needle. The injections are carried out from several points, which are later used for injecting with longer and thicker needles. It is therefore necessary to select points for injection and make them insensitive by the endermatic infiltration or the formation of a wheal, as described by Reclus and Schleich, the wheal formation at the same time renders the points visible to the eye. Points for injection should never be made upon sensitive parts as like the flexor surface of the finger.

Endermatic infiltration is performed in the following way: The needle is inserted into the corium parallel to the skin surface with the bevel upward, avoiding the subcutaneous connective tissue, until the opening of the needle has entirely disappeared in the tissues. A small amount of the 0.5 per cent. novocain-suprarenin solution is injected, thus producing a raised white area or wheal which instantly becomes anesthetic and at the same time marks the first point of injection (Fig. 19). The other points of injection are made in like manner. When the skin is very thin and movable, raise a fold of skin between the thumb and index finger and make the injection for the wheal as before mentioned. In certain portions of the body like the scalp, palm of the hand, the soles of the feet, the endermatic injection requires considerable pressure, for which reason it is very essential to select a small syringe with a piston of short diameter for the formation of wheals. Schleich and Reclus began every operation with endermatic infiltration.

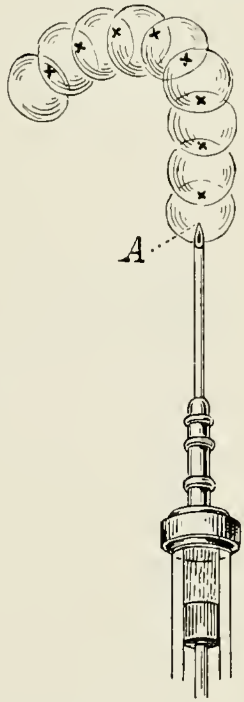


Fig. 20.—Formation of a series of wheals, according to Schleich.

After the formation of the first wheal, the needle may be inserted, if desired, into the anesthetic edge of each successive wheal; in this manner a small anesthetic line of any desired form and length can be outlined in the skin (Fig. 20). In case the skin is normal, there is no objection to this method of anesthesia except that it is unnecessary, as the skin will become anesthetic without endermatic infiltration. For these reasons we only use the infiltration of the skin for the purpose of marking and anesthetizing the place of puncture of the needle.

For the purpose of making a straight incision through the skin and subcutaneous tissue proceed as follows: The upper end of the incision where the needle puncture is to be made is marked by a wheal. A syringe containing 5 c.c. of 0.5 per cent. novocain solution, is attached to a long needle; this needle is then passed through the previously formed wheal into the subcutaneous connective tissue (Fig. 21), where under the guidance of the fingers of the left hand the needle is pushed to the lowest point of incision parallel to the skin surface. Pressure upon the skin, so that its under surface is likely to be abraded, should be avoided as it occasions considerable pain. During the insertion and withdrawal of the needle constant even pressure should be made upon the piston, so that a narrow line of subcutaneous connective tissue is infiltrated. As to the necessary quantity of solution for injection, it is approximately correct to say that for every c.c. of the proposed line of incision 1 c.c. of the solution be injected; with a 1 per cent. solution a correspondingly smaller quantity is used. Immediately after the injection the skin of the area so treated is raised above the surface of the surrounding skin in the form of a low, narrow wall, which disappears in a very short time. The elevated line is then replaced by a white stripe in consequence of the rapid action of the suprarenin. In a few minutes this strip of skin becomes anesthetic, the injected solution having not only produced an infiltration anesthesia but at the same time a conduction anesthesia of the overlying skin, and

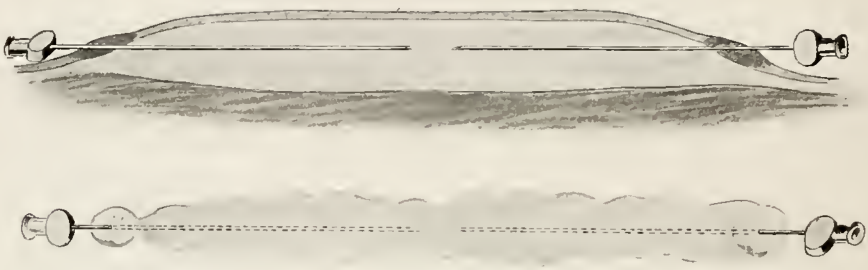


Fig. 21.—Injection of the subcutaneous connective tissue from two points.

the nerve supply to the skin has been interrupted. This is the simplest form of conduction anesthesia. In case one point of puncture or the length of the needle is insufficient for infiltration of the proposed line of incision, injection from two wheals can be made corresponding to the ends of the incision (Fig. 21). At times it may be more desirable to make the wheal in the centre of the proposed line of incision and inject from both directions. In irregular or angular lines of incision the injection can be carried out from the apex of the angle (Fig. 22, *B*) or from two points of injection (Fig. 22, *A*). The injection of the curved surfaces of the body by straight introduction of the needle from one point of injection naturally has its limitations, for instance, in the circular injection of the forearm. For this purpose four equidistant points for injection are selected from which the circular injection is carried out (Fig. 23). In the infiltrated area just described not only the subcutaneous tissue and overlying skin become anesthetized, but likewise the entire area innervated by the cutaneous nerves passing through the infiltrated area.

If the subcutaneous connective tissue is systematically infiltrated in all directions from one, two, or more wheals, using a long needle, and injecting a 0.5 per cent.

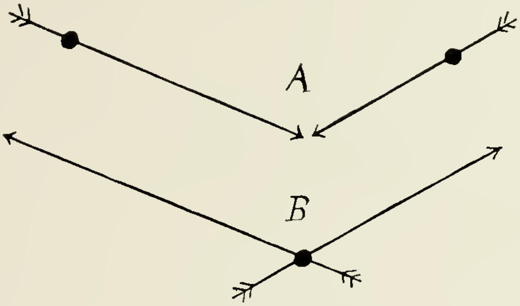


FIG. 22.—Subcutaneous injections made at an angle.

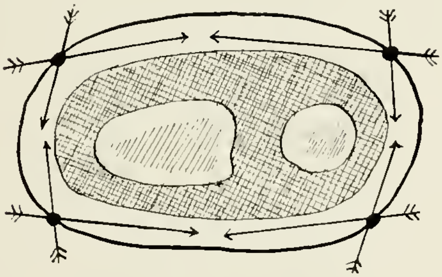


FIG. 23.—Schematic cross-section of the forearm. Infiltration of the subcutaneous connective tissue from four points.

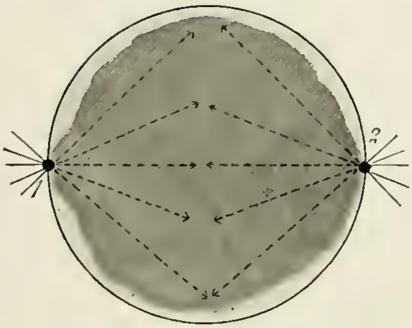


FIG. 24.—Superficial infiltration of the subcutaneous connective tissue.

novocain-suprarenin solution during the insertion and withdrawal (Fig. 24), an anesthetic area of any desired size can be produced. In this manner extensive diseased areas of the skin can be excised and in like manner this method can be used for the cutting of Thiersch grafts. Subcutaneous infiltration of the tumor base is sufficient for the excision of pendulous skin tumors (Fig. 25). The tumor itself should under no circumstances be infiltrated; it will then not become enlarged and resemble a cucumber, as has been stated by Schleich.

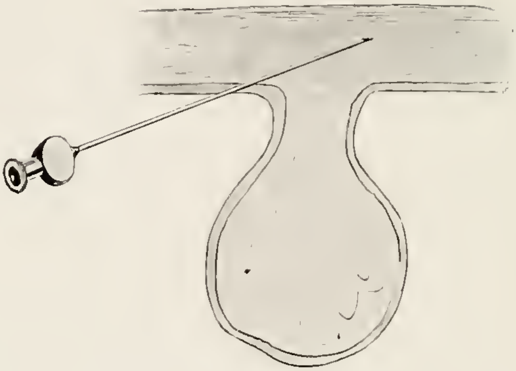


Fig. 25.—Infiltration beneath the pedicle of a skin tumor.

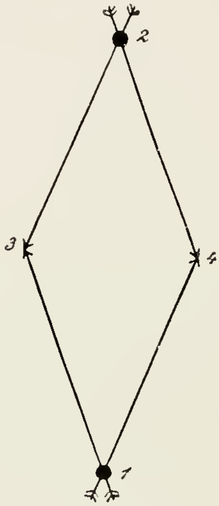


Fig. 26.—Hackenbruch's rhombus.

What has been said regarding the anesthesia of the skin and subcutaneous connective tissue applies to the mucous membranes, except in the formation of wheals. The injections, therefore, should be confined to the submucosa, which will necessarily render the overlying mucous membrane insensitive. In many parts of the body—for instance, the scalp—the sensory nerve trunks of the skin and fasciæ lie in the subcutaneous connective tissue, for which reason large contiguous parts of the surface of the body have no direct nerve connection with the subfascial tissue. For this reason it is not always necessary to anesthetize the skin and subcutaneous connective tissue of the operative field, it being frequently sufficient to circumscribe the operative field by subcutaneous injections. Hackenbruch utilized these facts in his circular analgesia (Fig. 26). Wheals are made at points 1 and 2. From these points the subcutaneous connective tissue is infiltrated in the direction 1 to 3, 1 to 4, 2 to 3, 2 to 4, thus surrounding the entire field of operation by a subcutaneous wall of anesthesia in the form of an elongated rhombus, termed Hackenbruch's rhombus. The longest diagonal of the rhombus lies in the direction of the proposed line of incision. Wheals can also be made at points 3 and 4 if more convenient, and the form of the encircling wall of the operative field may be square, circular, or any other desired form that the operation may require. The number and position of the points of injection are determined by the form and size of the operation (Fig. 27).

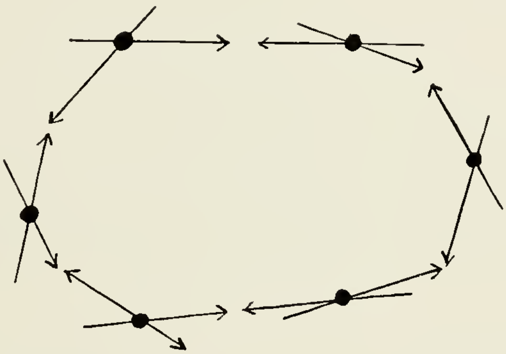


Fig. 27.—The subcutaneous circuminjection of an operative field from six points.

In certain parts of the body all of the sensory nerves supplying not only large areas of skin but likewise the deeper structures are located in the subcutaneous tissues. As an example we might mention the sensory nerves, supplying the skin, periosteum, and bones of the skull, which in the neighborhood of the base, particularly the forehead, are found in the subcutaneous connective tissue. A simple circular subcutaneous injection, as shown in Fig. 27, can be used in outlining such operative fields of any desired size and will produce complete anesthesia of all structures, including the bone. It may then be said that the Hackenbruch circuminjection should be considered the normal procedure in anesthesia of the skull. Hackenbruch has rightly stated that anesthesia of a finger, as described by Oberst, depends upon this same principle, as the subcutaneous connective tissue of the finger base contains the sensory nerves. If, therefore, the subcutaneous tissues of the finger base are circularly injected this entire member will become anesthetic.

It is only in such parts of the body having the type of innervation as already described that the subcutaneous injection alone produces a useful anesthesia. Anesthesia will not be complete in operative fields circumscribed by anesthetic injections if they receive their innervation from below. For example, if an operative field in the region of the chin is injected, having the exit of the mental nerve in its centre, anesthesia will not occur. One of the most elementary procedures for the induction of

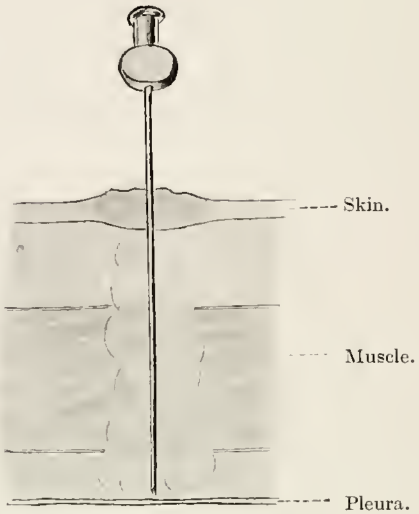


Fig. 28.—Infiltration of the needle tract used in aspirating the body cavities.

local anesthesia consists in the sytematic infiltration of the different layers of the tissues. The simplest form of this mode of anesthesia has been described by Schleich in connection with anesthesia for aspirating various cavities of the body (Fig. 28). The point of injection is marked by a wheal; a needle of proper length is then inserted as far as the subpleural or subperitoneal connective tissue, injection of the anesthetic agent being continuous during the insertion and withdrawal of the needle. The infiltration should be ample, as mentioned in connection with the subcutaneous injections; however, it is unnecessary to go to the other extreme and render the tissues edematous as in the Schleich method. The pleura and peritoneum never require infiltration, as the innervation of these structures is derived from the subpleural or subperitoneal connective tissue. This simple procedure may be amplified by infiltration of parts of the body to any desired extent (Fig. 29).

The arrows indicate the usual direction of the needle, which is inserted through two wheals. The injection is begun in the deepest layer, in this case the bone, and finished with the injection of the subcutaneous connective tissue. The needle is therefore inserted through one of the indicated points into the subcutaneous connective tissue, then perpendicularly to the deepest point—the bone, subperitoneal connective tissue—and the injection carried out as for simple aspiration. The needle is then drawn back into the subcutaneous connective tissue and again passed to the same depth but in a more oblique direction toward the centre of the area to be infiltrated. The last injection is made directly under the skin, as shown in (Fig. 19). During the insertion and withdrawal of the needle the anesthetic fluid must be constantly injected. If the needle is long enough, the anesthesia can be completed from one wheal placed either at the end or in the centre of the line of injection.

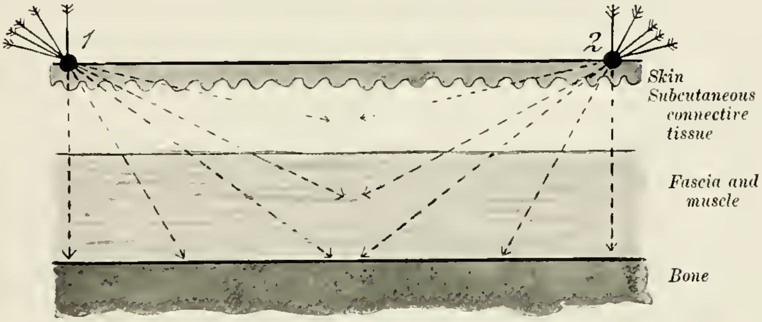


Fig. 29.—Infiltration of a plane through the body tissues.

It is never necessary in any part of the body to inject beneath the periosteum to render it insensitive, notwithstanding the fact that Reclus, Schleich, and others, advised subperiosteal injections which, from a practical stand-point, were carried out with difficulty, if at all. The skin receives its innervation from the underlying subcutaneous connective tissue, for which reason, if the latter be infiltrated, the skin becomes anesthetized. The periosteum receives its innervation from without and not from the bone; it will therefore be rendered insensitive if the tissues overlying it be infiltrated. Infiltration of the thicker layers of the tissues in the manner described requires considerable practice; one must learn to feel with the needle-point, and must know at all times where the point of the needle is, for which reason an exact knowledge of anatomy is necessary. The hand holding the syringe must be able to detect the minutest change of structure, as when the needle-point encounters a layer offering certain resistance to its passage, and then passes into a connective tissue layer of softer and looser structure. The puncture of the muscle fascia always causes slight pain. To avoid injecting larger quantities of the anesthetic into a vein, the syringe must be in constant motion, injecting during the insertion and withdrawal of the needle, as has already been recommended by Reclus (*injection traçante et continué*). The continuous injection likewise causes an even distribution of the anesthetic in the tissues.

When injections are to be made in the neighborhood of large vessels, it is advisable to insert the needle first without the syringe, and if no blood flows from the needle, the injection should be made during its withdrawal. The occasional puncture of large arteries or veins should be avoided. This accident, according to our experience, is perfectly harmless. Of course, the use of thin needles is essential (page 174).

The technique of the injection just described is sufficient for infiltration anesthesia of a narrow line of incision and conduction anesthesia in the area supplied by those nerve trunks which have been affected by the injection.

The first is practical when a simple incision is to be made through normal tissues, as, for instance, the removal of a foreign body when its position is definitely known. Conduction anesthesia produced by the above-mentioned infiltration is of much more importance in rendering the operative field insensitive.

Occasionally, by a simple infiltration of a narrow area, it is possible to interrupt the larger part of the nerve supply to the operative field. This is made use of in operations in the anterior triangle of the neck and in inguinal and femoral hernia operations. In other cases several areas must be infiltrated at the same time, which areas may be some distance from the field of operation, so that they will surround and isolate the operative field from the rest of the body.

The technique of these procedures can be more definitely shown by a diagram. Fig. 30 represents a pyramid with apex, 5, lying in the depth beneath the centre of the operative field. Its base 1–2–3–4 is located upon the skin surface; its lateral surfaces bound the operative field. The first step is to endeavor to anesthetize these four lateral walls. The points 1–2–3–4 represent the points for injection. A long needle is inserted into each one of the before-mentioned points and injections made in the direction of point 5, then in various directions from the laterally located points, as 1 to 7, 4 to 7, 4 to 6, 3 to 6, 3 to 9, 2 to 9, etc. The subcutaneous connective tissue is finally infiltrated in the form of a Hackenbruch rhombus, in the directions 1–2–3–4. Shortly after the injection the field of operation becomes insensitive, whether it has come into contact with the anesthetic or not.

Two points of injection are often sufficient for the injection of this figure; in other cases four or more will be necessary, depending upon the extent of the field of operation. Sometimes it will take the form of a cone or a part of it, at other times a trough-like shape, as is shown in Fig. 31. Two points of entrance are designated in the diagram by 1 and 2. From these points injections are made in the directions 3, 4, 5, 6, 7, and, lastly, the subcutaneous tissue is infiltrated in the form of a Hackenbruch rhombus. Fig. 32 shows how, in the case of bone, the operative field is surrounded by an encasing form of injection which renders all parts of the operative field insensitive.

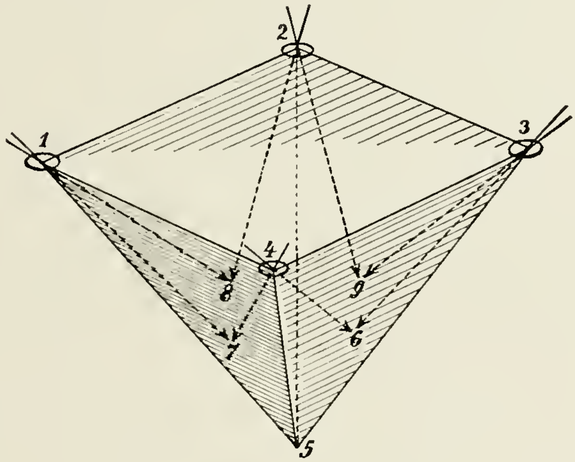


Fig. 30.—Pyramidal form of injection.

For all these injections 0.5 per cent. novocain-suprarenin solution is the most suitable anesthetic; it interrupts the conductivity of small and medium-sized nerve trunks quickly and with certainty if the connective tissue layers containing the

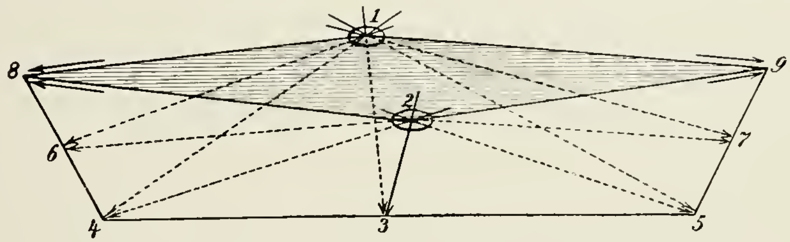


Fig. 31.—Encasing or trough-like injection.

nerve trunks are infiltrated without necessarily hunting these nerves. Concentrated solutions of novocain-suprarenin (1 to 4 per cent.) are recommended in cases where large quantities of fluid might cause discomfort or injury, as in the orbit, eyelids, prepuce, the fingers, etc. It must be remembered that these concentrated solutions produce considerable effect on tissues situated at some distance from the place of injection. An injection of such a solution after a short time produces infiltration anesthesia not only in the area injected but likewise for some distance beyond, and nerve trunks will be blocked if passing through this area by the so-called indirect infiltration anesthesia. Much use is made of this method in practice.

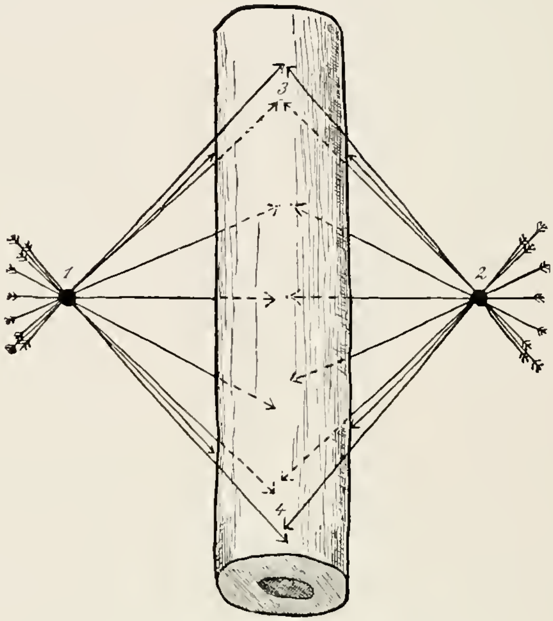


Fig. 32.—Encasing injection surrounding a bone.

The combination of direct anesthesia of the larger nerve trunks in connection with the circuminjection of the operative field requires definite rules for its performance and is accomplished by a definite guidance of the needle. Seeking the nerve trunks with the point of the needle is easy and certain when the position of the nerve can be definitely located in connection with bony landmarks which aid in the guidance of the needle. It is much more difficult when these landmarks are absent and the nerve is situated in the midst of thick soft parts. A good guide in all cases is the radiation of sensations of paresthesia toward the periphery, which occurs following the irritation of the nerve with the needle. If possible, the patient must be instructed in this regard before the introduction of the needle, and must be told to speak at once as soon as he notices the paresthesia. If these sensations occur, it is certain that the point of the needle is in the proper place. For the blocking of large nerve trunks it is advisable to use concentrated solutions, as 1 to 5 c.c. of a 2 to 4 per cent.

novocain-suprarenin solution. The length of time necessary after the injection for blocking to occur depends upon how the nerve was reached. If the needle can be introduced into the nerve trunk, as is possible after a little practice, for instance, with the branches of the trigeminus, the interruption of conduction occurs instantly. If the anesthetic is injected only in the neighborhood of nerves, it will require five to twenty minutes before it interrupts the conductivity of the nerve.

Freely exposed nerve trunks can be instantly blocked if one injects into the trunk a 0.5 or 1 per cent. novocain-suprarenin solution. A spindle-shaped swelling of the nerve occurs which disappears very quickly. It seems as though the injected fluid is disseminated between the nerve bundles. It can therefore happen that, after an endoneural injection, branches of the nerve may be interrupted which leave the trunk proximal to the point of injection. The method of injection in individual cases, whether it be infiltration, circuminjection, or blocking of the nerve trunks for the purpose of rendering the operative field insensitive, whether it deals with injury, removal of a foreign body, inflammatory conditions or tumors, is the same. The nature of the anesthesia will be seldom influenced by the nature of the disease.

Care must be taken to infiltrate a sufficiently large area around the operative field, allowing a certain amount of play, as it were, so as not to be cramped for room, for which reason the lines for circuminjection should never be too near the line of incision. That no injections should be made too near diseased tissues has been repeatedly mentioned, and injection into the diseased tissues themselves is, of course, not permissible. This latter applies particularly to septic infections. A small circumscribed furuncle can be injected in the form of a pyramid if the inflamed tissues are avoided; diffuse phlegmons are only suitable for anesthesia when nerve blocking can be accomplished some distance from the operative field. Local anesthesia is not contra-indicated for malignant growths if the entire operative field can be excluded without injecting into the immediate neighborhood of the tumor.

In excision of cystic tumors, retention cysts, bursæ, etc., it is sometimes advisable to deviate from the rule of completing the injections before operation, if the injection is made with difficulty. In these cases the approach to the cyst is made insensitive, and, after opening it, the surrounding parts are infiltrated from its inner surface before resecting the sac. Naturally, after making the second injection time must be given for it to act.

It is needless to say that the operative fields most suitable for this method of anesthesia are those where innervation can be readily interrupted, as will be specified in the following chapters. The anesthesia of synovial membranes in aseptic joint operations has already been mentioned on page 147. Anesthesia for fractures and dislocations will be described according to the method of Quénu and Lerda in Chapter XVI.

CHAPTER XI.

OPERATIONS ON THE HEAD.

The head receives its sensory innervation chiefly through the trigeminus nerve. The occipital region, region of the ears, and the under border of the lower jaw also receive innervation from the spinal nerves (occipitalis major and minor, auricularis magnus, and cutaneus colli). The trigeminus nerve innervates, besides the skin of the face, the bones and cavities of this part and the organs contained in them. The base of the tongue, pharynx, middle and inner ear are innervated by the glosso-pharyngeal nerve, while the vagus supplies the sensory innervation to the outer ear and drum.

OPERATIONS UPON THE SCALP, FOREHEAD AND SKULL.

As will be noted in Fig. 33, the sensory nerves supplying the forehead, temporal region, and the scalp emerge and pass through the fascia and skin on a line approximately drawn from the occipital protuberance to the eyebrow, encircling the skull. They pass in a direction toward the crown of the head where they subdivide. In this entire distribution the nerves are subcutaneous, that is, subfascial; for which reason an anesthetic area of any desired extent can readily be produced by interrupting these nerves. These same nerves innervate not only the skin and fascia but likewise the bone and periosteum of the crown of the head. The dura mater is only sensitive toward the base of the skull. The brain, as has been previously mentioned, is insensitive to all irritation (see page 35). For this reason the simple subcutaneous or subfascial circuminjection is sufficient to render anesthetic an operative field of any desired size for skull and brain operations. Only in those places where the skull is covered by muscle layers will it be found necessary to anesthetize these structures by an additional line of infiltration anesthesia. The circuminjection of a line running bilaterally from the eyebrows above the outer ear to the occipital region will render the entire top of the skull insensitive. The modern anesthetic agents permit us to inject an area of this extent without fear. Subperiosteal injections are never necessary and serve no purpose.

The circuminjection with novocain-suprarenin solution serves not only for producing anesthesia, but inasmuch as the arteries supplying the skull run radially in the same direction as the nerves, they will undergo contraction, and as a result the operative field will be rendered bloodless. For this reason local anesthesia in skull operations makes the use of various devices for stopping hemorrhage unnecessary, such as the temporary suturing of the scalp alone (Heidenhain), or in connection with metal plates (Kredel), or the clamping of the wound margins with spring clamps (Vorschuetz). Complete interruption of the circulation does not occur and should not occur from this method of injection. The larger arteries bleed slightly and must be ligated; hemorrhage from the smaller vessels, however, is absent. This method in skull operations is sufficient and possesses many advantages over the unsatisfactory provisional methods for stopping hemorrhage.

Fig. 33.—Points of emergence of the nerves of the head through the fascia and their course under the skin and aponeurosis of the occipitofrontalis muscle. 1, frontal; 2, supra-orbital; 3, zygomaticotemporal (second branch of the trigeminus); 4, auriculotemporal (third branch of the trigeminus); 5, auricularis magnus; 6, occipitalis minor; 7, occipitalis major; 8, supra- and infratrochlearis; 9, infra-orbital; 10, external nasal branches of the ethmoidal; 11, mental nerve.

For the circuminjection of small operative fields the 0.5 per cent. novocain-suprarenin solution is sufficient, but in larger and more vascular areas the use of 1 per cent. novocain-suprarenin solution should be preferred owing to its better blood-stilling properties.

Brain Puncture.—A wheal is made at the point of the contemplated puncture and an injection of a few cubic centimeters of a 0.5 per cent. novocain-suprarenin solution is made beneath this wheal.

Extirpation of Atheromata.—Two points for injection are chosen which correspond to the ends of the proposed line of incision (Fig. 34). From these points injections are made in a rhombic or quadrilateral form, injecting 10 to 30 c.c. of a 0.5 per cent. novocain-suprarenin solution in the direction of the dotted line.

Fig. 34.—Anesthesia for an atheroma of the skull.

Methods to be Used in Extensive Injury of the Soft Parts, or Complicated Fractures of the Skull.—In the neighborhood of the injury a number of points of entrance are marked by wheals which completely surround the operative field. As shown in Fig. 35, six points are made. They should not be farther separated from one another than the curvature of the skull will permit in connecting these points with a straight needle beneath the fascia. From these points the loose subfascial tissue should be injected in the form of a narrow line completely surrounding the operative field in the direction indicated by the dotted line and infiltrated with a 1 per cent. novocain-suprarenin solution. After the injection the skin of the injected strip is raised in the form of a narrow wall above the surface of the surrounding skin. In one or two minutes, however, this elevation disappears. About 5 c.c. of this solution should be injected to each 5 cm. of the proposed line of injection. In this instance about 40 c.c. of a 1 per cent. novocain-suprarenin solution will be necessary. In all cases the line of circuminjection must be so made that all accessory incisions, no matter how far removed from the wound, will be included within this area before beginning the operation. The anesthesia of this operative field is complete after a few minutes.

In very severe head injuries, in which the patient is comatose, anesthesia of any sort is unnecessary, while in those partially conscious it may at times be necessary to use light general anesthesia in addition, but even in these cases we use the method of circuminjection on account of the bloodlessness of the operative field. For the repair of the majority of head injuries general anesthesia is unnecessary.

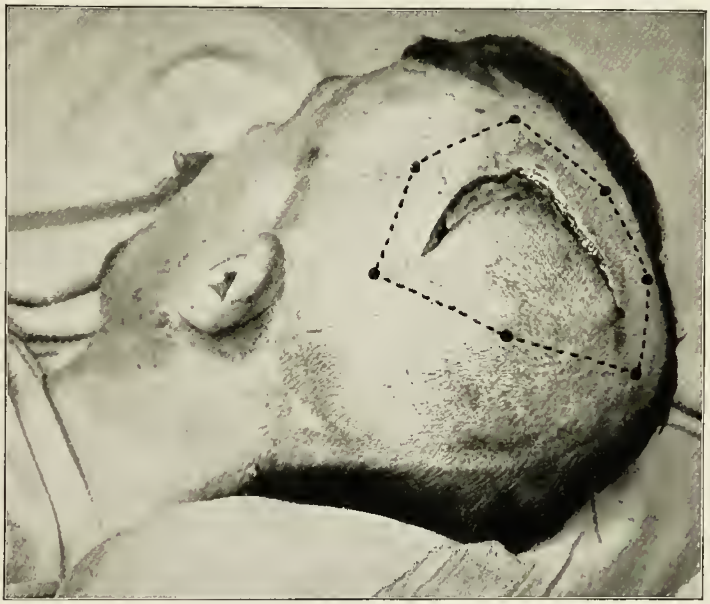


Fig. 35.—Circuminjection of a complicated fracture of the skull.

Extirpation of a Rodent Ulcer of the Scalp with Resection of the Skull.—In this case the tumor was removed along with a section of bone $7\frac{1}{2}$ c.c. in diameter; the dura was, as usual in this region, insensitive. Fig. 36 shows the patient after healing; the skin defect was covered by epithelial grafts. This operation was done in 1905 in the days of cocain anesthesia, and was probably the first resection of the skull performed under local anesthesia. The circuminjection as shown in the figure was carried out from six points 30 c.c. of a 0.2 per cent. cocain solution with 0.1 mg. of suprarenin were used. At the present time 30 to 50 c.c. of a 1 per cent. novocain-suprarenin solution would be used.

Extensive Resection of the Skull with Repair of the Dura and Plastic Skin Flap.—The case was one of a large carcinoma of the right side of the roof of the skull, springing from the periosteum and adherent to the skin (Fig. 37). This large defect after the extirpation was covered with a pediculated skin flap taken from the left side of the occipital region; no attempt was made to replace the bone. For this purpose the

FIG. 36.—Circuminjection for resection of the skull for rodent ulcer.

FIG. 37.—Sarcoma of the skull, showing half of the circuminjection figure. The other half includes the flap used for plastic repair of defect.

entire roof of the skull was surrounded by a line of infiltration, only half of the points for injection and line of injection being shown in Fig. 35. Above the zygoma and in the occipital region the parts were injected not only subcutaneously but also intramuscularly, as will be more fully described in the next case; 75 c.c. of a 1 per cent. novocain-suprarenin solution were used.

This operation, which was performed in 1911, was painless and free from an appreciable loss of blood. The skin surrounding the tumor was incised and the bone in the same area was outlined with Borchardt's forceps; the dura was finally excised, as it was found to be adherent to the tumor. As usual, the excision of the dura in the temporal region above the zygoma caused slight pain, whereas its separation from the upper portion of the skull was absolutely insensitive. Fig. 38 shows the tumor with the resected portion of the dura adherent to it. Fig. 39 shows the patient

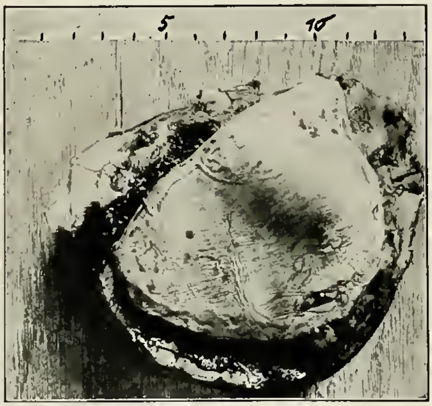


Fig. 38.—Sarcoma of the skull, showing section after removal.

after removal of the tumor. The flattening of the exposed surface of the brain due to the pressure of the growth is easily observed. Fig. 40 shows the patient with the skin flap ready to be placed in position. This was done after the defect in the dura was closed by a piece of the fascia lata, which was also removed under local anesthesia. The patient is sitting upright on the operating-table unaided, save for the head, which is being held by an assistant for the purpose of being photographed. The operation was concluded by sewing the skin flap in the defect of the right half of the scalp, and covering the secondary defect by epithelial grafts taken under local anesthesia.

Fig. 41 shows the patient after healing, which occurred by primary intention, with the exception of a small marginal area of the transplanted flap which became gangrenous. Although the transplanted piece of fascia was exposed to the air for a time

Fig. 39.—Sarcoma of the skull, showing patient after removal of the tumor.

Fig. 40.—Sarcoma of the skull, after transplantation of fascia for covering the defect in the dura, and the skin flap separated.

it nevertheless retained its vitality and became covered with epithelium. The photographs show that the hemorrhage was very slight owing to the use of local anesthesia.

FIG. 41.—Sarcoma of the skull, showing patient after healing.

Resection of the Skull in the Temporal Region.—The auther has frequently performed operations in this region, usually for the purpose of removing an epidural hematoma, and once for the removal of a foreign body which lay exactly in the centre for speech, after which the motor aphasia disappeared. Everyone of these operations demonstrated the fact that the dura toward the base was distinctly, if only slightly, sensitive to pain. Fig. 42 shows the arrangement of the wheals and the circuminjection figure used in the excision of a bone-muscle flap in the temporal region. Point 1 lies in the middle of the upper border of the zygoma and from this point a 0.5 or, better, a 1 per cent. novocain-suprarenin solution is injected not only subcutaneously in the direction of the dotted line indicated in the diagram but also transversely, the line of infiltration extending through the temporal muscles, according to Fig. 43. The cut shows schematically a transverse section through the skin, temporal muscle and temporal bone made from wheal 1; this line corresponds to the upper border of the zygoma and parallel with it. From point 1, the needle is first inserted perpendicularly to the skin surface until it reaches the bone (arrow 1), then in a more oblique direction toward the anterior and posterior edge of the temporal muscle, until bone is again felt (arrow 2). The injections are all made in the same horizontal plane. Finally, the last injection is made beneath the subcutaneous connective tissue (arrow 3) toward points

2 and 6 (Fig. 42). For the injection from point 1, about 30 c.c. of the solution are necessary; for the subcutaneous circuminjection of the operative field another 30 c.c. Therefore at least 60 c.c. of novocain-suprarenin solution are necessary for the entire injection.

Fig. 42.—Wheals marking the points for injection and the location of the skin incision for resections of the skull in the temporal region.

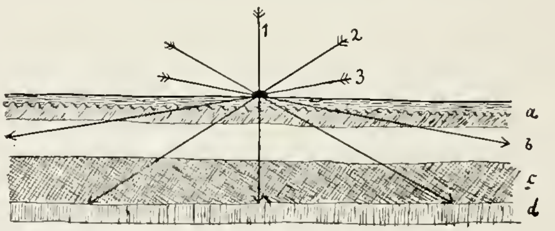


Fig. 43.—*a*, skin; *b*, subcutaneous connective tissue; *c*, cross-section of the temporal muscle; *d*, temporal bone.

Krause has recently reported the excision of the Gasserian ganglion under local anesthesia, with the patient previously prepared by the administration of pantopon-scopolamin. It is advisable in this operation not only to circuminject the field of operation but also to block the mandibular nerve in the foramen ovale or to inject the Gasserian ganglion direct, according to the method of Haertel. This method will scarcely require further consideration, as it is possible to reach the trunk of the trigeminus at its point of exit, or puncture the ganglion direct, after which alcohol is injected, which destroys the ganglion without extirpating it.

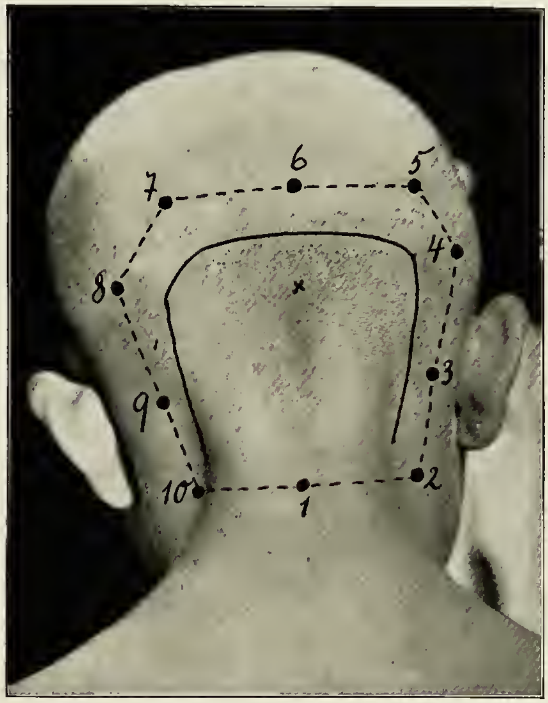


Fig. 44.—Wheals marking the points for circuminjection for exposure of the cerebellum.

Exposure of the Cerebellum.—The author has performed this operation 5 times under local anesthesia without causing any pain whatever. Like success was also noted in two previous case reports. The simultaneous suprarenin anemia is of the greatest importance in these operations, as it makes it unnecessary to postpone opening the skull until a subsequent time. Fig. 44 shows the arrangement of the points for injection and the line of incision for the exposure of both hemispheres of the cerebellum. It is advisable not to depart from the arrangement as shown in the diagram even if only half of the cerebellum is to be operated upon. The points 3 and 9 lie immediately back of the base of the mastoid process. From these two points, as well as from the points

1, 2, and 10, the necessary injections are made into the muscles of the neck. The object of these injections is to infiltrate the muscle layers with suprarenin solution in a cup-shaped manner, which isolates the operative field from the rest of the body. The operative field itself is not injected. The direction of the needle in this injection is analogous to that of the temporal muscles (Fig. 43). The needle-point must always be inserted as far as the transverse processes of the cervical vertebræ and the occiput. The connections of the various points of injection are made subcutaneously. It will be necessary to use between 100 to 120 c.c. of solution, more than half of which is used for the injection of the muscles of the neck. The 0.5 per cent. novocain-suprarenin solution will cause complete anesthesia and anemia. The dura of the posterior fossa of the skull and cerebellum are insensitive.

In resections of the skull under local anesthesia the use of the chisel should be limited as far as possible, as its manipulation is very unpleasant to the patient. The use of morphin, pantopon-scopolamin, etc., in patients with brain injuries and affections causing pressure should be avoided owing to the unfavorable action on the respiratory centre. If the operator confines himself to the use of the saw and bone-forceps, patients do not complain of skull and brain operations carried out under local anesthesia.

Bier has recently reported operations on the cerebrum under local anesthesia. He found that the irritability of the cortex was diminished, even though the injections were made on the outer surface of the skull. If this observation proves to be correct, local anesthesia will not be suitable in operations for epilepsy.

OPERATIONS UPON THE ORGANS OF HEARING.

The muscles of the ear are innervated by the auricularis magnus, auriculotemporalis, occipitalis minor, and the auricular branch of the vagus. The skin and bony canal of the ear as well as the outer surface of the drum are innervated by branches of the auriculotemporalis and the auricular branch of the vagus passing from the skin and bony canal into the organs of hearing. The inner surface of the drum, the mucosa of the antrum, epitympanic recesses, and the Eustachian tube are innervated by the tympanic branch of the glossopharyngeal nerve. The mucous membrane of the mastoid cells and of the antrum of the tympanum is innervated by the nervus spinosus, a branch of the mandibular, which passes from the cranial cavity through the petrosal fissure into the temporal bone.[1]

[1] It is impossible for the author at this time to consider extensively anesthesia in connection with the so-called special operation, as he has not had sufficient personal experience.

Anesthesia of the Membrana Tympani.—The ear-drum reacts but slightly to anesthetic agents (cocain or alypin) applied to its surface, owing to its protective epidermis. Applications of carbolic acid are much more effective (Bonain), or a combination as recommended by Hechinger can be used, which consists of acid. carbol. 0.5, cocain muriat. menthol āā 2.0, alcohol 10.0. This solution is applied to the drum by means of small tampons.

Paracentesis and incision of furuncles can usually be made without pain. Tiefenthal, for anesthetizing the drum for paracentesis, injected 2 to 4 drops of a 5 to 10 per cent. cocain-suprarenin solution with a fine needle into the tympanic cavity. Albrecht used cataphoresis for anesthesia of the drum. He saturated a cotton applicator, attached to the positive electrode with a 20 per cent. cocain solution and applied it to the drum. After three or four minutes it was insensitive.

FIG. 45.—Van Eicken's injection for anesthesia of the auditory canal.

FIG. 46.—Anesthesia of the muscles of the ear.

Anesthesia of the External Auditory Canal.—Complete anesthesia of the external auditory canal can easily be obtained by an injection of the anesthetic near the bone, both in front of and behind the canal, as recommended by Eicken and Laval. By means of this injection the vagus and auriculotemporalis, which supply the auditory canal, are blocked. The point for injection lies in front of the tip of the mastoid behind the attachment of the ear. The lobule is drawn forward and outward, the needle is then directed along the anterior surface of the mastoid process, passing the auditory canal, to the temporal line; 1 or 2 c.c. of a 2 per cent. novocain-suprarenin solution are injected. The needle is then passed in a line near the front of the auditory canal and back of the maxillary articulation as far as the junction of the zygoma with the temporal bone (Fig. 45). In making the anterior injection, Eicken and Laval recommend that the mouth be open, so that the head of the inferior maxillary bone will be pushed forward. Sensation in the drum will be diminished after this injection but not entirely lost.

Anesthesia of the External Ear.—By means of a subcutaneous injection carried out from two points around and under the attachment of the ear (Fig. 46), using about 20 c.c. of a 0.5 or 1 per cent. novocain-suprarenin solution, the entire external ear may be rendered insensitive.

Anesthesia of the Tympanic Cavity.—In case of destruction of the drum the mucous membrane of the tympanic cavity can be anesthetized by dropping into the ear a few drops of a 10 to 20 per cent. solution of cocain or alypin. The complicated shape of this cavity makes it difficult to obtain an even distribution of the anesthetic which not infrequently interferes with complete anesthesia. Tiefenthal's injection through the unruptured drum has already been mentioned. Neumann claims that if fluid be injected beneath the upper wall of the external auditory canal, the soft parts will be separated from the bone and the fluid must pass under the drum membrane and the mucous membrane of the tympanic cavity, and in this manner cause both the drum and the tympanum to become completely anesthetized.

Neumann has described this injection as follows: The needle is passed through the cartilage and beneath the periosteum of the upper wall of the external auditory canal about 0.5 to 1 cm. from the beginning of the bony part. This point of injection can be readily determined by moving the ear up and down, the cartilaginous portion forming a fold where it adjoins the bony part. Another means of distinguishing this boundary is the difference in appearance between the cartilaginous and the bony part of the canal. The former appears dull, while the latter is glossy. After fixing the point for injection, the needle is passed in an oblique direction upward until the bony canal is felt; the anesthetic solution is then injected under medium pressure. It will be necessary to wait about ten minutes before anesthesia is complete.

The method of Neumann has been used with marked success in Politzer's clinic for operations upon the internal ear, as in the removal of the hammer and anvil, etc. Gompertz, Thies, Halacz, Barany, Harley, and others, have stated that a very satisfactory anesthesia of the drum and tympanic cavity can be obtained by means of the Neumann injection in combination with the application of strong anesthetics.

The Chiselling of the Mastoid Process, Opening of the Tympanic Cavity and the Radical Mastoid Operation.—We will now consider the most extensive of these operations, which will suffice for all the minor operations in this region. The attempts of Alexander to perform the radical mastoid operation by means of Schleich's infiltration anesthesia has not found many followers. It was through the work of Neumann that progress was made in this direction, which consisted in the circuminjection of the external auditory canal, as already described by Eicken and Laval, combined with anesthesia of the drum and tympanic cavity by means of the Neumann injection, thus producing complete anesthesia of the ear muscles, the soft parts overlying the bone, and the internal ear. Kulenkampff used this method in his series of 30 radical operations. The author has also used this method and can state that the results have been very good in cases in which the above-mentioned technique has been carried out. He also recommends the following procedure, which in principle has been suggested by Neumann:

With the patient's head lying on the healthy side, begin by instilling a few drops of a 20 per cent. alypin or cocain solution with the addition of suprarenin into the external auditory canal. Inasmuch as the drum is usually destroyed, the solution itself enters the tympanic cavity and can act upon the mucous membrane during the subsequent injection. This is not always necessary.

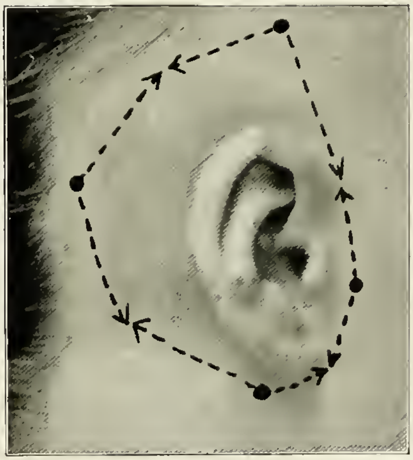


Fig. 47?—Circuminjection of the operative field for the radical mastoid operation.

The circuminjection of the entire operative field is carried out from 3 or 4 points as shown in Fig. 47. It will be necessary to use 40 c.c. of a 0.5 per cent. novocain-suprarenin solution for this injection, more than half of which should be used along the lower border of the operative field in the region of the occipital and great auricular nerves. Injections in the line of incision, as recommended by Neumann, are not necessary. The photograph, as shown in Fig. 48, was made immediately after the injection and shows this surface raised above the surrounding skin; this condition disappeared within a few minutes. It will now be necessary to anesthetize the auditory canal, which is done in the following manner: With the ear drawn for-

Fig. 48.—Appearance of the operative field for the radical mastoid operation immediately after injection

Fig. 49.—Position of the point of injection back of the auditory canal.

ward, a point of entrance is marked just behind the ear (Fig. 49), the needle is passed along the anterior surface of the mastoid process as far as the bony canal, and 2 c.c. of a 2 per cent. novocain-suprarenin solution injected. This injection requires considerable pressure, for which reason the solution will be evenly distributed around the entire canal. This is followed by the previously described Neumann injection (2 c.c. of a 2 per cent. novocain-suprarenin solution) in the upper wall of the canal. The latter is painless because the canal has already been rendered insensitive. It is also necessary to make an injection of 1 to 2 c.c. of a 2 per cent. novocain-suprarenin solution from within, along the anterior wall of the canal.

If this injection has been properly made, the incision of the soft parts, the separation of the periosteum, the separation of the membranous portion of the canal from the bony portion, and any plastic incisions, will be absolutely painless. Following the suggestion of Dr. Kulenkampff the latter incision should be completed before beginning the operation on the bone, which permits a much better approach to the rest of the field of operation. If a traction suture is passed through the membranous part of the canal, after its incision, the ear and canal can be easily held forward without the aid of hooks. The chiselling of the mastoid process and the opening of the antrum is entirely free from pain. In fact these parts do not seem to be possessed of marked pain sense. Anesthesia of the tympanic cavity may be imperfect and it may be necessary, after the separation of the membranous canal, to apply a 20 per cent. alypin or cocain-suprarenin solution to the mucous membrane. The region of the tube nearly always remains sensitive. The anemia of the operative field is of marked advantage in this operation, and makes possible the previously mentioned plastic incision at the beginning of the operation. The drawback to this method of operating is the very unpleasant sensation to the patient from the use of the chisel. If the surgeon selects his cases, excluding the nervous and excitable ones, he will find that the majority of radical operations can be carried out with perfect satisfaction to both the patient and the operator if morphin or morphin-skopolamin precedes the anesthetic.

The opening of the mastoid process and the antrum under local anesthesia was attempted before this method was tried for the radical operation (Reclus, Schleich, Scheibe, Thies, Alexander, Neumann). Inasmuch as these cases usually belong to the acute septic type, it is well to consider carefully the advisability of injecting into such an operative field. According to the author's judgment there must be very definite conditions contra-indicating the use of general anesthesia before local anesthesia should be attempted. At any rate, this method of anesthesia will be used much more frequently in the radical operation than in cases of acute otitis. In perforation of phlegmonous suppurations these injections are not permissible.

For the opening of the antrum the Neumann injection is not necessary, and the operator should proceed as in the radical operation. For the simple opening of the mastoid cells, infiltration of the soft parts is sufficient.

Attempts have been made to block the glossopharyngeal nerve at the base of the skull by injections through the mouth, but without result. However, Hirschel has apparently succeeded in blocking the glossopharyngeal and vagus by means of an injection between the condyle of the lower jaw and the mastoid process. Whether it will be possible to block the upper branches supplying the organs of hearing remains to be seen.

Blocking of the Trigeminus Nerve.—The blocking of one or more branches of the trigeminus nerve is advisable in nearly all operations upon the face which are not confined to the skin or subcutaneous tissue. The blocking can be carried out, according to the demands of the operation, either at the points of exit of the nerve trunks at the base of the skull in the course of one or more of their branches, or intracranial in the Gasserian ganglion itself.

Anesthesia of the trigeminus nerve at the base of the skull was first performed by Matas in the foramen rotundum. Bockenheimer, at the suggestion of Payrs, likewise carried out this procedure. The first contribution and description of several operations upon the face was published by Peuckert. The method has since been materially improved following the introduetion by Schloesser of alcohol injections in the treatment of trigeminal neuralgia, and by the work of Haertel. We are indebted to Offerhaus for his important communications in reference to the technique of injection of the third branch of this nerve. He devised this method independently, following his experiments with alcohol injections. He likewise used anesthetic substances to render operations painless.

For the central trigeminus injection the long thin needles Nos. 5 and 6 (page 174) should be used. The needleholder as shown in Fig. 14 will be found very helpful with needles of this length.

Ophthalmic Nerve.—The peripheral branches on the forehead are easily reached by a subcutaneous injection of 5 to 10 c.c. of a 1 per cent. novocain-suprarenin solution made transversely above the eyebrows. Fig. 50 shows the extent of the anesthesia following this injection. The area of this anesthetic field is quite variable and the principle as previously laid down should always be followed, that in operations upon the forehead and scalp, large operative fields should always be circuminjected.

The trunk of the ophthalmic nerve cannot be directly injected, inasmuch as it usually divides into its branches, the lacrimal, frontal, and nasociliary, before entering the orbit. The nasociliary passes through the annulus tendineus into the apex of the orbit and innervates the eye (Fig. 51). Its two branches, the ethmoidal nerves, leave the apex of the orbit and pass into the anterior and posterior ethmoid foramen. The frontal and lacrimal lie entirely outside of the apex of the orbital wall, and like the ethmoidal nerves are inaccessible to injections in the posterior portion of the orbit.

The walls of that portion of the orbit which are straight and not concave are particularly suitable for injection, and serve as a guide for the needle to the orbital apex beyond the muscular covering, keeping the needle in constant contact with the bone. These conditions are found along the lateral walls and the upper portion of

Fig. 50.—Extent of absolute anesthesia after blocking the frontal branches of the ophthalmic nerve.

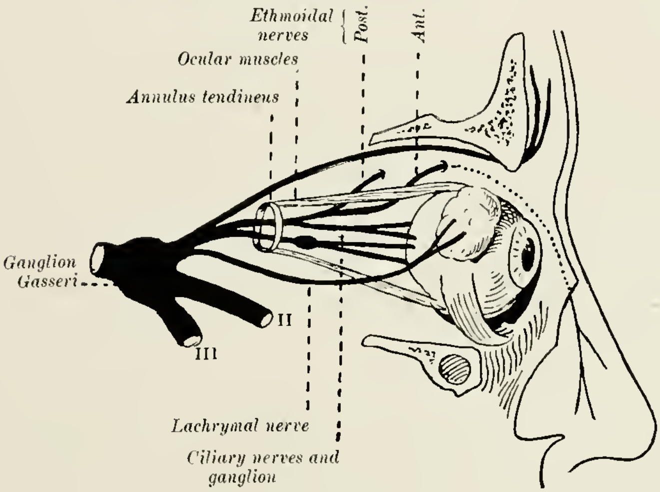


Fig. 51.—Diagrammatic course of the ophthalmic nerve. (After Corning.)

the median wall of the orbit. In other places where the point of the needle cannot be held in contact with the bone there is always danger of injury to the eye-ball. The use of curved needles cannot be recommended, as the exact location of the point is never known. The lateral point of injection lies immediately above the outer canthus of the eye. The needle is passed with its point constantly in contact with the bone to a depth of 4.5 to 5 cm. and here crosses the superior orbital fissure (Fig. 52). The point encounters the distal border of this fissure in the upper wall of the orbit which prevents its further introduction. About 2.5 c.c. of a 2 per cent. novocain-suprarenin solution is injected in the neighborhood of the superior orbital fissure.

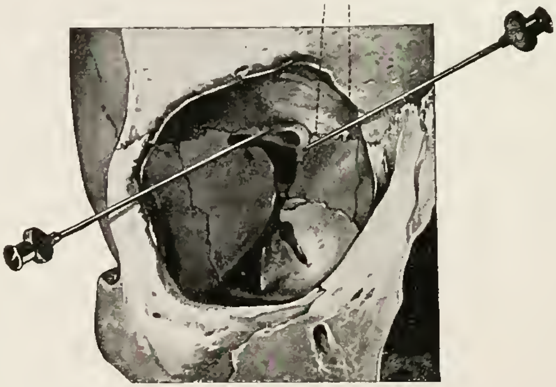


Fig. 52.—Median and lateral orbital injections.

The point of entrance for the median orbital injection lies one fingerbreadth above the inner canthus of the eye. The needle is again passed to a depth of 4 to 5 c.c., keeping it at all times in contact with the bone, and the same quantity of solution injected at this point.

The lateral orbital injection blocks the frontal and lacrimal nerves which is necessary in operations in the orbit and frontal sinuses. The frontal nerve and its branches can likewise be blocked farther forward in the orbit by injections made above the bulb.

The median orbital injection blocks the anterior and posterior ethmoidal nerves which supply the mucous membrane of the cribriform plate of the ethmoid, frontal, and sphenoid sinuses. Besides these parts the anterior ethmoidal nerve supplies a portion of the nasal mucous membrane (Figs. 79 and 80), and then passing from the nose at the junction of the cartilaginous and bony part is distributed in the skin of the tip of the nose and its surroundings (Fig. 33). The median orbital injection is, therefore, necessary in operations upon the nasal cavities and other accessory sinuses.

After the injection a mild, transient protrusion of the bulb and edema of the upper lids occurs. The injections into the orbit cause very little pain if the points for injection are first made insensitive by means of a wheal. The injected fluid is entirely outside of the muscular boundaries of the orbit, for which reason the sensory nerves of the bulb, ciliary nerves, ciliary ganglion and the optic nerve are not, as a rule, affected. If the nerves just mentioned are to be anesthetized the solution must be injected behind the bulb and within the muscle boundaries of the orbit (see page 232).

Serious disturbances following orbital injections and injury to the bulb are practically impossible. Small hematomata occur occasionally in the orbital fat, particularly following the lateral injections, but are of no consequence. Kredel observed amaurosis lasting ten minutes following an injection into the orbit. It is possible that this occurrence may have been more frequently observed than reports indicate, inasmuch as the optic nerve can be affected by the anesthetic as well as by the anemia consequent upon the use of suprarenin. Another case of temporary amaurosis following local anesthesia for empyema of the frontal sinuses has been reported by Jassenetzky. This condition occurred on the day following the operation and was due to an inflammatory edema of the orbit, and inasmuch as the case was a septic one, it is very questionable whether the injection had anything to do with the inflammatory symptom.

Maxillary Nerve.—The peripheral branches of this nerve are the infraorbital, superior, posterior, and median alveolar nerves. The latter penetrate the upper jaw posteriorly to the maxillary tubercle (see Fig. 95, page 257). Both of these branches are readily blocked.

The infraorbital foramen can be reached by passing a needle beneath the upper lip where the submucosa is reflected from the alveolar process along the anterior surface of the upper jaw to the point of emergence of this nerve, or, better, by passing the needle from without directly into the infraorbital foramen. The injection after either method is 2 c.c. of a 2 per cent. novocain-suprarenin solution. When passing the needle from without into the infraorbital foramen, a fine one should be used and inserted just beneath the lower orbital border and passed until it touches the bone, where a small quantity of a 2 per cent. novocain-suprarenin solution is injected, following which the opening of the canal is sought with the needle. The injection of 1 c.c. of a 2 per cent. solution is sufficient for blocking the nerve. Fig. 53 shows the extent of the anesthesia following a bilateral injection. The following structures are anesthetized: the lower eyelids, the upper lip, the larger part of the alæ of the nose (skin and mucous membrane), a part of the skin and mucous membrane of the cheek, the labial mucous membrane, the anterior portion of the upper alveolar process and its periosteum, the anterior wall of the upper jaw and the pulp of the central and lateral incisor teeth.

The superior, posterior, and median alveolar nerves are easily injected at the maxillary tubercle either from the mouth or from without. With the former method the needle is passed beneath the zygoma where it joins the superior maxillary bone beneath the mucous membrane to the posterior border of the upper jaw (see Fig. 97). The method of directing the needle from without will presently be described and is the same as used for injections of the foramen rotundum, only it is not necessary to pass the point of the needle into the pterygopalatine fossa. In either ease 5 c.c. of a 1 or

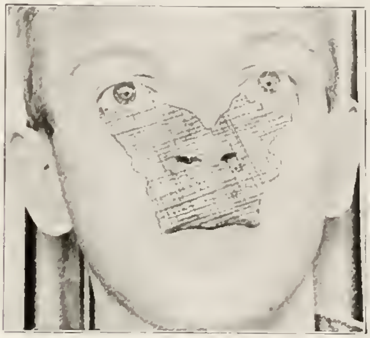


Fig. 53.—Extent of skin anesthesia following a bilateral injection into the infra-orbital foramen.

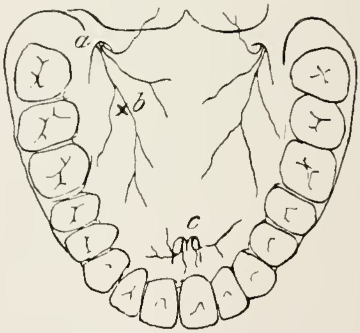


Fig. 54.—Innervation of the hard palate: *a*, ant. palatine nerve; *b*, point for injection; *c*, nasopalatine nerve. (Scarpa.)

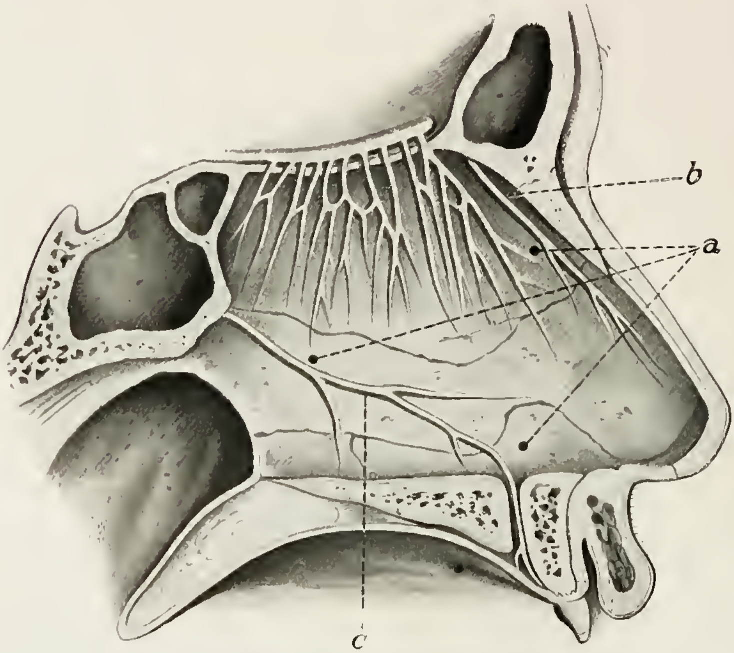


Fig. 55.—Anesthetizing the nasal mucous membrane according to the method of Killian: *a*, point of injection; *b*, ethmoidal nerve; *c*, nasopalatine nerve.

2 per cent. novocain-suprarenin solution is injected along the posterior border of the upper jaw, which produces anesthesia of the pulps of the molar and bicuspid teeth and mucous membrane of the antrum of Highmore.

The nerves supplying the hard palate can be readily interrupted by peripheral injections. These nerves are the anterior palatine and the nasopalatine. The former emerges from the foramen palatinum magnum in the neighborhood of the third molar tooth, and the latter from immediately behind the incisor teeth (Fig. 54). If a few

FIG. 56.—Injection of the foramen rotundum from without.

drops of a 2 per cent. novocain-suprarenin solution be injected beneath the covering of the hard palate back of the left central incisor, followed by 1 to 2 c.c. of the solution injected at the point marked *b* (Fig. 54), which is about 1 to 1.5 cm. from the gum-line and internal to the second molar tooth, anesthesia of the corresponding half of the hard palate, and its soft parts, the lingual side of the gums and the periosteum, will be obtained. The roots and pulp of the teeth in this neighborhood are not anesthetized by injections into these nerves.

Killian, by injections under the mucous membrane near the upper border of the vomer and upper border of the septum (Fig. 55), has attempted to anesthetize the peripheral branches of the first and second divisions of the trigeminus (ethmoidal and nasopalatine).

Matas was the first to attempt to anesthetize the maxillary nerve in the foramen rotundum. Before the introduction of suprarenin this was not possible owing to the large dose of cocain necessary for a protracted operation. His method was to pass the needle beneath the lower border of the zygoma and along the posterior surface of the upper jaw into the pterygopalatine fossa, which is simple and certain.

FIG. 57.—Injection in the foramen rotundum from without, showing the cork guide on the needle. The patient has a large root cyst of the left lower jaw and a similar cyst of the right upper jaw. This injection is being made for operation upon the latter.

This method was likewise used by Schloesser for the injection of alcohol. Fig. 56 shows the position of the bony parts and Fig. 57 the position of the needle after introduction through the face. The point of insertion of the needle lies immediately behind the lower palpable angle of the malar bone and is marked by a wheal. From this point the needle is pressed inward and upward; its point passes through the masseter muscle and then comes in contact with the superior maxillary tubercle and is forced carefully along the surface of this bone. The needle-point will occasionally strike the wing of the sphenoid, in which case the direction of the needle must be slightly changed or, if necessary, withdrawn entirely and another point of entrance made just back of the middle of the zygoma. The needle will then suddenly pass deeper into the pterygopalatine fossa and reach the nerves at a depth of 5 to 6 cm. At the same moment the patient will complain of radiating pain in the face, after which 5 c.c. of a 2 per cent. novocain-suprarenin solution is injected, moving the needle back and forth slowly. The needle is then partially withdrawn and 5 c.c. of 0.5 to 1 per cent. novocain-suprarenin solution is injected back of the upper jaw to cause a contraction of the branches of the internal maxillary artery.

The foramen rotundum may be reached by injections through the orbit (Fig. 58). Payr, after experimenting on the cadaver, advised this method in resections of the upper jaw.[1]

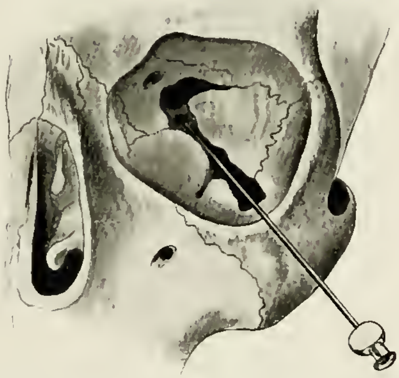


FIG. 58.—Injection at the foramen rotundum, through the orbit.

Upon Payr's suggestion, Bockenheimer anesthetized the second branch of the trigeminus and resected the same for neuralgia. During the past year the writer has used the orbital method in operations upon the teeth and antrum of Highmore, likewise for alcohol injections. The method is as follows: A point is chosen for injection where the lower edge of the orbit meets the outer edge. The needle is passed into the orbit at this point in an almost vertical direction, and kept in constant contact with the bone forming the floor of the cavity (Fig. 59). The inferior orbital fissure is now sought and recognized by the needle passing into it. As soon as this happens, the end of the needle is lowered so that it will assume a horizontal position (Fig. 60), which prevents it passing into the infratemporal fossa or into the orbital fat, which is also to be avoided. A false passage will be recognized by the absence of resistance to the progress of the needle. This resistance always occurs

[1] The author regrets having overlooked the reports of Payr and Bockenheimer, which, however, do not seem to have been applied practically to any extent.

when the proper direction is taken and causes immediate radiation of paresthetic sensations which frequently require the injection of a few drops of the novocain-

Fig. 59.—Injection at the foramen rotundum through the orbit.

Fig. 60.—Injection at the foramen rotundum through the orbit.

suprarenin solution. At a depth of about 5 cm. the needle will be in the foramen rotundum and there encounter the bony obstruction at the base of the skull.

After a successful injection, anesthesia will immediately occur in the entire area of distribution of the maxillary nerve. Injections which have been only partially successful require ten to twenty minutes before the full effect is obtained. After these injections the corresponding half of the face becomes anemic in consequence of the action of the suprarenin on the end branches of the internal maxillary artery.

One of the secondary effects which may follow injection into the pterygopalatine fossa, besides small hematomata on the posterior surface of the upper jaw, is paralysis of the muscles of the eye, particularly the oculomotor nerve, due to the needle occasionally passing through the inferior orbital fissure into the orbit. This paralysis disappears with the return of sensation. Although the dangers following injections for purposes of anesthesia are slight one must be particularly careful with alcohol injections. Alcohol must never be introduced until after the nerve has been blocked with anesthetics in order to prevent these secondary effects on the muscles of the eye.

Injection through the orbit does not cause paralysis of the muscles of the eye, inasmuch as the needle passes entirely out of the orbit, for which reason alcohol injections can be made much more safely by this route. Hematomata on the floor of the orbit and in the upper lid occasionally occur after orbital injections.

Mandibular Nerve.—There are two methods of injection for the third branch of the trigeminus, both of which are certain and bring about a rapid blocking of the nerve. The first consists in interrupting the inferior alveolar and lingual nerves by injection on the inner surface of the lower jaw into the region of the lingula; the other consists in blocking the nerve trunk in the foramen ovale.

Descriptions of the method of anesthetizing the inferior alveolar and lingual nerves at the lingula were given by Halsted and Raymond (1885). Raymond described an injection performed in this region, using 13 drops of a 4 per cent. cocain solution. After about seven minutes almost complete loss of sensation was observed in the right half of the tongue, gums, and teeth of the right lower jaw, so that cavities in the first molar tooth could be treated without pain. After about twenty-eight minutes sensation returned to normal. Schleich later directed attention to this method again. He used, however, dilute solutions of cocain with which he was unable to block the nerve trunk completely. Efforts were then made by dentists to block the inferior alveolar nerve at the lingula (Thiesing, Krichelsdorf, Dill, and Huebner) by means of cocain-suprarenin solution, and this method has now become one of the common procedures of the dentist. The technique of the operation is as follows:

The finger is passed into the mouth until it touches the ascending ramus of the jaw. At about 1.5 cm. lateral to the third molar tooth the sharp edge of the coronoid process can be recognized, which runs downward along the side of the third molar tooth and becomes lost in the oblique line (Fig. 61). Medially from this edge there is a small, three-cornered, concave, bony area covered with mucous membrane, directed

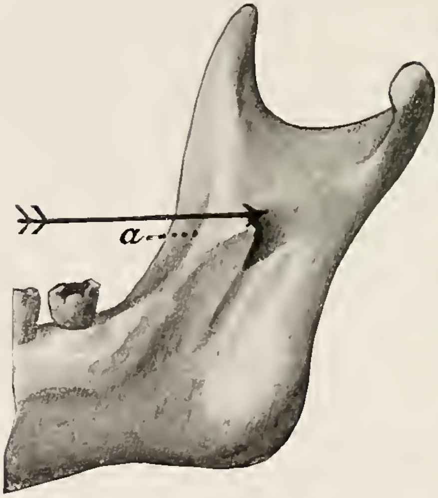


FIG. 61.—Injection at the lingula.

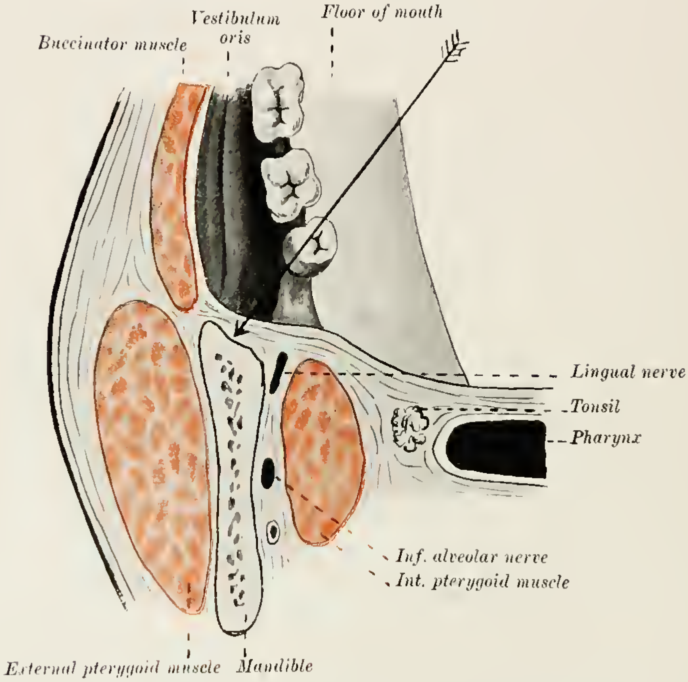


FIG. 62.—Cross-section through the ascending ramus of the jaw parallel to the biting surface of the teeth of the lower jaw. (From a preparation by the author.)

forward and inward, and toward its median side bounded by an easily palpated bony ridge (Fig. 61, *a*). This area has never received an anatomical name, but for purposes of description it can be called "trigonum retromolare." With the mouth closed this area lies to the inner side of the third molar tooth; with the mouth open it lies laterally to the upper and lower teeth and is easily accessible. The point of entrance is in the middle of the "trigonum retromolare," about 1 cm. above and a like distance laterally from the biting surface of the teeth of the lower jaw. A line through this point and the ascending ramus of the jaw, with its overlying soft parts, must be parallel to the biting surface of the lower molar teeth as shown in Fig. 62.[1]

In looking from above into the vestibulum oris the oblique line is seen on the posterior end of the lower alveolar process of the left side. With the three last molar teeth the tongue is seen on the floor of the mouth toward the median line. On the cross-section of the lower jaw the "trigonum retromolare" is observed in the anterior portion of the vestibulum oris. The lingual nerve lies immediately adjoining its inner edge, just under the mucous membrane. The inferior alveolar nerve is 1.5 cm. back of this point and is reached just after emerging from its bony canal above the lingula, lying in intimate contact with the bone. It is separated from the bone a little above this point, while below it is covered by the lingula. In order to anesthetize both nerve trunks proceed in the following manner: With the patient in a sitting posture and the mouth wide open the operator introduces the index finger of the left hand and locates the anterior border of the coronoid process and the "trigonum retromolare." The syringe and needle are held in the manner shown in Fig. 63 and remain in this position during the entire procedure. The needle is directed from the opposite lateral incisors toward the point of injection and held parallel to the biting surface of the lower teeth. The needle is inserted at the above-mentioned point 1 cm. above and lateral to the biting surface of the last molar tooth into the "trigonum retromolare." Immediately under the thin mucous membrane the bone should be felt. If this is not the case, the point of the needle is too far from the median line, a mistake frequently made by beginners. In this case the needle must be directed more toward the median line until the border *a* (Fig. 61) is felt. The needle finally passes along the inner surface of the lower jaw into the deeper parts. It must now be further inserted to a depth of 2 to 2.5 cm., keeping it always in contact with the bone. As soon as the needle begins to penetrate the region where the lingual nerve lies, 5 c.c. of 1 to 2 per cent. novocain-suprarenin solution should be injected.

Proceed with the injection, as shown in Fig. 63, using long needles, so that the discomfort occasioned by the introduction of the syringe into the mouth can be avoided. In no case should needles be so short that they can be lost to view during

[1] This line is horizontal only when the mouth is closed, not when it is open. These cuts have been made from decalcified bones and the finished specimens imbedded in celloidin.

the injection, as it is a very difficult matter to remove a broken needle from this area. The interruption of both nerves occurs as a rule in a few minutes and can be tested by the loss of sensation in the lower lip, the tongue, and the floor of the mouth.

Schloesser, for the injection of alcohol into the inferior alveolar nerve, passes a curved needle from without just under the end of the mastoid processes around the joint of the lower jaw to the lingula.[1]

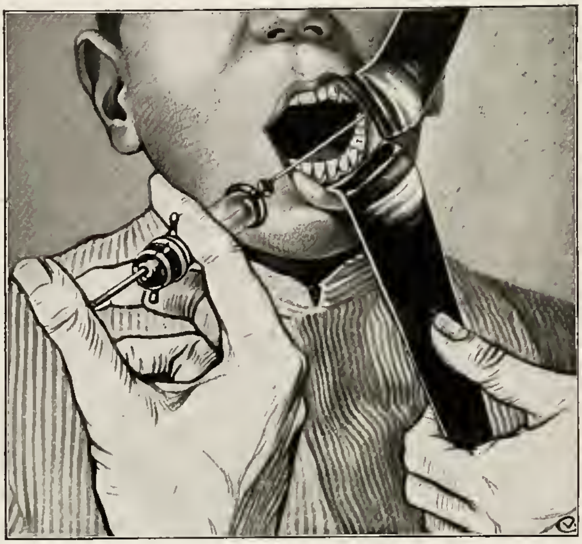


Fig. 63.—Injection at the lingula, showing the position of the syringe.

It is sometimes necessary to interrupt the end branches of the inferior alveolar nerve and the mental nerve. This can be accomplished by the injection of a 1 to 2 per cent. novocain-suprarenin solution into the mental foramen which, as a rule, is below the space between the first and second bicuspid teeth.

The shortest and most certain way of reaching the foramen ovale is from without, the needle being passed just below the border of the zygoma, and if the directions of Offerhaus are followed there is almost absolute certainty that the anesthetic solution will not only be injected around the foramen ovale but directly into the trunk of the mandibular nerve where it emerges from the skull.

Offerhaus found, after accurate measurement of 50 skulls, that the line (linea intertubercularis Fig. 64, *c*, *d*) connecting the articular tubercle lies just in front of the

[1] The writer has had no experience in the use of this method, and does not believe that the lingual nerve will be interrupted with an injection of this kind.

maxillary articulation, and intercepts the two points (*a* and *b*) which are just a few millimeters below and, as a rule, the same distance in front of both foramen ovale.

Inasmuch as the mandibular nerve after its emergence from the skull passes forward and downward, the intertubercular line crosses these nerve trunks exactly at the foramen ovale.

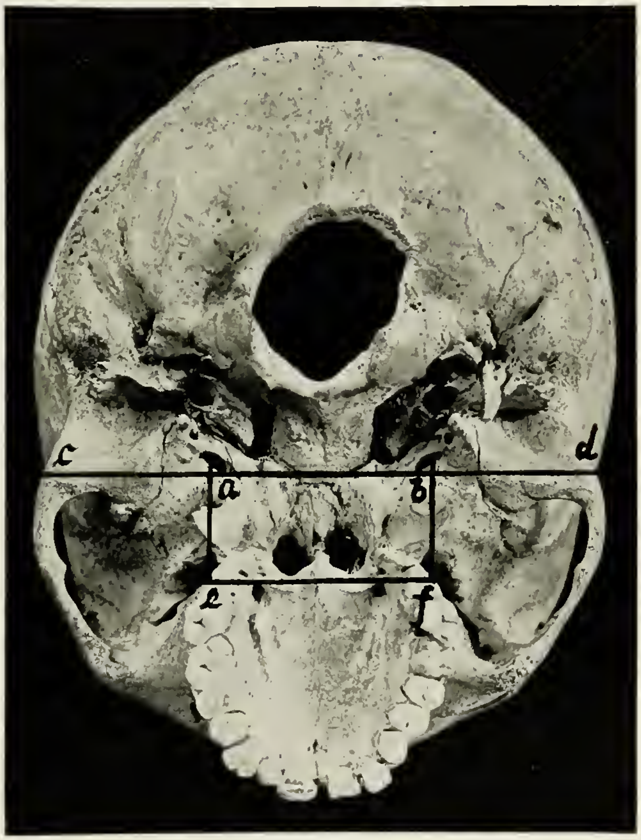


Fig. 64.—Skull measurements, according to Offerhaus, for the determination of the foramen ovale from the tuberculum articulare.

Offerhaus also noted that the distance between the alveolar processes of the maxilla measured from the outside behind the last molar tooth (Fig. 64, *e*, *f*) corresponds within a few millimeters to the distance between both foramen ovale, so that if the width of the alveolar processes is subtracted from the length of the intertubercular line, and this result divided by 2, the result will give within a few millimeters the distance of points *a* and *b* from the articular tubercle of the same side. According to the measurements of Offerhaus the minimum distance would be 3.6 cm. and the maximum 4.7 cm., the usual distance being 3.7 to 4.3 cm. In order to find the direction and length of the intertubercular line in the living patient, Offerhaus constructed the apparatus shown in Fig. 65. If the points of this apparatus are placed on both articular tubercles, the direction of the intertubercular line is indicated by the adjustable points of the instrument, and the distance between both tubercles is measured on the sliding scale.

Fig. 65.—Compasses of Offerhaus.

The injection is performed in the following manner: On the side where the injection is to be made, the articular tubercle is marked by a wheal, and the point on the opposite side marked with a blue pencil. The distance between the outer side of the alveolar process of the maxilla behind the last molar teeth is measured with ordinary compasses, and with Offerhaus compasses the length of the intertubercular line is determined. For example, if these distances are 5 and 14 cm., the points *a* and *b* will be $\frac{14-5}{2}$ = 4.5 cm. distant from the point of insertion of the needle. A small cork placed on the needle, about 1 cm. farther than the above-mentioned length will show how far the needle should be inserted and also allow for additional play. The needle, however, should never penetrate deeper than this. The Offerhaus compasses are again placed upon the head and the needle passed into the tissues in the direction indicated by the points on the compasses. The direction of the needle is indicated in Fig. 66, needle 1. Exactly at the point determined, the patient will complain of radiating pains in the lower jaw. As a rule, the resistance of the thick nerve trunk can be felt at the needle-point, and at times the needle can be pushed into this trunk. After the needle is in the nerve trunk a very few drops of a 2 per cent. novocain-suprarenin solution are sufficient; if near the nerve trunk 5 c.c. of this same solution are injected. The blocking of the nerve often occurs instantaneously, but never requires more than five to ten minutes.

Fig. 66.—Guidance of the needle for injection at the foramen ovale: 1, according to Offerhaus; 2, according to Braun.

The following description of the injection of the foramen ovale is somewhat simpler than the above: The point of entrance for the needle is marked just below the middle of the zygoma (Fig. 66, 2), and the needle inserted in an almost transverse direction. This direction is easily determined by holding a skull with the direction marked by a sound along side the head of the patient. At a depth of 4 to 5 cm. the end of the needle touches the bone, the pterygoid process (Fig. 66). In this injection the needle is about 1 cm. distant from the foramen ovale. This distance is marked on the needle with the movable piece of cork. The needle is then withdrawn as far as the subcutaneous connective tissue, and is passed back again at a slight angle to the same depth and possibly a few millimeters more. The characteristic radiating pains will then occur.

This last method can be further simplified by computing the depth at which the foramen ovale is found. As a rule the author combines both methods in directing the needle, but passes it somewhat more anteriorly than Offerhaus, feeling for the base of the pterygoid process. Then, as already mentioned, the needle is directed slightly backward and inserted 0.5 to 1 cm. more than the previously computed distance. Hematomata or other secondary effects never follow injections into the foramen ovale when made from without.

The methods described by Ostwalt and Schloesser for the injection of alcohol into the foramen ovale cannot be compared with the method just described for certainty and freedom from danger. In this method Ostwalt passes a long angular needle through the wide-open mouth behind the last molar tooth through the external pterygoid muscle, and, by using the external lamina of the pterygoid process as a guide, reaches the foramen ovale. Schloesser for like purposes locates with the finger in the mouth the lower end of the wing of the sphenoid, passing a long straight needle through the cheek, coming out just below the finger in the mouth, and then through the mucous membrane and under the finger toward the wing of the sphenoid above, until the resistance of the base of the skull is felt. The needle-point must now lie a few millimeters in front of the foramen ovale.

Haertel has described a very exact method for directing the needle in puncture of the Gasserian ganglion, which is in part similar to Schloesser's. His method is likewise of great value in the interruption of the third branch of the trigeminus.

Puncture of the Gasserian Ganglion.—Frequently after the injection of anesthetic solutions, and almost regularly after alcohol injections into the trunk of the mandibular nerve in the foramen ovale, sensory paralysis takes place not only in the second branch of the trigeminus but the first is also affected. This can only be explained by the theory that the fluid injected into the nerve trunk is disseminated into the Gasserian ganglion.

Haertel[1] completed experiments begun by Schloesser, Ostwalt, Harris, and Offerhaus for the passing of the needle into the foramen ovale and Gasserian ganglion.

It is necessary in this technique to pass the needle as nearly parallel to the course of the mandibular nerve as possible. This has already been mentioned by Ostwalt and Schloesser, but Haertel avoids the possibility of infection by not passing the needle into the mouth.

[1] Dr. Haertel was kind enough to loan the illustrations shown in Figs. 65 to 67. The writer unfortunately has not been able to describe in detail at this time the results in connection with his work on the puncture of the trigeminus trunk and the Gasserian ganglion.

Fig. 67 shows the position of the needle in the skull. A No. 6 needle 9 to 10 cm. in length should be used. About 3 cm. lateral to the corner of the mouth a wheal about the size of a dollar is injected, so that the puncture can be changed in case of necessity without causing pain. With the finger in the mouth as a guide, the needle is now passed from the above-mentioned point beneath the mucous membrane of the mouth, then upward between the ascending ramus of the jaw and the maxillary tubercle until the point reaches the smooth, hard infratemporal surface just in front of the foramen ovale. The operator feels with the end of the needle, observing the

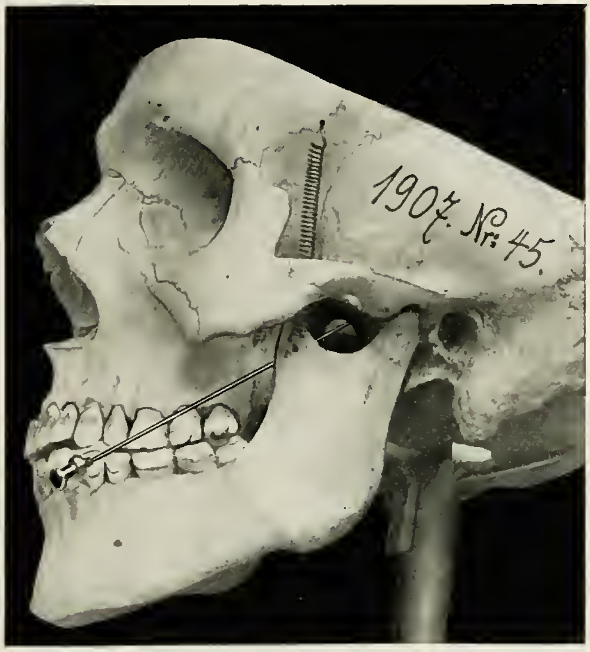


FIG. 67.—Puncture of the Gasserian ganglion. Position of the needle in the skull.

following points: the position of the opposite Gasserian ganglion, the long axis of the orbit, and the line connecting the articular tubercle of the zygoma. If the patient is viewed from the front, the needle should lie in a plane intersecting the pupil of the eye of the same side (Fig. 68). Viewed from the side the needle should lie in a plane interseeting the articular tubercle (Fig. 69).

It is very essential to locate the infratemporal plane so that the needle will not be passed behind the foramen ovale. To guard against this it is best to pass the needle in the plane intersecting the pupil, as shown in Fig. 68, sharply upward so that when

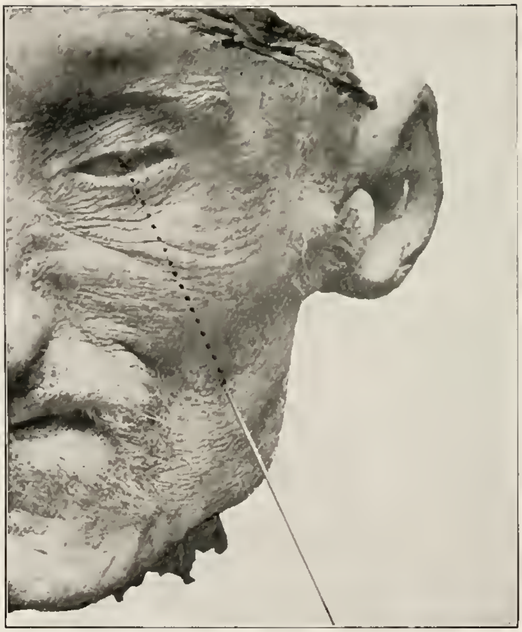


Fig. 68.—Puncture of the Gasserian ganglion, viewed from in front.

Fig. 69.—Puncture of the Gasserian ganglion, viewed from the side.

viewed from the side the plane of the needle instead of intersecting the articular tubercle intercepts the middle of the zygoma. The hub of the needle is then gradually raised, keeping it always in the plane of the pupil, until the point of the needle passes behind the infratemporal plane. These manipulations become clear if they are carried out on the cadaver, with a skull alongside as a guide. Fig. 70 shows a patient with the needle in the ganglion. Radiating sensations in the lower jaw is evidence that the mandibular nerve is located. The distance from the point of entrance to the foramen ovale is 5 to 7 cm. The needle is inserted for 1 to 1.5 cm. farther in the same direction until the patient complains of paresthesia in the upper jaw.

Fig. 70.—Needle in ganglion preparatory to the injection of alcohol.

The foramen ovale can be reached objectively, independent of any statement from the patient, and its position readily determined from the manner in which the needle suddenly passes into the depths behind the infratemporal plane. The Gasserian ganglion can, therefore, be punctured under general anesthesia, which is of the utmost importance in the treatment of very severe trigeminal neuralgia. As soon as the needle is properly placed, 0.5 to 1 cm. of a 2 per cent. novocain-suprarenin solution is injected. Nerve blocking occurs immediately in all three branches of the trigeminus and lasts from one to three hours. The injection is frequently accompanied by vomiting and attacks of vertigo, particularly if more solution is injected than mentioned above. The technique is not at all difficult after a little practice, unless the configuration of the skull is abnormal. Whether the method of intracranial injection is quite free from danger remains to be seen. It is suitable in the revolutionary treatment of trigeminal neuralgia as introduced by Schloesser, but it is impossible at this time to give full details.

OPERATIONS IN THE ORBIT. EYE OPERATIONS.

General anesthesia as used in ophthalmology is always attended by certain serious disadvantages which at the present time have happily been overcome by the introduction of local anesthesia.

One of the most important of these disadvantages lies in the fact that general anesthesia of the eye must be very deep to be effective, much deeper than in operations upon other parts of the body because of the well-known fact that sensation of the eye is the last to disappear. With this necessary increase in depth the danger of general anesthesia is proportionately increased, due to necessary interruptions on account of respiratory difficulties or vomiting. These interruptions are so dangerous that certain eye operations if undertaken might result seriously. Then again, under general anesthesia motion in the eye ceases, a distinct disadvantage in some operations. So it happens that local anesthesia has proved to be the most important anesthetic procedure in ophthalmology, and is used in the majority of all eye operations today.

Ophthalmologists use local anesthesia partly as an instillation and partly as subconjunctival and subcutaneous injections. The conjunctival sac is a particularly suitable place for the superficial application of anesthetic agents, because when the eye is closed it forms a closed sac which holds the instilled anesthetic for a considerable time and spreads it over tissues which have a high power of absorption. For this reason it is easy to bring large quantities of an anesthetic substance in contact with the cornea and conjunctiva, much more than in applications to the nose and larynx, as in the latter case the drug is in contact with the mucous membrane for only a short time. For the same reason anesthesia of the eye is not confined to the surface but penetrates the cornea and the fluid contents of the anterior chamber, even at times affecting the bulb to a greater or less extent. Dilute solutions can be used in the eye very advantageously for local anesthesia owing to its structure. All substitutes for cocain are tested by preference in the eye. It is a very sensitive organ and, therefore, a particularly advantageous field for testing new substances as to their anesthetic action as well as their irritating properties.

Cocain has never been displaced from its dominant position in ophthalmology by any of the newer drugs. For its early practical use in eye operations see Chapter VII. Almost all the new substitutes cause more or less irritation upon instillation into the conjunctival sac. β-eucain, tropacocain, and holocain are the only substitutes which have found any advocates among the various substitutes. Holocain, however, owing to its marked toxic properties, has only been used for very superficial anesthesia. Tropacocain (3 to 5 per cent.) and holocain (1 per cent.) have been highly valued as anesthetic substitutes, owing to the fact that they do not irritate, their action is rapid and profound, and, in contrast to cocain, cause neither paralysis of the pupil and accommodation nor any change in ocular tension. Recently novocain and alypin have found considerable support in the profession. Reichmuth still holds that cocain is the best anesthetic for the ophthalmologist, inasmuch as it causes the least injury to the eye, and for this reason the majority of ophthalmologists have remained true to it. As the instillation of fairly concentrated cocain solutions is not likely to cause toxic symptoms, there is no reason why this remedy should be supplanted by any other. For all injections, however, novocain is to be preferred. Ophthalmologists were likewise the first to recognize the effect of suprarenin upon the action of cocain (see Chapter VIII).

Anesthesia of the Eye by Instillation.—Instillations of 2 to 5 per cent. cocain solutions are used, and the activity of the drug can be markedly increased by the addition of suprarenin. For superficial operations upon the conjunctiva and cornea a single instillation is, as a rule, sufficient. The results following its use are as follows: The space between the lids increases, giving rise to an apparent protrusion of the bulb, the pupil is enlarged, and the accommodation, depending upon the dosage, is more or less affected. The conjunctiva and cornea become completely anesthetic to touch as well as to the action of heat or cold. The blood supply of the conjunctiva becomes also markedly diminished. Anesthesia following the use of strong solutions which have been repeated frequently is very prompt in normal eyes, and its duration is of variable length. The instillation of a 2 per cent. cocain solution into the eye produces anesthesia in about two minutes and continues from seven to ten minutes, after which time sensation gradually returns. In the older literature much is said regarding the injurious action of cocain upon the eye. The conjunctival irritation is often due to contamination of the solution by acids or strong antiseptics, particularly sublimate, whereas the affection of the cornea is due in large part to the non-observance of certain precautionary rules regarding the use of cocain. Owing to the increase in the space between the lids and the absence of winking, due to the action of cocain, the cornea may become dry, the degree depending upon the duration of the anesthesia, and thus occasion cloudiness or casting off of the epithelium to a varying extent. It may even cause infection with the formation of ulcers. It is probable that some of these injuries to the cornea are due to the improper use of antiseptic substances. The injurious results of drying can easily be avoided during operation if the operator or an assistant closes the eye frequently, or keeps it moist by the application of compresses (Czermak). The mydriatic action of cocain can likewise be avoided by the addition of miotic drugs to the instilled solution.

Following a single instillation of cocain into the eye the anesthesia is limited to the surface, whereas, if a 5 per cent. solution is instilled every three minutes for half an hour, the iris will, as a rule, become insensitive. The operations which can be performed upon the eye following the instillation of cocain are superficial operations on the conjunctiva, removal of foreign body from conjunctiva and cornea, cauterization of corneal ulcers, plastic operations on the cornea, cataract operations, and operations upon the lens and iris.

Subconjunctival Injections.—Subconjunctival injections are made, as a rule, after the conjunctiva has been rendered insensitive in the usual manner. The injection method is used in anesthetizing the iris in operations for glaucoma in which the instillation method is not sufficient, and in strabismus operations. As a rule, rather concentrated solutions are used (3 to 5 per cent.). These solutions are not free from toxic action, but, nevertheless, poisoning in ophthalmology very seldom takes place. Schwarz recommends a 2 per cent. solution of cocain with the addition of 1 to 5000 to 1 to 10,000 suprarenin in operations that require anesthesia of the entire iris, such as the separation of numerous synechia. The solution must be circularly injected without interruption beneath the conjunctiva around the entire cornea.

The anesthetic action takes place after about five minutes. Haab suggested for similar purposes the placing of cocain crystals in the anterior chamber of the eye so that direct action could be produced upon the iris. These crystals are obtained by evaporating alcoholic solutions of cocain. Others have suggested the injection of anesthetic solutions into the anterior chamber. In operations for strabismus the anesthetic solution is injected at the point where the conjunctiva is to be opened for the purpose of reaching the necessary tendon; the solution is spread throughout the tissues by gentle massage applied to the lid, after which anesthesia occurs in about five minutes.

Innervation of the Orbit.—The orbit and globe are innervated by the ophthalmic nerve; its course in the orbit has already been described on page 241, Fig. 51. Besides this nerve the zygomatic branch of the maxillary nerve passes through the orbital cavity and is distributed to the skin of the temporal and zygomatic region, and also to the outer canthus of the eye.

Exenteration of the Orbit.—An injection of 10 c.c. of a 1 per cent. novocain-suprarenin solution can be made without danger in the deepest portion of the orbit behind the bulb. Long needles and the median and lateral orbital injections are used (see page 212). These injections in connection with an additional one into the foramen rotundum (see page 216) will induce complete anesthesia of the entire orbital cavity with its contents and also the eyelids. The author has repeatedly performed this operation in connection with resections of the upper jaw; solutions injected in this way block the optic nerve. Anesthesia of the same extent can be produced by injections into the Gasserian ganglion according to Haertel's method.

Enucleation and Exenteration of the Eye-ball.—Schleich has reported enucleation of the eye by injections of his cocain solution, but has not given definite details as to the technique. Weiss later used the Schleich method in 5 cases in 3 cases he used Schleich solution No. 3, with 0.01 per cent. of cocain, and in 2 cases 0.2 per cent. cocain. After cocainizing the conjunctiva with a 2 per cent. solution he rendered the ocular conjunctiva markedly chemotic by the injection of Schleich's solution, after which he pushed the needle carefully into the axis of the orbit to both the nasal and temporal side of the bulb and infiltrated the deeper parts of the orbital cavity. The operations were not entirely free from pain, particularly in those cases where long-continued inflammation had previously existed. This same observation was made by Meyers. For the certain blocking of the ciliary nerves Schleich's solution is just as unsuitable as it has proved to be in blocking nerves in other parts of the body. Further reports regarding enucleation have been made by Hackenbruch. After the cocainization of the conjunctiva and cornea he injected a 0.5 per cent. solution of eucain and the same percentage of cocain circularly behind the bulb, after which a glaucomatous eye became painless and could be readily enucleated. Haab used the same cocain and eucain solution but limited its application to those cases in which inflammation was absent; he was thus able to operate without pain. He injected the solutions first above the attachments of the eye muscles and after separating them injected large quantities behind the globe with curved needles. In about five minutes anesthesia occurred. If the capsule of Tenon remains intact, the entire bulb can be made insensitive by filling this space with an anesthetic solution, but in diseased conditions of the eye adhesions frequently take place between the bulb and this fascia, for which reason results are often imperfect. In recent years, since the introduction of suprarenin, ophthalmologists have been using injection anesthesia more and more frequently for enucleations and exenterations of the orbit. The method consists in infiltration of the orbit following a cocainization of the conjunctival sac.

Loewenstein passes a straight needle through the lateral commissure of the lid slightly below its centre. The needle is then directed more toward the median line until its point reaches a depth of 4.5 c.c., which brings it in the neighborhood of the optic nerve and ciliary ganglion. In this position 1 cm. of a 1 per cent. cocain solution with the addition of suprarenin is injected. The bulb is also circularly injected beneath the conjunctiva with 0.5 c.c. of the same solution. In 24 out of 26 cases the bulb was made anesthetic.

Mende reports the results obtained by Siegrist with reference to his previous work. He recommends the use of a slightly curved needle which is introduced from the temporal and nasal side back of the bulb to the points of entrance of the optic and ciliary nerves, injecting at each point 2 c.c. of a 0.5 per cent. novocain solution with the addition of suprarenin. Subconjunctival injections of 1 c.c. of the same solution are made in the region of the attachments of the recti muscles. From 1906 to 1910 155 exenterations and enucleations were performed under local anesthesia and 61 under general anesthesia. The patients were given sedatives and narcotics before the operation. In the 155 cases anesthesia was insufficient in 8 cases owing to improper technique and lack of observance of the proper indications. Local anesthesia is contra-indicated in excitable patients, in severe injuries of the globe, and purulent conjunctivitis and perforating panophthalmitis, whereas irritation of the eye has no effect on the results of this method.

Seidel, who was not always satisfied with the method of Siegrist, injected 1 to 2 c.c. of a novocain-suprarenin solution beneath the conjunctiva around the bulb. He then injected the connective tissues behind the bulb from 4 points with a straight needle passed through the conjunctiva to the middle of a line connecting the optic foramen and the point of entrance of the optic nerve into the bulb. During the insertion of the needle 1 c.c. of this solution was injected retrobulbar. The operation was begun twenty minutes after the injection.[1]

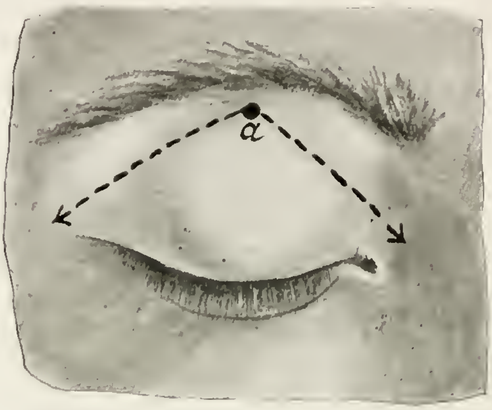


Fig. 71.—Anesthesia of the upper eyelid.

Kroenlein's Operation.—The outer orbital wall is innervated by the first two branches of the trigeminus so that in temporary resections an interruption of these trunks will render the operation easy. The first Kroenlein operation under local anesthesia was performed by Haertel for the removal of a tumor of the posterior and

[1] The author has never had any personal experience with operations carried out in this way, but believes it would be more convenient to inject back of the bulb, from the orbital border, than from the conjunctiva, as has already been described in operations for exenteration of the orbit.

median portion of the orbit which had invaded the nasal cavity. He injected the Gasserian ganglion for this purpose.

Operations upon the Eyelids and Tear-sac.—Operations confined to the eyelids require neither central orbital injections nor blocking of the second branch of the trigeminus. To render the upper lid insensitive a point of injection is marked in the centre of the upper orbital ridge and 3 to 5 c.c. of a 1 per cent. novocain-suprarenin solution injected along the bony orbital edge (Fig. 71). The anesthesia will also include the conjunctiva; the same procedure can be carried out on the lower lid. In the latter, injections into the infra-orbital foramen can also be used (see page 214). The entire cheek is thus made insensitive at the same time. It should also be remembered that the median end of the lower lid is innervated by the infratrochlear nerve. The latter can be reached by passing the needle above the median to the inner canthus and injecting 2 c.c. of a 2 per cent. novocain-suprarenin solution toward the median orbital wall. By this injection the infratemporal nerve supplying the tear-sac will also be rendered insensitive.

OPERATIONS UPON THE SOFT PARTS OF THE FACE.

The extent of the innervation of the face from the three branches of the trigeminus and their overlapping fibers, which is very variable, will be seen in Fig. 72. The blocking of the third branch of the trigeminus at the foramen ovale produces complete anesthesia of the face, excepting a small area of variable size on the lower lip which is due to an overlapping of the cervical nerves. The blocking of the second branch of the trigeminus produces an anesthetic area of the face not much larger than that following injections into the infraorbital foramen (see page 214).

The skin of the nose is innervated by the second branch of the trigeminus and to a greater or lesser extent by the end branches of the ethmoidal nerves derived from the first branch of the trigeminus. This applies particularly to the tip and alæ of the nose (see Fig. 33, page 195). The central blocking of the trigeminal branches is of much importance in anesthesia of the cavities of the face, but the soft parts, owing to the overlapping of the neighboring nerves, and those from the opposite side, must be circuminjected to produce anesthesia. The typical form of these circuminjections has already been described in connection with operations upon the jaw. The anemia obtained from this injection is of the greatest importance. Only the blocking of all three branches of the trigeminus by injection into the ganglion will cause extensive anesthesia of the face. Even then, areas near the midline must be injected unless the Gasserian ganglion is blocked on both sides. In superficial operations upon the soft parts of the face, central injections at the base of the skull are, as a rule, not necessary; circuminjection of the part is usually sufficient.

Anesthesia of the Exterior of the Nose, Upper Lip, and Cheek.—As an example of operations upon the nose we will describe the removal of a rhinophyma (Fig. 73). As a rule, three points of entrance for the needle are necessary, one on either side of the alæ of the nose, the third upon the bridge at the bony and cartilaginous junction. From the two former points 0.5 per cent. novocain-suprarenin solution is freely injected subcutaneously along the border of the pyriform aperture as far as the bridge of the nose. This injection must sometimes be supplemented by injections from wheals on the bridge of the nose. Injection is then made beneath the attach-

Fig. 72.—Innervation of the face and scalp. (Corning.) Black dotting, R. I N. Trigemini; red shading, R. II N. Trigemini; black shading, R. III N. Trigemini.

ment of the alæ and frenulum to the upper lip, and require 20 to 25 cm. of the solution. Following this injection the tip and alæ of the nose, including cartilage, mucous membrane and frenulum, will be rendered insensitive. This operation for rhinophyma and the excisions of areas of lupus will be found of definite advantage owing to the anemia of the operative field. In case the upper lip is to be included in the anesthetic field, injections of 10 c.c. of a 0.5 per cent. novocain-suprarenin solution are made from points 1 and 2 in two lines subcutaneously and submucously to the angle of the mouth, the needle being guided by the finger in the mouth (Fig. 74).

A still larger anesthetic field will be noted in Fig. 75. Besides circuminjecting from points 1–5–3–6–2, it is necessary to inject a line to either side from point 4 so as to from points 5 and 6. The lines of injection, 1–5, 2–6, are made from points 5 and 6, exclude the ethmoidal nerves, as well as an injection into the infra-orbital foramen guiding the needle by the finger under the lip, as shown in Figs. 74 and 75.

Fig. 73.—Circuminjection of the nose for rhinophyma.

Fig. 74.—Anesthesia of the outer parts of the nose and upper lip.

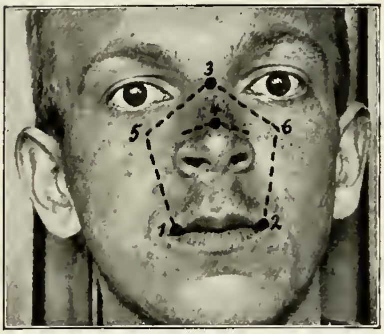


Fig. 75.—Anesthesia of the outer parts of the nose, upper lip, and cheek.

Hare-lip operations are regularly performed without general anesthesia. The upper lip is injected on both sides in a line from the angle of the mouth to the alæ of the nose, using 2.5 c.c. of a 0.5 per cent. novocain-suprarenin solution on either side. The anterior surface of the upper jaw is also injected as far as the infra-orbital foramen. Injections are then made beneath the alæ of the nose, in single hare-lip on one side, and in double hare-lip on both sides, using 5 c.c. of the same solution. The injections control the hemorrhage; children, as a rule, sleep during the entire operation. Splitting the cheek, as a preliminary to operations in the mouth, is accomplished by simple infiltration of the proposed line of incision. For this a single point of injection at the anterior border of the masseter muscle is sufficient (Fig. 76). With the index finger in the mouth as a guide the proposed line of incision is injected with long needles under the skin and mucous membrane as far as the angle of the mouth.

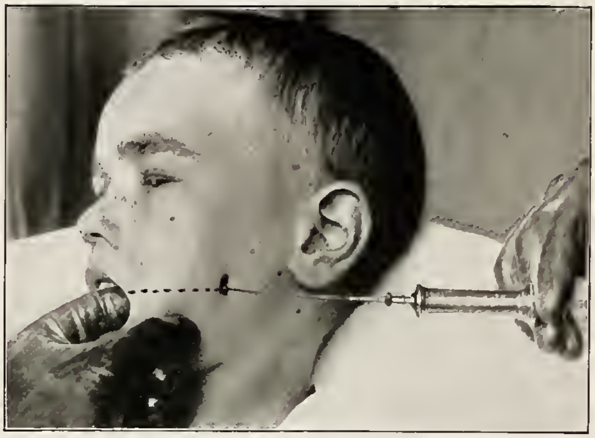


Fig. 76.—Injection for transverse cutting of the cheek.

Operations upon the Lower Lip and Region of the Chin.—For operations limited to the lower lip, a wedge-shaped circuminjection is made according to the method of Hackenbruch (Fig. 78, 1–4–5). From point 1 marked on the chin the needle, guided by the finger in the mouth, is introduced beneath the mucous membrane to point 4, infiltrating the entire line; the needle is then partly withdrawn and a subcutaneous infiltration is made to point 4. A similar injection is made toward point 5. For this injection, as is shown in Fig. 78, 20 to 25 c.c. of a 0.5 per cent. novocain-suprarenin solution is necessary; the entire area as indicated by lines 1–4–5 is rendered insensitive. In cases of carcinoma the line of injection must be removed some distance from the lesion, points 4 to 5, as a rule, being at the angle of the mouth. The wedge-shaped excision in carcinoma should not correspond to the lines of injection 1–4–5, but should lie within these lines. It is possible in this way to avoid the infiltration of diseased tissues. In case it is desired to anesthetize the larger part or the entire lower lip with the adjacent skin of the chin, 2 points for injection are made at 2 to 3 (Fig. 78), and the tissues infiltrated in the lines designated by 9–2–3–10. Where the soft parts join the bone, injection is first made deep to the periosteum, then under the skin. The remaining portion of the injection is performed, as already described, guided by a finger in the mouth and using 0.5 per cent. novocain-suprarenin solution. Complete anesthesia is not obtained by this injection; to do this it is necessary to anesthetize the inferior mental nerves at their exit from the foramina *a* and *b*, or to block the inferior alveolar nerve at the lingula. After this the entire field of operation and the underlying bone should be rendered insensitive. Fig. 78

Fig. 77.—Technique for injection of the lower lip.

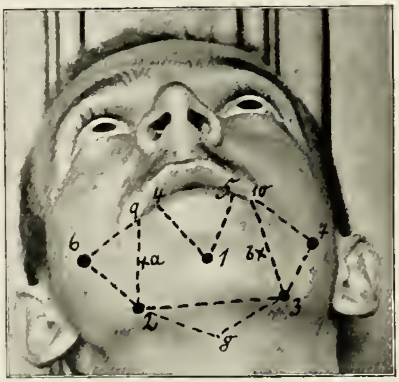


Fig. 78.—Circuminjection of the lower lip and chin. *a*, *b*, points of emergence of the mental nerve.

shows how the anesthetic field of the cheek and submental region can be enlarged, this is done by marking additional points for injection at 6 and 7. By circuminjection the field designated by 9–7–2–8–3–7–10 or portions of it can then be rendered anesthetic. The injection from 2 to 6 is carried out as was described for lower lip anesthesia and from 6 to 9 like that for transverse cheek incisions. Where plastic operations are to be performed on the face with pediculated flaps, the method as described above should be used, except that the anesthetic should be injected some little distance from the pedicle, for self-evident reasons. The form of anesthesia must therefore be guided accordingly.

OPERATIONS ON THE NASAL CAVITIES AND THE BONY PART OF THE NOSE.

The nasal cavities in their anterior portions are innervated by the ethmoidal and ophthalmic nerves, the posterior portion by the maxillary nerve. Figs. 79 and 80 show the nerve distribution schematically. The sphenoid cavity and the antrum of Highmore are supplied by the maxillary nerve alone. The frontal sinuses are supplied by the ethmoidal nerves. The cells of the ethmoid are supplied by both of these nerves.

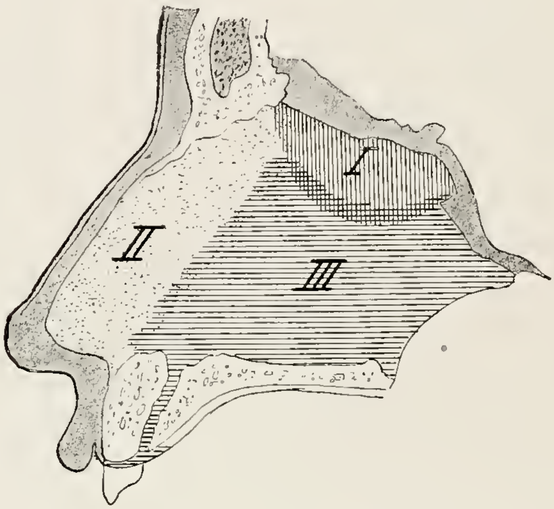


Fig. 79.—Innervation of the nasal septum. 1, olfactory nerve; 2 ethmoidal nerve; 3, maxillary nerve.

Cocainization of the nasal mucous membrane has been of marked importance in the development of rhinology. The exact examination of the nasal cavities and accessory sinuses as well as the performance of many operations were heretofore impossible. This agent not only renders the mucous membrane insensitive with an inhibition of its reflexes but also enlarges the nasal cavities through its power to contract the bloodvessels of the mucous membrane, making them much more accessible. This same condition can at present be produced with many other anesthetic substances by the addition of suprarenin, but cocain has never been displaced in rhinology by the newer substitutes. Among the newer preparations alypin has been highly praised by both Seifert and Ruprecht. They use this agent in a 10 per cent. solution, Ruprecht adding suprarenin.

Cocain solutions are used in the following manner (these directions are given by Bresgens): "A bit of cotton is fastened to a very fine sound and saturated with the anesthetic solution. After illuminating the nasal cavities the cocain solution is gently rubbed over the nasal mucous membrane, beginning in the anterior portion and proceeding backward, also touching the middle and lower nasal tracts. The patient is then directed to bend his head sharply forward so that the anesthetic does not run into the throat, he is also at the same time directed to blow the side of the nose which has been anesthetized, the opposite half of the nose being closed. The middle portion of the nasal cavity is anesthetized, the anesthesia being continued high up in the nose, after which the lower portions are again touched with the cocain solution. This entire procedure is repeated once more, after which in most cases the entire nasal mucosa becomes anesthetic and shrunken. In the majority of cases the second application of the anesthetic is sufficient—in some cases one application, whereas in other cases four or more applications must be used."

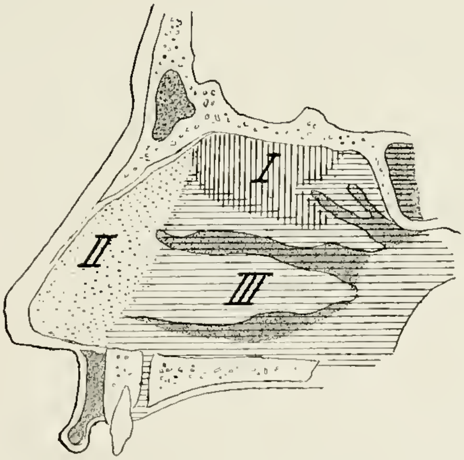


Fig. 80.—Innervation of the lateral wall of the nasal cavity. 1, olfactory nerve; 2, ethmoidal nerve; 3, maxillary nerve.

In cases where it is only necessary to sound the frontal or maxillary sinuses, it is sufficient to anesthetize only the mid-nasal tracts, and to place a small cotton tampon saturated with the solution at the outlet of the cavity to be sounded.

Anesthesia produced in this way is limited to the mucous membrane. Whenever it becomes necessary to anesthetize the bony or cartilaginous part of the nose the submucous membranes must be infiltrated with a 2 per cent. novovain-suprarenin solution. This is readily carried out upon the septum and makes the operation for deviations of this structure very easy. The injection is made with a 1 c.c. syringe and very fine needle. Beginning anteriorly the injection is extended backward on both sides of the septum as far as the limit of the field of operation. The desired operation can then be very easily performed owing to the anemia from the suprarenin. Killian advises that injections be made at the points of emergence of the ethmoidal and nasopalatine nerves (see page 214). In regard to the details of anesthesia for the numerous superficial operations in this particular field the reader is referred to works on rhinology.

Fig. 81.—Carcinoma of the skin and bony parts of the nose.

Fig. 82.—After operation, patient is unable to open eyes owing to edema of the upper lids.

For extensive operations on the bony structure of the nose neither anesthesia of the mucous membrane nor submucous injections from inside the nose, nor the circuminjection as described on page 237 will be sufficient. In such cases the method as described by Peuckert and Offerhaus must be used. An example will probably best explain the technique. Take, for instance, excision of a carcinoma of the nose in which not only the entire nose was removed, but also the nasal bones, the edges of the pyriform aperture, the anterior part of the hard palate, and the exenteration of the entire interior of the nose (see Fig. 82). The injection begins with blocking of both maxillary nerves from the lower border of the zygoma (see page 216) and blocking of the ethmoidal nerves by a bilateral median orbital injection (page 212). The injection of the outer nose with a 0.5 per cent. novocain-suprarenin solution is carried out according to Fig. 83, in which the points for injection are the same as those used for blocking the maxillary nerve. A third point for injection lies on the bridge of the nose. The operation is painless and bloodless. Fig. 82 shows the patient just after completion of the operation. The eyelids are edematous, for which reason the patient is not able to open the eyes.

FIG. 83.—Figure for circuminjection in nasal operations. 1, point for the median orbital injection; 2, point for the injection of the maxillary nerve.

With this same procedure the author has repeatedly performed the preliminary operation to freely expose the interior of the nose and the base of the skull; for the reflexion of the outer nose according to Kocher; and for the temporary reflexion of both bones of the upper jaw, also according to Kocher, for the removal of tumors. It is advisable when operating upon tumors at the base of the skull and the pharynx to again inject the visible portions of the pharyngeal wall after exposing the operative field, and to infiltrate the nasopharyngeal fibroma at its attachment before completing the extirpation.

Any one who has seen this operation carried out under local anesthesia, and has learned the method of blocking the trigeminus trunk, would never again think of performing it under general anesthesia or without the anemia induced by suprarenin. For operation upon the hypophysis carried out through the nose no more suitable means of anesthesia could be found than the one just described.[1]

[1] v. Eiselsberg, Archiv. f. klin. Chir., vol. 100, p. 70). v. Eiselsberg in the past has also performed operations upon the hypophysis by means of the external circuminjection of a 0.5 per cent. novocain-suprarenin solution for the purpose of checking hemorrhage.

OPERATIONS UPON THE FRONTAL SINUSES.

The operations upon the frontal sinuses which previously were performed under local anesthesia were confined to the simple opening of these cavities with a chisel after infiltration of the soft parts overlying the small operative field. This anesthesia has, as a rule, proved insufficient. Peuckert was the first to develop our present technique of anesthesia for the radical operation, consisting in complete removal of the anterior and posterior wall known as Killian's operation. This technique was partially described in the second (German) edition of this work; 13 cases were reported later in which the radical operation was performed, some being unilateral, others bilateral.

Fig. 84.—Figure for circuminjection in operations upon the frontal sinuses. 1, point for the medial orbital injection; 2, point for the injection of the maxillary nerve.

Fig. 85.—Figure for circuminjection in bilateral radical operations upon the frontal sinuses.

It is usually sufficient to anesthetize with the median orbital injection (see page 212), introducing the anesthetic solution in the roof of the orbit; the lateral injection can then be omitted. Previously the attempt was made to block the second branch of the trigeminus which innervates the nasal mucous membrane by applying solutions of cocain or alypin to the mucous membrane before beginning the operation. Inasmuch as patients complained of pain when connecting the frontal sinuses with the nose and on opening the posterior cells of the ethmoid, it is now customary to block the maxillary nerve by preference at the foramen rotundum (page 216). The operative field is circuminjected in the unilateral operation from seven points of entrance,

FIG. 86.—Radical operation for empyema of the frontal sinuses. (Killian's operation.)

FIG. 87.—Radical operation for empyema of the frontal sinuses. Complete removal of the lateral and posterior wall.

the position of which are indicated in Fig. 84. One of these corresponds to the point necessary for the median orbital injection. The operative field on the forehead and nose is circuminjected from points on the orbital border, as shown in the diagram. Injections are then made beneath this edge and under the roof of the orbit. For the blocking of the ethmoid and maxillary nerve 10 c.c. of a 2 per cent. novocain-suprarenin solution is necessary. For the circuminjection 40 to 50 c.c. of a 0.5 per cent. novocain-suprarenin solution is used. The technique for injection in bilateral operations is shown in Fig. 85. The field of operation after these injections is absolutely painless. The ethmoidal cells can be removed as far as necessary, also the anterior and upper wall of the frontal sinuses. The orbit is accessible even to the deepest parts so that the opening can be made through the nasal bone and mucous membrane into the nasal cavities. The anemia of the operative field simplifies this procedure very much. Nobody will be induced to perform this operation under general anesthesia after observing the accessibility and learning the advantages of the method just described. Figs. 86 and 87 represent photographs taken of two patients during and at the completion of the operation.

OPERATIONS UPON THE JAWS.

The Operative Treatment of Empyema of the Antrum of Highmore.—There are really only two operations for treating suppurations in the upper jaw: (1) the opening of the antrum of Highmore from the canine fossa in acute cases, and (2) the removal of the anterior and nasal wall, including a portion of the pyriform aperture in chronic suppurative processes, according to Friedrich. The operation on the bone in the latter case can be carried out by incision of the outer soft parts or from within the mouth, if it can be opened sufficiently wide and the upper lip is fairly movable. The use of local anesthesia simplifies this radical operation so that the patient can be discharged with a healed wound after one to two weeks.

The upper jaw is entirely innervated by the maxillary nerve. In the radical operation the ethmoidal nerve is also encountered. Both of these trunks must be blocked. Anesthesia of the maxillary nerve in operations for empyema of the upper jaw was suggested by Muench in 1909. This anesthesia is, however, not sufficient, the technique of injection being of secondary importance to the pronounced suprarenin anemia.

Anesthesia for the radical operation is performed in the following manner: Three points of entrance are marked as shown in Fig. 88, the first and second points corresponding to the point of injection for blocking the maxillary and ethmoidal nerves. The third adjoins the ala of the nose. From point 1, 5 c.c. of a 2 per cent. novocain-suprarenin solution is injected into the pterygopalatine fossa, and upon the withdrawal of the needle 5 c.c. of a 0.5 per cent. novocain-suprarenin solution is injected to the maxillary tubercle. From point 2 the median orbital injection is made with 2.5 c.c. of a 2 per cent. novocain-suprarenin solution (see page 217) after which the soft parts are infiltrated, guided by a finger in the mouth, in a line from point 1 to the angle of the mouth, just as was done in the transverse splitting of the cheek (page 238). From 15 to 20 c.c. of a 0.5 per cent. novocain-suprarenin solution is used. This injection excludes the lateral innervation from the third branch of the trigeminus, at the same time causing contraction of the end branches of the external

Fig. 88.—Circuminjection for the radical operation for empyema of the antrum of Highmore. 1, point of injection for the maxillary nerve; 2, point for median orbital injection.

maxillary artery. From point 3, 10 to 15 c.c. of a 0.5 per cent. novocain-suprarenin solution is injected along the pyriform aperture under the alæ of the nose and frenulum and in the midline of the upper lip as far as the red margin. The latter can be more readily performed without another point for injection if the lip is raised and drawn toward the opposite side. The injection in the upper lip controls the overlapping nerves and arteries from the opposite side. The radical operation cannot be carried out without pain or loss of blood, either from without, according to the method of Friedrich, or from within the mouth after cutting the mucous membrane from the middle line to the attachment of the zygomatic process to the maxilla.

For the simple opening of the antrum of Highmore from the canine fossa the same form of injection is used as for the extraction of several teeth from the upper jaw on one side (page 258), except that the gums may be disregarded. The injection of the anterior surface of the upper jaw eliminates the innervation from the infra-orbital nerves which pass into the antrum of Highmore, and at the same time renders the operative field bloodless. The other injection at the tubercle of the maxillary bone blocks the superior, posterior, and median alveolar nerves (Fig. 95).

Fig. 89.—Direction of the needle in opening the antrum from the canine fossa.

Both of these injections can be readily made from a single point of entrance situated beneath the lower angle of the zygoma (Fig. 89). A wheal is made at this point and the needle inserted below the infra-orbital foramen and pushed as far as the bone of the nose. At this point 5 c.c. of a 2 per cent. novocain-suprarenin solution are injected. The needle is now partially withdrawn and passed toward the posterior surface of the upper jaw, injecting at this point 5 c.c. of a 2 per cent. or 10 c.c. of a 1 per cent. novocain-suprarenin solution. The introduction of the needle to the foramen is not necessary. The injection, as is frequently done by dentists, can be carried out from within the mouth (see page 257). The customary injection of the anterior surface of the upper jaw is not sufficient for complete anesthesia of an acutely inflamed sensitive mucosa of the antrum of Highmore, as can be readily understood from the innervation of the upper jaw.

The Resection of the Upper Jaw.—A resection of both halves of the upper jaw, including the hard palate, was performed by Matas in 1900 under local anesthesia. He proceeded as follows: A long needle was passed through the sphenomaxillary fissure to the sphenopalatine fossa of both sides and injection of 1.5 c.c. of a 1 per cent. cocain solution made in order to block the infra-orbital nerves. In about five minutes the skin of the cheek, upper lip and the alæ of the nose became anesthetic. The septum and hard palate were infiltrated direct with Schleich's solution. The operation was carried out, the only painful part being the cutting of the vomer. This operation was not again attempted; in fact, before the introduction of suprarenin it was not possible to perform an operation of this kind and duration and be certain

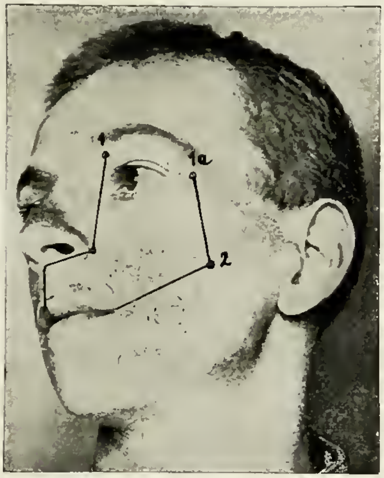


Fig. 90.—Circuminjection for unilateral resection of the upper jaw. 1, 1*a*, points for median and lateral orbital injections; 2, point for injecting maxillary nerve.

of the anesthesia. Total and partial resections of the upper jaw are today performed under local anesthesia as the anesthetic of choice. Peuckert in 1911 was the first to report the technique of the injection, and the author performed resections of the upper jaw eight times under this method of anesthesia. Offerhaus, from his studies of the technique of alcohol injections in trigeminal neuralgia, also used local anesthesia for resection of the upper jaw.

For the unilateral total resection of the upper jaw, if the incision is not to extend beyond the middle line, the unilateral orbital injection (page 212) with the blocking of the maxillary nerve (page 216) is sufficient. If the orbital floor is to be preserved, the lateral orbital injection is not necessary. The external field of operation is circuminjected, as is shown in Fig. 88, for the purpose of checking hemorrhage as well as to exclude the innervation from the third branch of the trigeminus and other skin nerves from the opposite side. Four points of injection are necessary. The upper lip can readily be injected from the point adjoining the alæ of the nose (see page 248). The hard and soft palate must also be infiltrated where they are to be cut. For the central injection 10 c.c. of a 2 per cent. novocain-suprarenin solution are necessary and 80 to 100 c.c. of a 0.5 per cent. novocain-suprarenin solution for the circum-injection. Haertel also advises painting the palate and pharynx with a 10 per cent. cocain solution to prevent reflex vomiting. A better substitute for this solution would be a 10 per cent. alypin-suprarenin solution. In case the orbit is to be cleaned out, 10 to 15 c.c. of a 0.5 or 1 per cent. novocain-suprarenin solution are injected

Fig. 91.—Resection of the upper jaw with removal of contents of orbit under local anesthesia.

without fear into the posterior portion of the orbit. The latter injection can be made in case it becomes necessary to remove the eye during the operation, the patient's consent of course being obtained. This latter operation is photographically shown in Fig. 91. Fig. 92 shows a case in which the floor of the orbit was not removed.

In two cases of resection of the upper jaw, described by Offerhaus, it was necessary to block the third branch of the trigeminus owing to the extent of the tumor. The invasion of the sphenopalatine fossa by the tumor led Offerhaus in two cases not to interrupt the maxillary nerve in the foramen rotundum. The author had a similar experience in one case. In this case we were able to complete the operation by the use of 5 c.c. of chloroform. In similar cases today we would advise the injection of the Gasserian ganglion according to Haertel's method. The external circuminjection is also necessary.

In three cases the author has performed the temporary resection of the upper jaw (under local anesthesia) according to the method of Kocher for the removal of tumors of the nasopharynx. The anesthesia was similar to that described for operations upon the nose and shown in Fig. 81. It was also necessary to infiltrate the hard and soft palate in the line of division. The operation under local anesthesia is surprisingly easy owing to the absence of the usual severe hemorrhage.

Fig. 92.—Resection of the upper jaw for carcinoma of the hard palate with retention of the floor of the orbit. The removed portion is shown above.

Local anesthesia has completely changed the operation for resection of the upper jaw. It cannot be considered a serious operation today, having lost its terrors, and the difficulties and dangers have been materially lessened. A preliminary operation is not necessary, such as tracheotomy, ligation of the carotids or the intubation of Kuhn, as there is scarcely any hemorrhage. The operation can now be completed with certainty and without haste and loss of blood. The patients are as well after the operation as they were before; they are never collapsed. It is rarely necessary for them to take to their bed. In 10 resections of the upper jaw we have not lost one, and have never had a postoperative lung complication. Haertel reports 9 cases from Bier's clinic carried out under local anesthesia and states that the introduction of local anesthesia in major operations upon the areas supplied by the trigeminus is an advancement of vital importance.

FIG. 93.—Circuminjection for minor operations upon the lower jaw.

Operation Upon the Lower Jaw.—The lower jaw and floor of the mouth are innervated by the mandibular nerve. This nerve must be blocked in all operations upon the lower jaw either at the lingula or, if the field of operation extends to the base of the skull, at the foramen ovale. In all operations made from without, the cervical nerves must be blocked by subfascial or subcutaneous circuminjections of the field of operation. As an example of the simplest case we might take a suture of a fracture or other minor operation on the horizontal ramus of the jaw. The operation is begun by injecting at the lingula (page 220). The field of operation is circuminjected from 3 points with a 0.5 per cent. novocain-suprarenin solution as shown in Fig. 93. The bone can then be exposed in the injected area and cut, chiseled or sutured. Fig. 94 shows the plan for circuminjection in resection of the left horizontal ramus of the lower jaw for carcinoma of the alveolar process. The submaxillary salivary glands and lymph glands were removed at the same time with the bone. The mandibular nerve was blocked on both sides at the lingula. In case the jaw is to be disarticulated, it will be necessary to block the mandibular nerve at the foramen ovale (page 224) and the lateral lines of circuminjection of Fig. 94 will also have to be extended somewhat farther back. In all cases it is advisable for purposes of producing anemia to infiltrate the entire floor of the mouth with a 0.5 per cent. novocain-suprarenin solution from one of the points beneath the border of the jaw. This should be done even though the entire area has been previously rendered anesthetic by a central injection. The technique for injections in operations upon the neck must frequently be combined with injections of the lower jaw in cases in which the lymphatics are to be removed. The temporary cutting of the lower jaw will be described in connection with operations upon the tongue and floor of the mouth.

FIG. 94.—Circuminjection for resection of the left ramus of the lower jaw with removal of the submaxillary salivary gland and lymph glands.

EXTRACTION OF TEETH AND OTHER OPERATIONS UPON THE ALVEOLAR PROCESSES OF THE UPPER AND LOWER JAWS.

History.—Ether and ethyl chloride sprays which were formerly very much in use for the extraction of teeth give very unsatisfactory results. Even when ethyl chloride spray is successful for the painless extraction of teeth, it should be borne in mind that the inhalation of small quantities of the drug could have produced sufficient general anesthesia to render the entire body insensitive for a short time (Kulenkampff). This ethyl chloride drunk is possibly satisfactory for the extraction of a single tooth, but its action is not local and the anesthesia could be better carried out by the inhalation of ethyl chloride rather than its application to the gums.

The introduction of cocain opened up new paths for practical local anesthesia in dentistry. This preparation was injected beneath gums in the neighborhood of the tooth to be extracted. Attempts were also made to anesthetize the inferior alveolar nerves by means of perineural injection. The painless extraction of a tooth by means of subgingival injection is brought about by the diffusion of this drug through the bone to pulp cavity and the nerve supplying the peridental membrane. That dissolved substances can actually diffuse through bone was demonstrated upon a cadaver by Dzierzawskis, who showed that colored solutions injected beneath the gums diffuse to a greater or lesser extent into the bone, in the upper jaw reaching as far as the floor of the antrum of Highmore. It is very improbable (see page 153) that solutions injected beneath the mucosa or periosteum can be mechanically forced into the bone. By means of such an injection the fluid under great pressure will naturally take the course of least resistance which would be in the soft parts surrounding the bone. We have, therefore, come to believe that this process is carried on by diffusion. The extent of the anesthetic or colored solution so injected must depend upon the concentration of the quantity injected into the gums. This must be true, inasmuch as the diffused substance becomes more and more dilute the farther it is removed from the point of injection, and therefore the solutions which reach the pulp and innervate the roots must be of sufficient concentration to be effective. The agent requires considerable time to reach the points above mentioned and a tooth can never be extracted immediately without pain, no matter how much has been previously injected into the gums.

Owing to the danger, injections of 5 to 20 per cent. of cocain solutions into the gums were soon given up by dentists and replaced by solutions of 1 to 2 per cent. The injection of a 1 per cent. cocain solution into the gums has been proved without danger in a large number of cases, Bleichsteiner in 1892 reported 1400 extractions. Following the use of dilute solutions the anesthesia of the alveolar process became insufficient. It was possible to anesthetize the gums and alveolar periosteum with certainty, but the pulp and peridental membrane could rarely be sufficiently anesthetized for dental operations. The author does not believe that Legrand, a pupil of Reclus, should be credited with the statement that all extractions can be rendered painless with the use of a 1 per cent. solution of cocain, nor does he believe those who are sceptical regarding the use of any injection. Laewen and Quéré made the following statements regarding cocain injected into the gums and as to its anesthetic effect upon teeth with living pulp: (1) in no case is absolute anesthesia obtained, (2) in the majority of cases there is a marked lessening of pain, (3) in a certain number of cases cocain does not seem to produce a perceptible analgesia. Quéré, Reclus, and Dastre agree that in the latter class of cases osteoperiostitis of the alveolar process is present. Those with the formation of abscesses and inflammatory infections of the gums are the cases, however, in which anesthesia is most necessary. The conditions are different for the physician because as he sees patients whose teeth have been neglected and frequently extracts teeth which the dentist could have preserved. For ten years the author has extracted teeth with a 1 per cent. cocain solution and he agrees entirely with Quéré. This applies not only to cases as above mentioned but also to persons with thick bones in whom the anesthesia frequently failed in extraction of the lower molars. The patient could never be promised a painless extraction, for which reason this method of injection has never been generally accepted. According to the author's experience the anesthesia is more certain if a more dilute solution is used and the gums and alveolar periosteum infiltrated with Schleich's solution. One thing is certain, that these solutions do not produce serious general symptoms when used for these injections. The infiltration of the gums and periosteum with Schleich's solution only produces a satisfactory anesthesia when the tooth to be extracted has been freed of its pulp.

The local anesthetic methods have not been materially improved by the countless combinations of various anesthetic substances. With a 2 or 3 per cent. β-eucain (Reclus, Thiesing) and tropocain solutions (Dillenz and others) approximately the same effect is obtained as from a 1 per cent. cocain solution. More highly concentrated solutions of these agents are not free from possible injury and their use may be associated with considerable danger. A description of the various substitutes for cocain has already been described in Chapter VII. Reports of injury to the gums following the injection of anesthetic solutions occupy a most important place in dental literature. All of the pain-relieving drugs have been attended with swelling and edema of the tissues following injection, but it is difficult to determine whether the swelling should be attributed to the injection or the extraction. The most carefully performed extraction is always followed by more or less crushing of the bone or soft parts and naturally takes place in an operative field which is always infected with bacteria. If substances which produce tissue injuries are not used, as for instance guaiacol, and if the solutions are sterile and contain the proper quantity of salt, the swelling and edema should not be attributed to the injection, but rather to the extraction (Laewen). A pronounced improvement was obtained in anesthetizing the alveolar processes when Wiener, and later Schleich, advised infiltrating the periosteum first with cocain solution, followed by cooling the cocainized tissues with the ethyl chloride spray.

The advantage of this method depends upon the fact that more dilute solutions of cocain can be used when the tissues are chilled. When this method of injection is used it is necessary to wait at least five minutes after the gums have been frozen, so that the cocain can become most effective. The ethyl chloride spray should again be used just before extracting so as to take advantage of the anesthesia due to cold. With this latter method a number of extractions can be carried out without pain which would be only partially anesthetic with cocain injections, and also a 0.2 per cent. cocain or 0.5 per cent. tropococain solutions can be employed. It is not advisable to use solutions in the extraction of teeth which are too weak, as the success of the method may be sacrificed by too much dilution.

Cocain cataphoresis has found many supporters among the American dentists. Whether it is possible to convey the cocain by means of the galvanic current as far as the alveolus is questionable. A description of this method as well as the complicated apparatus necessary for its use is described in the work by Dorn. For the special history and literature of local anesthesia in dentistry the reader is referred to the monographs of Thiesing, Seitz, and Laewen.

In the description given in former editions of this work, the introduction of suprarenin for local anesthesia in dental operations was of incomparable value. Dentists have accepted the technique as described without change. They have studied the method along anatomical lines and have occasionally added to their equipment instruments better suited to their cases. The amount of space given to local anesthesia in the dental literature of late years is evidence of the importance of this method to this specialty. In this work the literature is referred to only so far as it concerns the physician. To those who are particularly interested the important work of Buente and Moral and the monographs of G. Fisher and Seidel can be recommended.

The Innervation of the Teeth.—The pulp and peridental membrane of the upper jaw as well as the labial side of the periosteum of the alveolar process and the gums are innervated by branches of the infra-orbital nerve (Fig. 95). These parts are supplied by branches from the main trunk, partly before entering the bony canal and partly after entering this canal, and are distributed to the bone, alveolar process, or mucous membrane between the antrum of Highmore and the anterior wall of the upper jaw (anterior, median, and posterior superior alveolar nerves), freely anastomosing with the superior dental plexus. The superior, posterior, and median alveolar nerves (Fig. 95, 2, 3) are located in the beginning on the tuberosity of the maxillary bone and penetrate the upper jaw in the region of the third molar tooth behind the attachment of the zygomatic process. The labial portion of the gums is also innervated by the end branches of the infra-orbital nerve after emerging from the infra-orbital foramen. The hard palate, the lingual side of the gums and periosteum are innervated by the anterior palatine nerve which emerges from the major palatine foramen above the third molar tooth and is distributed to the soft parts overlying the hard palate (Fig. 54, page 214); also from the end branches of the nasopalatine nerve which emerges anteriorly from the incisive foramen. The pulp and peridental membrane are not innervated by these nerves.

The teeth of the lower jaw are innervated in large part by the inferior alveolar nerve which passes into the bone at the lingula (Fig. 95). This nerve gives off many branches within the bony canal forming the inferior dental plexus immediately underlying the roots of the teeth (not shown in Fig. 95). The pulp and peridental membrane are supplied by the dental rami, and the gums by gingival branches which penetrate the bone. A larger branch, known as the mental nerve, leaves the bone through the mental foramen which is situated beneath the first and second bicuspid teeth. The smaller portion of the nerve contained within the bone innervates the canine and incisor teeth. The mental nerve supplies the skin of the chin and the skin and mucous membrane of the lower lip. The lingual side of the gums and periosteum are innervated entirely by the lingual nerve (rami isthmi faucium and sublingual

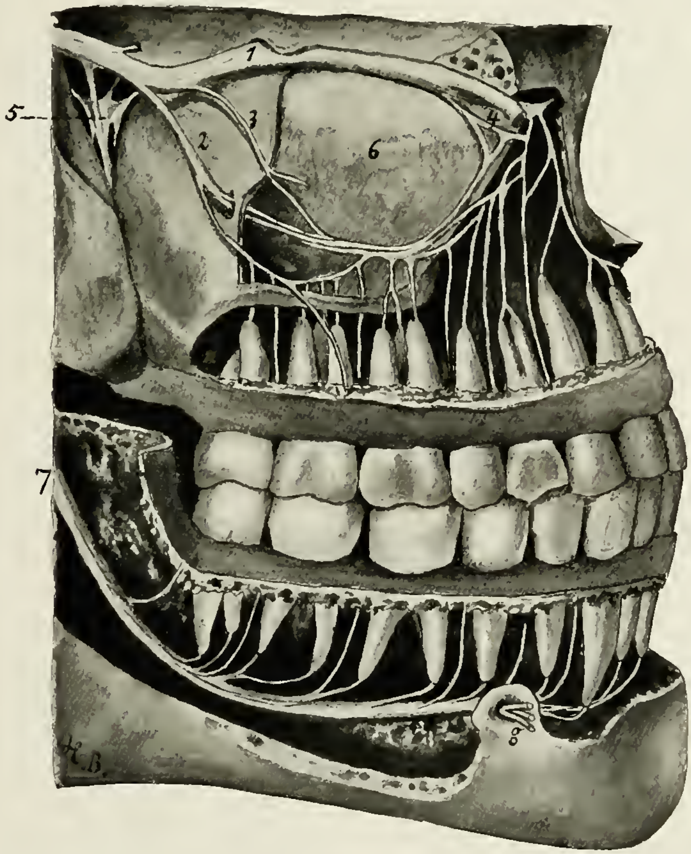
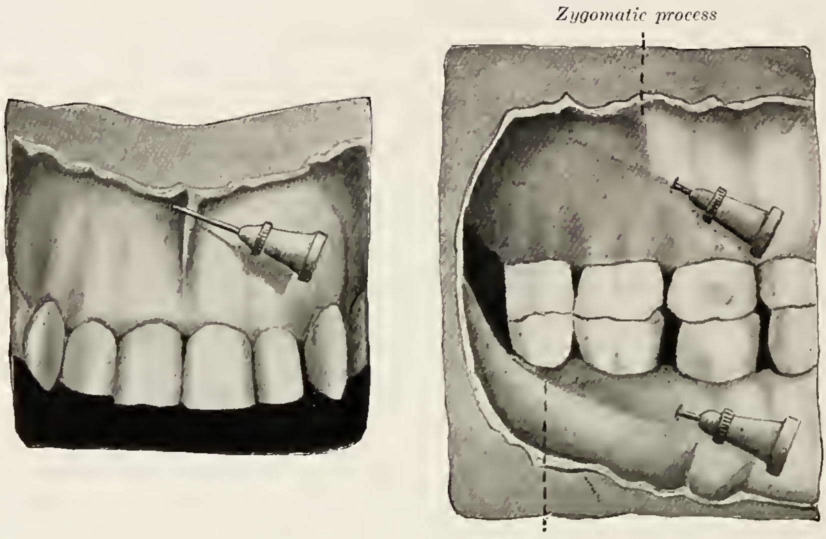


Fig. 95.—Innervation of the teeth. (Partly from Spalteholz.) The lateral wall of the orbit, the outer bony layer of the lower jaw, and parts of the anterior wall of the upper jaw have been removed. 1, infraorbital nerve; 2, branches of the superior posterior alveolar nerve; 3, branches of the superior median alveolar nerve; 4, branches of the superior anterior alveolar nerve; 5, sphenopalatine ganglion and palatine nerves; 6, mucous membrane of the lateral wall of the antrum; 7, inferior alveolar nerve; 8, mental nerve.

nerve). In the median line the inferior alveolar, mental and lingual nerves overlap one another more or less. It is also to be observed that the buccinator nerve to some extent innervates the labial side of the gums of the last molar tooth.

Methods to be Used in Operations upon the Upper Teeth.—It is important to know that the dental plexus, formed from the nerve fibers, lies above the roots of the teeth just below the thin anterior and lateral wall of the upper jaw where they can be readily anesthetized, and that the posterior superior alveolar nerves are just beneath the mucous membrane of the tuberosity of the maxilla where they can be injected before entering the bone, for which reasons the injections of the labial side are by far the most important in operations on the upper jaw. The technique of this injection has undergone characteristic changes in the course of time. One of the first publications in reference to cocain anesthesia for the extraction of teeth was that of Witzel. In 1886 he injected the fold of mucous membrane high up in the jaw, at its point of reduplication, using a 20 per cent. cocain solution, which was the one most commonly used at that time. Later, when much weaker solutions were used for injection, the dilution exerted less distal effect upon the nerves in the bones, and it became necessary to infiltrate the gums, periosteum, and alveolar process surrounding the tooth to be extracted with cocain solution. This procedure is not necessary today because we have solutions equally as effective as those containing 20 per cent. cocain, for which reason we can again return to the simple technique of Witzel.



FIGS. 96 and 97.—Submucous injections for the extraction of teeth.

The injections on the anterior surface of the jaw are made in the following manner: The lip and cheek are drawn away from the upper jaw so that the mucous membrane at the point of reduplication forms a right angle with the alveolar process. The syringe is held horizontally, the needle is inserted in a horizontal direction into the reduplicating fold above the roots of the teeth between the mucous membrane and the periosteum (Fig. 96). For rendering the incisor and canine teeth insensitive the point for injection lies next to the frenum; for the bicuspid and first molar teeth, above the roots behind the attachment of the zygomatic process under the mucous membrane covering the maxillary tubercle (Fig. 97).

In case it is desired to anesthetize one tooth, the needle is passed from a point corresponding to the tooth in front to the tooth behind the one to be anesthetized. In case several teeth of the upper jaw are to be rendered insensitive a strip of tissue should be injected continuously from the points mentioned as far as the maxillary tubercle of the same side, injections being carried out from 1, 2, or 3 points. Following the injection the reduplicating fold swells. Immediately upon the withdrawal of the needle the point of injection should be closed with the finger and the anesthetic distributed over the anterior surface of the upper jaw by light massage. The most suitable anesthetic for this purpose is a 2 per cent. novocain-suprarenin solution, or, according to Fischer, a 1.5 per cent. solution; for one or two teeth 2 to 3 c.c. will be necessary, for the entire half of the upper jaw 5 to 10 c.c. should be used. For the extraction of many teeth it is advisable to inject the anterior surface of the jaw and maxillary tubercle from the cheek, as was described on page 248. Anesthesia is complete in about five minutes, very rarely sooner, but sometimes later, and consists in complete anesthesia of the labial portion of the gum and periosteum in the region of the tooth or the entire half of the upper jaw, depending upon the extent of the injection. There will also be complete anesthesia of the pulp and peridental membrane. This injection alone is sufficient for operations upon the pulp and dentin, also for the removal of roots and other operations upon the anterior surface of the alveolar process. The end branches of the infra-orbital nerve outside of the bone are readily made insensitive if they are directly surrounded by the anesthetic solution.

For the extraction of the upper teeth it is necessary to anesthetize the lingual side of the gums and periosteum. For the extraction of a single tooth 1 c.c. of a 2 per cent. novocain-suprarenin solution should be injected beneath the hard palate adjoining the diseased tooth. For anesthetizing the entire half of the hard palate in the extraction of many teeth see page 214. The blocking of the entire maxillary nerve should be considered when operations for suppurative processes of the alveolar process would render the injection in its immediate neighborhood dangerous. Injections for dental operations at the base of the skull are otherwise unnecessary and are not to be recommended for dental work owing to the occurrence of hematomata.

Operations upon the Teeth of the Lower Jaw.—Injections under the mucous membrane of the alveolar process of the lower jaw can only be successfully performed in connection with the incisor and canine teeth. Posteriorly the bone is much too thick for the anesthetic to exert its effect upon the nerves of the pulp, and lingual injections are only made with difficulty. For these reasons it is advisable to block the alveolar and lingual nerves at the lingula (page 220), in this way producing complete anesthesia of both sides of the gums and periosteum of the bone, and the pulp as far forward as the canine tooth. In operations upon the last molar tooth it is advisable to make additonal injections into the labial side of the gum so as to block any branches from the buccinator nerve. In connection with operations upon the incisor teeth, which are doubly innervated by the overlapping of the inferior alveolar nerve, it is advisable to use a second injection besides that at the lingula which has been described by G. Fischer as follows: The lower lip is drawn out and the needle is inserted in the fold of reduplication beneath the canine tooth and passed along the anterior surface of the lower jaw to the mental fossa. This fossa usually contains numerous foramina which permit the injected fluid to reach the interior of the jaw. Injection is made during the entire passage of the needle, but the bulk of the solution, about 1 c.c. of a 2 per cent. novocain-suprarenin solution, is injected in the region of the mental fossa. When bilateral extractions or operations are to be performed, the lingula is injected on both sides, which will, of course, render the injection of the anterior surface of the lower jaw unnecessary.

The fear expressed by Buente and Moral of a disturbance of salivary secretion due to the blocking of the lingual nerve has never been reported, nor has injury to a patient's tongue anesthetized in this way been observed, if they have been previously cautioned. It might be stated that the above method of anesthesia for the entire alveolar process of the upper and lower jaw, either unilaterally or bilaterally, should always be the anesthetic of choice in all other operations upon the alveolar process.

A few words may be said regarding secondary hemorrhage following the use of suprarenin in the extraction of teeth. Personally, in over 1000 extractions the author has never experienced this complication and does not believe that suprarenin can cause a serious secondary hemorrhage which would not have occurred without its use; the hemorrhage, if it occurs, has been merely delayed by the suprarenin. Secondary hemorrhage following the extraction of teeth can be prevented if the alveolar process is packed with iodoform gauze for a day or two, as has been advised by Roemer. From a surgical stand-point this would seem to be the correct way of handling these cases. Where there are large cavities left in the alveolar process after extraction packing must naturally be done. Today the majority of dentists take the stand that general anesthesia should not be used for dental operations. This question has been investigated by Wolfram in the various German dental institutions where local anesthesia is taught and he found that general anesthesia was very rarely used. Knowledge of the application of local anesthesia is one of the leading questions of the day. The only general anesthetic which enters into competition with local anesthesia for the short and simple operation of extraction of a tooth is the ether or ethyl chloride ("rausch") drunk, as there is practically no danger associated with this form of anesthesia. In cases that are more or less complicated, that require more than a minute for their performance and that can be better carried out slowly, there is no general anesthetic which compares with local anesthesia. The extraction of many teeth under ether, chloroform, or ethyl bromide cannot be countenanced by the physician.

OPERATIONS ON THE PALATE. NASOPHARYNGEAL FIBROMATA.

Anesthesia of the soft and hard palate from 4 points of entrance for the needle was described on page 214. For a simple incision, infiltration of the proposed line of incision with 0.5 per cent. novocain-suprarenin solution is suggested. The removal of the hard palate requires a bilateral blocking of the maxillary nerve. Once again, the most cautious use of suprarenin is advised in plastic operations on the palate. The suprarenin anemia simplifies this operation to such an extent that it is scarcely permissible to dispense with it, but, as has already been stated on page 238 in reference to plastic operations in general, the operator must guard against nutritive disturbances in the separated Langenbeek flap by the cautious use of suprarenin.

It is advisable in making these injections to use at most but half the quantity of suprarenin that is usually advised for operations in general, for which reason the solutions should not be prepared from the tablets. In other operations upon the palate this precaution is unnecessary. Extirpation of nasopharyngeal fibromata has assumed an entirely different phase since the introduction of local anesthesia and suprarenin anemia; they can now be removed with practically no hemorrhage. A case in which a tumor of this nature was removed under local anesthesia by first performing a temporary resection of the upper jaw according to the method of Kocher is described on page 243. Simple cases, having a definite pedicle extending from the base of the skull, can readily be completed by incising the soft palate. Local anesthesia with suprarenin anemia limits the indications for preliminary operations in complicated cases.

This may be explained by citing a history: May 7, 1904, a man, aged eighteen years, had a hard fibroma attached by a broad base to the base of the skull in the nasopharyngeal space. The operation was begun for physical reasons under general anesthesia with the head dependent. The hard and soft palate were infiltrated with a 0.1 per cent. cocain solution with the addition of suprarenin; general anesthesia was then discontinued. The soft palate was split in the middle line without hemorrhage, under guidance of the finger in the nasopharyngeal space; a long needle was passed through the left nasal opening to the base of the tumor and the same solution was injected. After a few minutes the tumor was removed with curved scissors without hemorrhage. The palate was closed by suture, the nasopharyngeal space and nose were tamponed, no secondary hemorrhage following, the healing being very prompt. In two other cases the author removed large nasopharyngeal fibromata in this manner; in these cases, of course, 0.5 per cent. novocain-suprarenin solution was injected instead of the cocain solution.

OPERATIONS UPON THE TONGUE, FLOOR OF THE MOUTH AND TONSILS.

The anterior two-thirds of the tongue and the floor of the mouth are innervated by the lingual nerve, which can be readily blocked by injections at the lingula (page 220). The posterior portion of the tongue, tonsillar region and the pharynx are supplied by the glossopharyngeal nerve; the soft palate and anterior portion of the hard palate are supplied by the maxillary nerve. The region above the epiglottis is supplied by the superior laryngeal nerve.

Anesthesia of the tongue and the floor of the mouth by blocking the lingual nerve does not produce the important suprarenin anemia; for which reason in all operations upon these parts, as well as the palate and pharynx, infiltration and circuminjection are necessary.

Hirschel has recently reported a method of blocking the glossopharyngeal and vagus nerves at the base of the skull. He inserts a needle between the maxillary articulation of the lower jaw and the mastoid process, passing the styloid process in the direction of the occipital condyle to a depth of 3 to 4 cm. and injects in this region 10 to 15 c.c. of a 2 per cent. novocain-suprarenin solution. The glossopharyngeal, vagus and accessory lie near one another at the base of the skull in a connective tissue sheath which includes the internal jugular vein and internal carotid artery. A successful blocking of the glossopharyngeal nerve is readily recognized by a paralysis of the recurrent laryngeal and the accessory nerves. This method of Hirschel remains to be tested as to its certainty and freedom from danger. In operations in the pharynx and region of the tonsil the local circuminjection should be performed owing to the effect of the anemia produced. Sensation in these parts is not very pronounced; at any rate the failure to block the glossopharyngeal and vagus nerves has never been reported to cause any disturbance on the part of patients in excision of tonsils or pharyngeal carcinomata. The latter was performed either through the neck from without or following a temporary separation of the jaw. Whether the trunk of the vagus, after branching of the auricular nerve, possesses pain sense is very questionable. The point of most importance, however, is the anesthetizing of the operative field to such an extent as to permit of the free exposure of the pharynx. Pharyngeal reflexes can be allayed by applications of alypin-suprarenin solutions. As soon as the pharynx becomes accessible, the anesthesia can be completed by submucous injections. The blocking of the superior laryngeal nerve will be described in the following chapter.

Operations upon the Tongue without a Preliminary Operation.—We will take as an example the removal of a small tumor from the lateral portion of the tongue or from its anterior portion, or the removal of sections for microscopic examination. For this purpose a small wheal is injected upon the surface of the tongue with a 0.5 per cent. novocain-suprarenin solution. A needle is then passed through the tongue as far as the mucous membrane of its under surface. This tract is infiltrated with the same solution, after which a traction suture is passed through the anesthetized area so the tongue can be drawn forward and fixed. The diseased area is now circularly injected with 0.5 per cent. novocain-suprarenin solution, after which the tumor can be removed without pain or hemorrhage and the wound sutured.

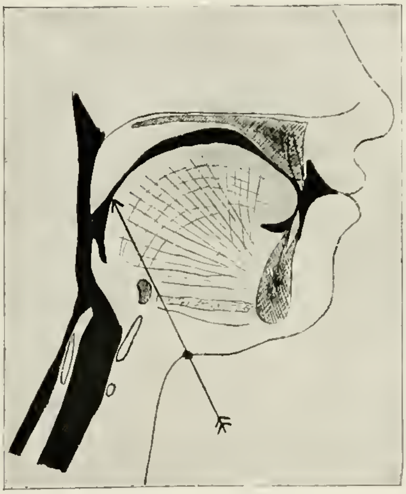


FIG. 98.—Infiltration of the base of the tongue.

In case the disease is more extensive, this circuminjection is dispensed with and in its place the entire tongue and floor of the mouth are rendered anesthetic and anemic by the following procedure: One point of entrance is marked by a wheal under the chin in the median line immediately over the hyoid bone. The left finger is then passed above the epiglottis to the base of the tongue in the same manner as when performing intubation. From this point a long needle is passed toward the tip of the finger infiltrating this area (Fig. 98); the needle is then passed in various directions, first in the median line, then more toward the right and left, and finally as far laterally as the lower jaw. This separates the tongue and floor of the mouth from their blood and nerve supply by an infiltrated barrier. For this injection 50 c.c. of 0.5 per cent. novocain-suprarenin solution is necessary. The tongue and floor of the mouth will become insensitive and anemic. The tongue can now be drawn out and the operation completed. Injections at the lingula are not necessary.

Minor Operations on the Floor of the Mouth.—Small cysts (ranula) or benign tumors of the floor of the mouth should be injected from without from a point under the chin. The needle is guided by the left index finger placed in the mouth, and the area is injected with 0.5 per cent. novocain-suprarenin solution. Large cysts in the median line of the floor of the mouth which cause a bulging in the chin region are better extirpated from without. This can be done after a bilateral blocking of the lingual nerve at the lingula. It will then only be necessary to circuminject the operative field in the usual manner.

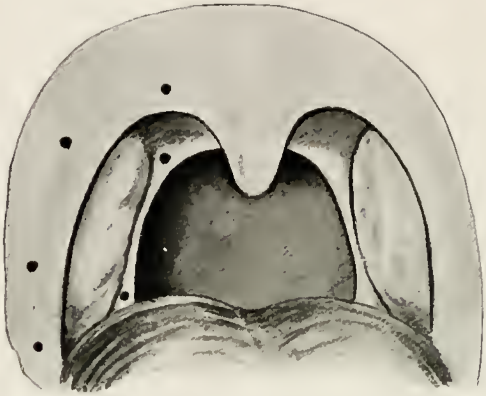


FIG. 99.—Points of injection for tonsillectomy. (After Heymann.)

FIG. 100.—Circuminjection for median section of the jaw. 3, point of injection over the hyoid bone.

Local Anesthesia for Tonsillectomy.—Anesthesia for tonsillotomy is usually not necessary, but the operation of tonsillectomy, as performed today by the specialists in this field, requires anesthesia. For anesthesia of this region the anterior and posterior pillars of the fauces should be infiltrated from several points (Fig. 99). This area as well as the tissues lateral to the tonsils is freely infiltrated with 10 to 15 c.c. of a 0.5 novocain-suprarenin solution. For anesthesia of the pharyngeal tonsil Ruprecht advises the application of tampons saturated with 10 per cent. alypin-suprarenin solution. These applications are made by means of a sound passed through the nasal canal.

Radical Operations for Carcinoma of the Tongue, Floor of the Mouth and Tonsillar Region.—The anesthesia is begun by a bilateral blocking of the lingual and inferior alveolar nerves at the lingula (page 220) and completed by an injection as is shown in Fig. 98. In case the operative field extends to the pillars of the fauces, tonsillar region, or lateral pharyngeal wall, these areas must be injected from below and behind

Fig. 101.—Excision of the base of the tongue and left tonsil for carcinoma. The lower jaw is cut, the tongue drawn to the right. The epiglottis is seen in the depths of the wound at the completion of the operation.

with 0.5 novocain-suprarenin solution. A blocking of the maxillary nerve is, as a rule, not required. It will now be necessary to anesthetize the parts for the preliminary operation, which consists of a transverse splitting of the cheek as described on page 238. The method of circuminjection for a median section of the lower jaw is shown in Fig. 100. Point 3 indicates where the needle must be passed for infiltrating the base of the tongue. For the circuminjection 30 c.c. of a 0.5 per cent. novocain-suprarenin solution is necessary.

The operation can now be performed without pain or hindrance from hemorrhage. Peuckert and the author have reported 13 cases of excision of the tongue, extirpation of the floor of the mouth in connection with resections of portions of the lower jaw, and extirpation of carcinoma of the tonsils, with this method of anesthesia. Fig. 101 shows one of our patients during the operation. What has been said already with reference to resections of the upper jaw holds for operations in the mouth; that is, local anesthesia has changed completely the appearance of these patients during operation. It has simplified the operation, which can be carried out in a much cleaner manner and all danger of aspiration pneumonia is eliminated. We had only two post-operative lung complications in the 13 patients operated upon under local anesthesia in connection with susprarenin anemia. A large number of cases of carcinoma of the mouth, in which formerly a median section of the lower jaw was necessary as a preliminary operation, can now be operated upon with as much ease by the simple section of the cheek.

CHAPTER XII.

OPERATIONS ON THE NECK.

Bier and Madelung have pointed out the possibility of performing major operations of all kinds upon the neck under local anesthesia. Bier lays special stress upon its use for thyroidectomy and extirpation of the larynx. Madelung states that he has for many years preferred a 1 per cent. novocain-suprarenin solution for local anesthesia in all major operations, such as thyroidectomies, removal of glands, resection and extirpation of the larynx, pharynx and esophagus.

Fig. 102.—The sensory innervation of the neck: 1, auricularis magnus; 2, cutaneus colli; 3, supraclavicular nerves.

The soft structures of the front of the neck are supplied by the anterior branches of the second, third, and fourth cervical nerves, whose terminal branches, the auricularis magnus, cutaneus colli, and supraclavicular, come to the surface at the posterior edge of the sternocleidomastoid muscle. Pain in the larynx and esophagus is probably transmitted only through the cervical nerves (Fig. 102). On the other hand it is quite inprobable that any pain is transmitted from the neck by the vagus. The mucous membrane of the esophagus is devoid of any sensibility.

A subcutaneous and subfascial injection along the posterior edge of the sterno-cleidomastoid merely renders the skin of the neck insensitive, which practically is of no value. Complete anesthesia of the region supplied by the specified nerves is only obtained by anesthetizing the nerves as they leave the spinal column.

Kappis recently reported that he had succeeded in blocking the cervical nerves just as they leave the foramina of the cervical vertebræ, and thus was able to anesthetize the whole cervical and brachial plexus. He introduces the needle from the back, laterally along the spinous processes to the transverse processes of the cervical vertebræ and even beyond them for another 1 to 1.5 cm. forward, and injects 1.5 per cent. novocain-suprarenin solution.

FIG. 103.—Line of the transverse processes of the neck. *a* and *b*, points of entrance for the needle.

Heidenhain's method for major operations of the neck is to inject from the side and freely infiltrate the region of the third to the fifth cervical vertebra, where the nerves concerned lie close together, using a 0.5 per cent. novocain-suprarenin solution. This is accomplished in the following manner: A line is drawn on the side of the neck indicating the location of the transverse processes of the cervical vertebra. This line begins above, immediately behind the tip of the mastoid process, and passes slightly backward from the posterior edge of the sterno-cleidomastoid muscle forming an acute angle with it. The transverse process of the atlas (first cervical vertebra) is felt under the mastoid process, and lower the transverse process of the sixth cervical vertebra (tuberculum carotideum) is felt as a rule. This indicates the line of the transverse processes in which the two points of injection *a* and *b* (Fig. 103) should lie. The upper injection should be made behind the angle of the jaw in a line continuous with its lower edge. The second injection should be made on a level with the prominence of the thyroid cartilage. From these two points the needle is directed to the transverse processes of the cervical vertebræ which must be felt with the needle, and all tissue layers between the process and the skin are thoroughly infiltrated with a 0.5 per cent. novocain-suprarenin solution, according to the diagram of Fig. 29 (page 189). For this injection about 30 to 40 c.c. will be required. This injection does not come in contact with the bloodvessels of the neck, but further injections into the field of operation will always be necessary. By making this injection on both sides complete anesthesia of all the organs in the front of the neck is obtained. Whenever the occasion demands the superior laryngeal nerve should also be blocked (see below). If the operation extends upward into the field of the third branch of the trigeminus, a bilateral injection at the lingula or a direct infiltration of the floor of the mouth becomes necessary.

In this manner a very definite type of anesthesia is obtained for all major throat operations. The injection for the transverse processes, as described, forms the basis for all circuminjections.

The Extirpation of Lymphatic Glands and Tumors of the Neck.—We will begin with the most extensive operation, one that taxes local anesthetic measures to the utmost, viz.: the total extirpation of all the fatty tissue of the neck, including the lymphatic glands and submaxillary salivary gland which lie under the jaw and surround the large bloodvessels, as a preliminary to operation for carcinoma of the lower lip and oral cavity.

Fig. 104 shows the diagram for unilateral and bilateral injections; *a–b* and *c–d* are the lines of injection which extend along the transverse processes of the cervical vertebræ. The subfascial and subcutaneous tissues in the field of operation are injected by means of long needles, parallel to the outer skin. When the submaxillary salivary gland is to be removed, the infiltration is made through the points of entrance marked on the edge of the jaw, because this region is supplied by the trigeminus. For this injection 100 to 125 c.c. of a 0.5 per cent. novocain-suprarenin solution will be necessary. Patients experience no pain during this operation, and the procedure is greatly facilitated by the suprarenin anemia. Fig. 105 shows one patient after a unilateral, and Fig. 106 one after a bilateral extirpation of glands. Disturbances of the phrenic nerve have never been reported in these bilateral injections of the transverse processes of the cervical vertebræ, but theoretically such disturbance might be possible.

Fig. 104.—Circuminjection for operations on the neck.

Fig. 105.—Removal of the left submaxillary salivary gland, submental and lymphatics of the neck under local anesthesia for carcinoma of the base of the tongue and left tonsil. The left jugular vein was resected.

Fig. 106.—Dissection of the neck for complete removal of the lymphatics of the neck and the submaxillary salivary gland under local anesthesia for carcinoma of the tongue.

It is interesting to note that no pain is felt in resection of the vagus, although it is not affected by the injection.

The only difficulties encountered in using the described method of anesthesia will be in extirpation of masses of lymphatic glands and tumors which have developed posteriorly over the edge of the sternocleidomastoid beyond the line of transverse processes and which cover the cervical plexus. In such cases Kappis states that good results will be obtained by making the injection from behind, along the transverse processes. Naturally the whole surface of the tumor must also be circuminjected.

Some circumscribed and movable tumors or masses of lymphatic glands can be injected in a pyramidal manner according to the plan in Fig. 28, provided no large vessels are encountered. The injection is more easily made if the tumor is lifted up.

In the following operations the lines of injection represent at the same time a section of those used for the whole front surface of the neck:

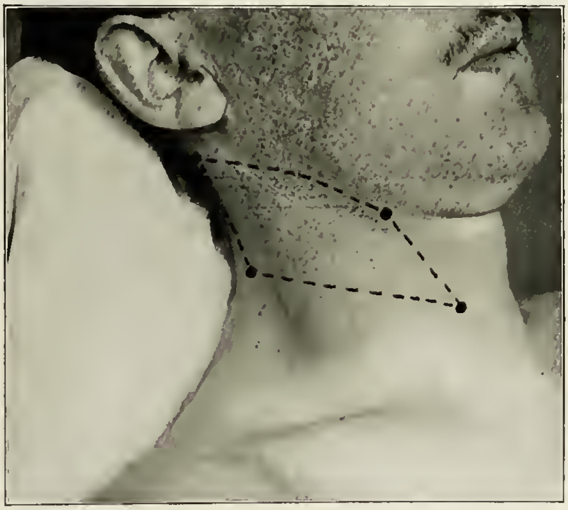


Fig. 107.—Injection for ligation of the superior thyroid or external carotid artery.

Ligation of the External Carotid or Superior Thyroid Arteries.—The essential point of this injection is to infiltrate a strip of connective tissue in the line of the transverse processes (Fig. 107). The field of operation is subfascially and subcutaneously injected in a rectangular or triangular form by long needles. The form of the injection naturally depends on the incision to be made.

Ligation of the Common Carotid or of Inferior Thyroid Arteries.—In Basedow's disease an extracapsular ligation of the inferior thyroid artery according to de Quervain is advised in every case. The line of injection is similar to the one in Fig. 107, but lies correspondingly lower. Here, too, the main point is the infiltration of the line of transverse processes.

Suprahyoid Pharyngotomy.—The author performed a unilateral suprahyoid pharyngotomy in one case for extirpation of a spindle-celled sarcoma which was situated under the submucosa of the left tonsil; the diagram of injection corresponded with the left upper quarter of Fig. 104. The floor of the mouth was also infiltrated through the points of injection marked on the border of the jaw, as in this operation the area supplied by the trigeminus is invaded; the operation was absolutely painless and bloodless.

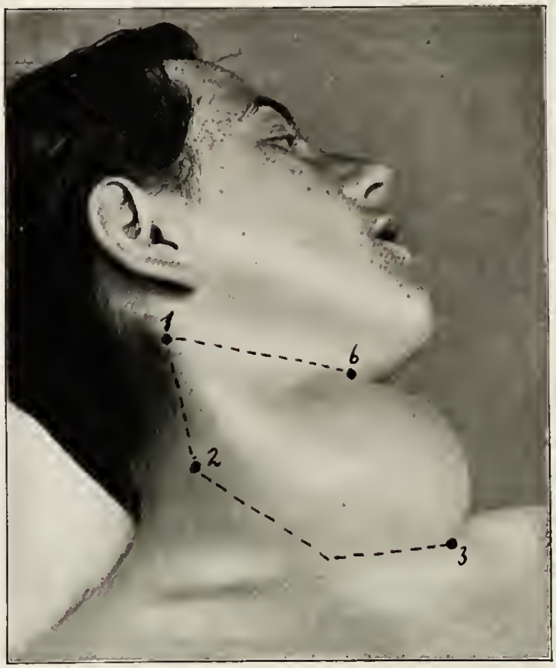


Fig. 108.—Thyroidectomy with excision of the right lobe and isthmus.

Thyroidectomy.—In this operation five, and in cases of large goitre six, points of injection are necessary as shown in Fig. 109. Points 1 and 2 correspond with the line of the transverse processes and these points serve for infiltration as far as the transverse processes. The other points are joined by subfascial and subcutaneous lines of injection, and are reached by long needles. In the lines 3, 4, and 5 these subfascial injections must be given generously in order to be sure of excluding the innervation from the other side. From 75 to 125 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary, depending of course upon the size of the field of operation. When both halves of the thyroid gland are to be removed at the same time, the injection is made throughout, as shown in Fig. 109. It is self-evident that the injection need not extend so far as the inframaxillary border. There must be a bilateral injection of the line of the transverse processes.

This method is preferred to that of von Hackenbruch, who injects close to the tumor, because there is no contact with the large vessels of the neck or with the thyroid veins, and because it can also be employed in malignant cases.

Fig. 109.—Thyroidectomy with excision of the right lobe and isthmus.

Anxious patients are usually given scopolamin-morphin (Bier). Hackenbruch prepares the patient by giving 20 to 30 drops of tincture of opium, because he has found that morphin given before thyroidectomy is apt to cause vomiting. Axhausen has made the same observation. Sensible patients need no opiate, since the operation causes no pain.

Formerly there was much reticence about using local anesthesia for thyroidectomy because of the incomplete anesthesia which most surgeons obtained. This has been overcome by circuminjecting the goitre in the above-mentioned manner.

From 1908 to 1911 there were 157 thyroidectomies performed under local anesthesia in the Hospital at Zwickau. In one case of substernal goitre, local anesthesia was found most serviceable. The upper part of the tumor in the supraclavicular space was freely exposed, the patient was then told to cough, and after a very few efforts at coughing, a little traction on the part of the operator, and the breaking up of a few adhesions, he literally coughed up from the thoracic cavity a goitre weighing 390 grams. There can be no doubt at the present time that local anesthesia is most satisfactory, both for removing the ordinary goitre and for the Basedow operations.

Fig. 110.—Method of injection for tracheotomy. (Most.)

Tracheotomy.—In performing tracheotomy, two entrance punctures should be made to the right and left of the trachea, and from these points the field of operation is injected in a trough-like manner, according to Fig. 31 (page 191). A diagram illustrating this injection, drawn by Most, is shown in Fig. 110. It is very important to avoid general anesthesia in patients suffering from stenosis of the trachea, for which reason it is advisable to use local anesthesia. Young children, however, are often so restless that it is impossible to get on without some general anesthesia. In emergency cases, it is well simply to infiltrate along the line of incision.

OPERATIONS IN THE LARYNX.

Repeated reference has been made to the inestimable benefit to the field of laryngology by the introduction of cocain. The mucous membrane of the larynx is usually anesthetized by swabbing it with a 10 to 20 per cent. cocain solution and in doing this it is well to prevent the excess of the cocain solution from running into the trachea and esophagus. After the swabbing, the patient should be permitted to cough and expectorate. The cocainizing should be done repeatedly, in order to arrest the reflexes of the mucous membrane of the larynx long enough for the patient to bear the introduction of the instruments. This is more important than overcoming the sensation of pain which is evidently very slight in this organ. The swabbing is very disagreeable to the patient, therefore many laryngologists prefer to apply a small quantity of the cocain solution to the larynx with a small spraying apparatus made for the purpose, or with a syringe. M. Schmidt prefers the syringe because with it the dosage of cocain can be more accurately controlled. The effect of the cocain lasts from 5 to 10 minutes and much longer if suprarenin is added. Siefert and Ruprecht report that alypin used in 10 per cent. solution with the addition of suprarenin is a splendid substitute for cocain.

The sensory innervation of the larynx, at any rate that part above the vocal cords, comes through the internal branch of the superior laryngeal nerve. This nerve emerges immediately under the posterior end of the hyoid bone, then runs forward under the anterior border of this bone for a short distance on the thyrohyoid membrane which it penetrates, sending branches into the mucous membrane of the larynx, the pyriform sinus, and the surrounding mucous membrane of the pharynx. The other two nerves which enter the larynx are essentially motor nerves; they are the external branches of the superior laryngeal and of the recurrent laryngeal.

Efforts to anesthetize the larynx by a bilateral blocking of the internal branch of the laryngeal nerve were unsuccessful until the introduction of suprarenin.

As early as 1903 the author succeeded in obtaining such complete anesthesia that Viereck, a surgeon, was able to curette a tuberculous larynx. Viereck, who continued these experiments, asserts that the anesthesia always extends to the epiglottis and the entire upper part of the cavity of the larynx to the glottis, but that it is not always complete below the glottis. Other favorable reports have been made by Frey, Chevrier and Cauzard, and Kuttner. It is a very simple matter to accomplish this blocking. A needle of medium size is inserted under the skin in the median line, between the thyroid cartilage and the hyoid bone, then into the thyrohyoid ligament. It is directed in this ligament toward the end of the hyoid bone which has been previously located by the examining finger. The ligament is infiltrated on both sides with 5 c.c. of 0.5 or 1 per cent. novocain-suprarenin solution. The mucous membrane of the larynx immediately becomes anemic in consequence of the contraction of the superior laryngeal artery, produced by the suprarenin.

Laryngotomy and Laryngectomy.—Fig. 111 illustrates the technique of injection necessary for this operation. Point 1 lies under the lower end of the contemplated skin incision or under an already existing tracheotomy wound, points 2 and 6 are close beside the larynx, points 3 and 5 are on each side of the lateral ends of the hyoid bone, point 4 is in the median line under the chin. The injection of 5 c.c. of a 0.5 per cent. novocain-suprarenin solution is first made from

Fig. 111.—Laryngotomy and laryngectomy.

point 4, or from another median point of injection into both sides of the thyrohyoid ligament. This is followed by deep injections of 0.5 per cent. novocain-suprarenin solution from points, 1, 2, 3, 5, 6, which include the larynx and trachea in a cup-shaped manner, according to Fig. 111. Finally, a subcutaneous circuminjection is made from one point of injection to another. Altogether about 100 c.c. of 0.5 per cent. novocain-suprarenin solution are necessary. Thanks to local anesthesia, operations on the larynx, resections of the jaw, and tongue operations have assumed a different aspect and have lost all of their technical difficulty, due to a great extent to the anemia produced by the suprarenin.

When the extent of the field of operation is indefinite, as when a carcinoma has penetrated the larynx, requiring the removal of the lymphatic glands, injections in the neighborhood of the larynx cannot be considered. In such cases the whole front surface of the neck must be anesthetized, according to Fig. 102, and the thyrohyoid ligament must also be infiltrated.

Subhyoid Pharyngotomy.—A subhyoid pharyngotomy for the removal of a carcinoma at the entrance of the larynx and surrounding parts has been performed under local anesthesia. The thyrohyoid membrane was infiltrated with 0.5 per cent. novocain-suprarenin solution. The field of operation was circuminjected from two points with the same solution in the shape of a transversely placed rhombus situated on the anterior border of the sternocleidomastoid muscle. After opening the pharynx the tumor was further circuminjected.

CHAPTER XIII.

OPERATIONS ON THE SPINAL COLUMN AND THORAX.

The Innervation.—Shortly after the thoracic nerves emerge from the intervertebral foramina of the dorsal vertebræ they send out connecting branches (rami communicantes) to the symphathetic nerves, and then divide into anterior and posterior branches. The latter supply the muscles of the back and innervate the skin to the right and left of the median line. The anterior branches, namely, the intercostal nerves, at their origin run approximately in the middle of the intercostal spaces. Near the angle of the ribs, they approach the lower border of the rib above. At first, they lie immediately upon the endothoracic fascia and the pleura; as they approach the angle of the ribs they lie between the external and internal intercostal muscles. Their further course is shown in Figs. 112 and 114. The lumbar nerves lie between the transverse processes of the lumbar vertebræ, in front of the transversalis muscle connecting the transverse processes, and are surrounded by the origin of the psoas muscle. The iliohypogastric and ilio-inguinal nerves, which are the most important nerves supplying the anterior abdominal wall, are derived from the twelfth dorsal and first lumbar, running like the twelfth intercostal nerve, on the front surface of the quadratus lumborum muscle, then between this and the outer surface of the fatty capsule of the kidney, continuing between the transverse and oblique abdominal muscles.

From the second lumbar nerve, the emerging nerve trunks take such a decidedly downward course and lie so close to the vertebral bodies that they can only be reached by making the injection close to the vertebral bodies.

The intercostal nerves and the first lumbar nerve furnish the sensory nerve supply to the chest wall and abdominal wall, including the parietal pleura and peritoneum.

The middle intercostal nerves do not in the beginning anastomose with one another; the first and second intercostal nerves send branches to the brachial plexus, immediately upon their emergence from the foramina; the twelfth intercostal sends branches to the first lumbar nerve. The intercostal nerves supplying the skin overlap each other to such an extent that, as a rule, the central blocking of a single one of them does not perceptibly alter the sensibility of the skin. The overlapping seems to occur to a greater extent from the upper to the lower segments, so that by the central blocking of a number of intercostal nerves, anesthesia of the skin will begin two segments lower than the uppermost injection.

At the upper end of the bony thorax, in the infraclavicular space, at the upper border of the scapula and in the axilla, the sensory innervation is supplied by the terminal branches of the cervical and brachial plexus. The supraclavicular nerves lie subcutaneous, crossing the clavicle and the scapular ridge and innervate the skin anteriorly frequently as far down as the nipple.

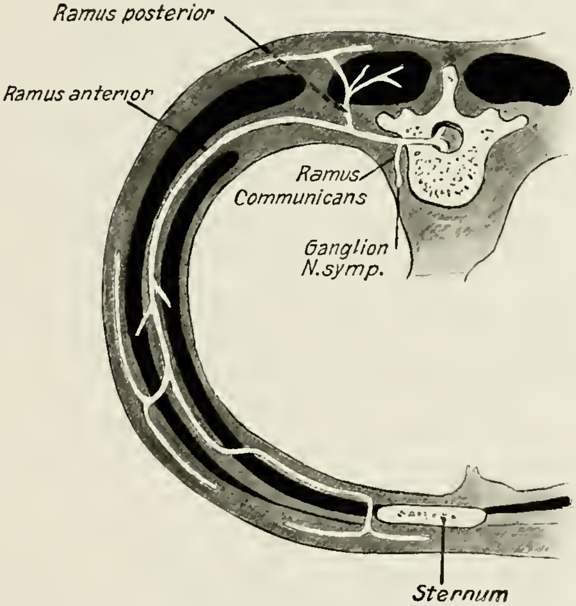


Fig. 112.—Diagram showing the course of the intercostal nerves. (After Corning.)

Paravertebral Conduction Anesthesia.—In this connection we will briefly discuss the experiment already mentioned on page 268, viz.: to emphasize the possibility of conduction anesthesia by means of injections into the intervertebral foramina. This idea originated with Sellheim, who attempted to block the eighth to twelfth intercostal nerves, as well as the iliohypogastric and ilio-inguinal nerves at their emergence from the spinal column for abdominal operations, and gave explicit directions for introducing and passing the needle. According to his suggestion, the needle is inserted laterally 2 to 3 cm. from the median line until the vertebral arch is touched. It is then passed laterally over the border of the vertebral arch between two transverse processes, for 1 to 2 cm. more; on the posterior surface of the vertebral arch it encounters the nerves emerging from the spinal foramen. While Sellheim's experiments were not altogether a failure, they were nevertheless practically impossible on account of the inefficient means of anesthesia then in use.

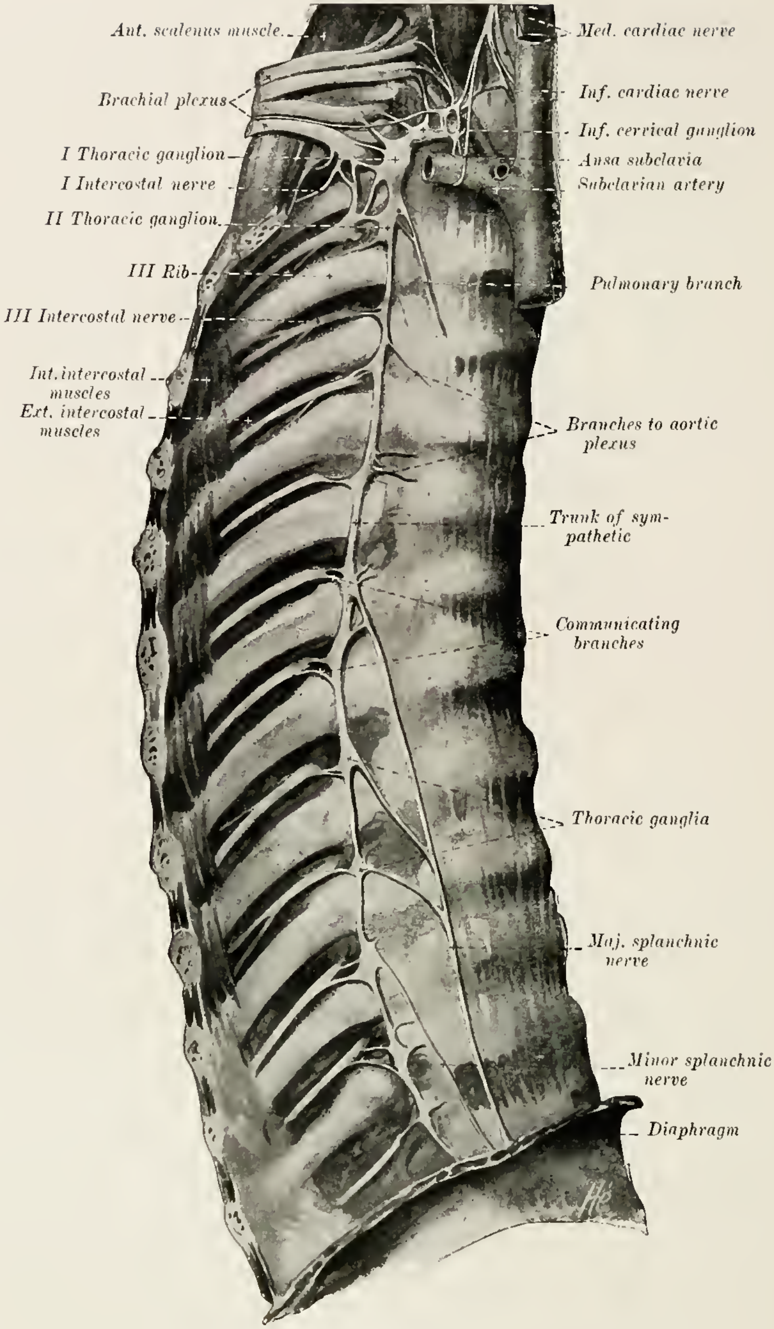


Fig. 113.—Intercostal and sympathetic nerves. (After Spalteholz.)

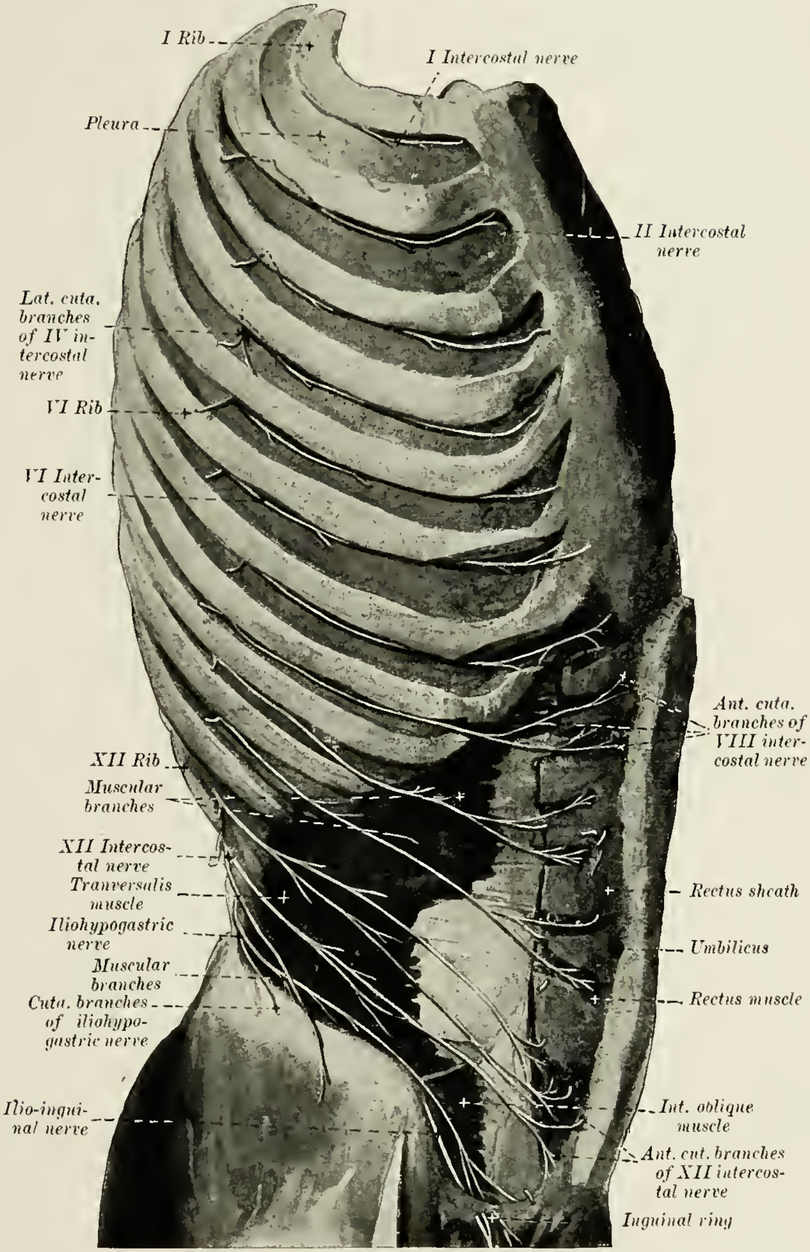


FIG. 114.—Course of the intercostal nerves. (After Spalteholz.) The intercostal and oblique muscles have been removed.

Laewen was more successful in his efforts. He called the method "paravertebral conduction anesthesia." In 1911 he reported having performed operations for inguinal hernia and nephrotomy (see Chapter XV) after blocking the lower dorsal and lumbar nerves. Finsterer used this method in major operations in the lower abdomen (Chapter XIV). Laewen anesthetized the twelfth intercostal nerve and the first to third or fourth lumbar nerves. He inserted the needle laterally 4 cm. from the uppermost angle of the spinous processes, between the transverse processes, directed it slightly inward and injected 10 c.c. of a 1 per cent. novocain-bicarbonate solution. Finsterer injected the eleventh to twelfth dorsal and the first to third lumbar nerves, the point of entrance being 3 to 3.5 cm. outward from the median line. The needle is directed over the upper edge of the transverse processes and inserted 1 to 1.5 cm. beyond; 5 c.c. of a 1 per cent. novocain-suprarenin solution is then injected in a fan-shaped manner.

It has been proved (Kappis, Franke) that the injection is dangerous if made directly at the intervertebral foramen, as the solution may penetrate the dura and reach the spinal canal, or the dura may be punctured and injection made directly into the spinal canal. These accidents have resulted in serious collapse, for which reason it is necessary to try to reach the nerves a short distance from their point of emergence by guiding the needle according to the suggestions of Laewen and Finsterer.

Kappis made comprehensive efforts with these methods in the clinics at Kiel. His method of injecting the anesthetic in front of and close to the transverse processes of the cervical vertebra is mentioned on page 268. The injection method for the first to the twelfth dorsal nerves, and the first to the fourth lumbar nerves, is described by Kappis as follows:

The point of injection lies 3.5 cm. from the median line. At a depth of 4 to 5 cm. the rib, or the transverse process, is felt, and the point of the needle is then directed past the lower border of this bone. When this has been done, the needle is directed toward the median line at an angle of 20° to 30° and is pushed from 1 to 1.5 cm. deeper and in this direction 5 c.c. of 1.5 per cent. novocain-suprarenin solution are injected. Besides operations on the thorax this method is suitable for kidney operations which, according to Kappis, were frequently done by injecting unilaterally the eighth dorsal to the first lumbar. After a bilateral blocking of the fifth to twelfth dorsal and first to third lumbar, for which 22 points of entrance and 110 c.c. of a 1 per cent. novocain-suprarenin solution were necessary, a number of painless laparotomies and bile-duct operations were performed. This method will be referred to again in the description of abdominal and kidney operations.

OPERATIONS ON THE SPINAL COLUMN.

The use of local anesthesia is of special value in performing laminectomies, owing to the field of operation being rendered bloodless (Braun).

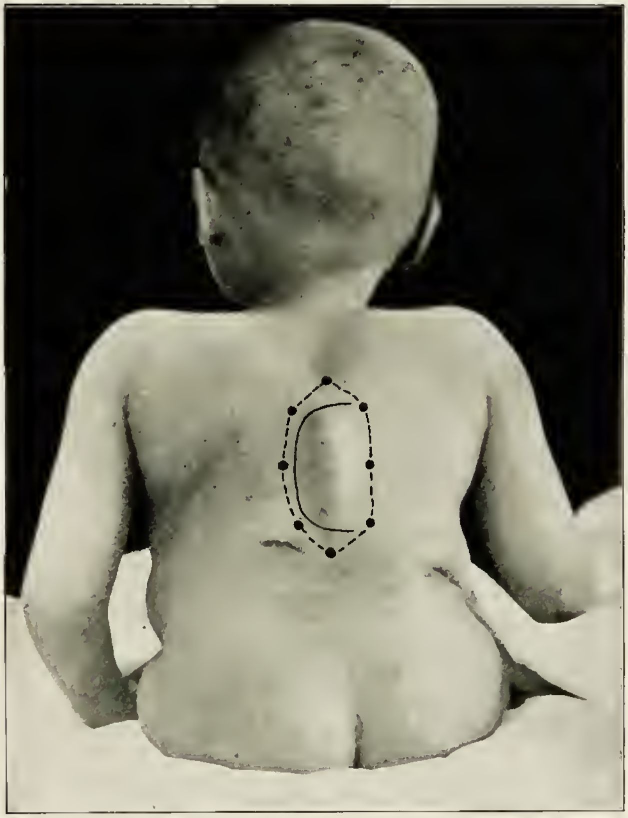


FIG. 115.—Injection for laminectomy.

Just as operations in the region of the trigeminus assume a totally different character after injections of novocain-suprarenin solution, so do operations on the spinal column. They can be performed almost without any bleeding, and the patient leaves the operating table in a decidedly better condition than we have formerly been in the habit of seeing. The unpleasant necessity of operating in two stages is not experienced in either laminectomy or Foerster's operation. A detailed discussion of these operations is needless at this time. The Foerster operation was performed upon one side of a corpulent elderly lady with spastic spinal paralysis without noticeably affecting her general condition.

In laminectomies, in addition to local anesthesia, general anesthesia should always be used in certain phases of the operation, as the Foerster operation is hardly possible without it, if the operator wishes to avoid intradural injections. Simple laminectomy for the relief of pressure on the spinal cord can, according to Heidenhain and Krause, be frequently performed without general anesthesia.

In performing laminectomy, the best method is usually as follows (Fig. 115): A number of points of entrance are marked surrounding the field of operation. This should be sufficiently large so that one is in no way hampered. The next step is to make a bilateral injection of a 1 per cent. novocain-suprarenin solution, according to Kappis, between the ribs and transverse processes respectively. Then the erector spinæ muscle is thoroughly infiltrated to the spinous tranverse processes and the ribs with a 0.5 per cent. novocain-suprarenin solution, and finally the whole field of operation is subcutaneously circuminjected with the same solution. In exposing the spinal column there is no pain in any case. If the patient complains during the removal of the bony parts, it is advisable to give a little ether. There is practically no bleeding.

OPERATIONS ON THE THORAX.

Puncture of the Pleura.—Anesthesia for pleural puncture is produced (according to Fig. 28 (page 188) with a very fine needle. For this injection 0.5 per cent. novocain-suprarenin solution is sufficient. It is much easier on the patient if the anesthesia instead of being limited to freezing the skin extends over the entire tract to the pleura before inserting a thick needle or trocar.

Resection of Ribs and Thoracotomy for Empyema.—Fig. 116 represents three successive ribs; from the middle one that part is to be resected which is marked in black. Wheals marking the four points for injection are made over the two neighboring intercostal spaces, and at these points the needle is inserted perpendicularly to the surface of the skin, and 5 c.c. of 1 per cent. novocain-suprarenin solution is injected between and into the intercostal muscles. In making this injection, the point of the needle should always seek the next rib above in order to find the necessary depth, and then pass along its lower border into the intercostal space. The muscle covering the rib and the subcutaneous connective tissue are then infiltrated with 30 to 40 c.c. of a 0.5 per cent novocain-suprarenin solution in the direction of the arrows. This operation is always performed under local anesthesia, even in children under four years of age, the patient being placed in a sitting posture. In children it is usually necessary to use some pyschic influence; if they permit the injection to be made, however, the rest is easy. One of our little patients ate a sandwich during the operation. Fig. 117 represents a patient during the resection of a rib.

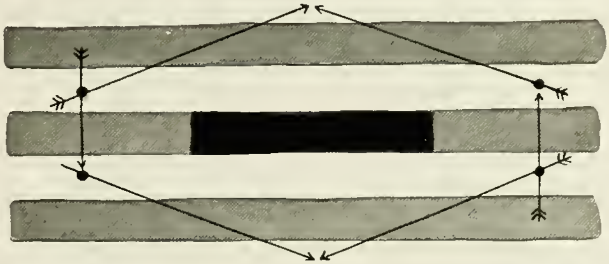


Fig. 116.—Injection for resection of the ribs for empyema. (Diagrammatic.)

Fig. 117.—Patient during resection of ribs for empyema. Skin is painted with iodine.

Resection of Several Ribs or Rib Cartilages and Parts of the Thoracic Wall.—If the described intercostal injections are made not only in one, but in two, three, or four intercostal spaces, in front of and behind the field of operation, and if the soft parts covering the thorax are circuminjected with a 0.5 novocain-suprarenin solution (Fig. 118), larger areas of the thoracic wall can be made insensible; large pieces of rib can be removed and parts of the thoracic wall can be resected.

FIG. 118.—Anesthesia of several ribs by intercostal injections and circuminjection.

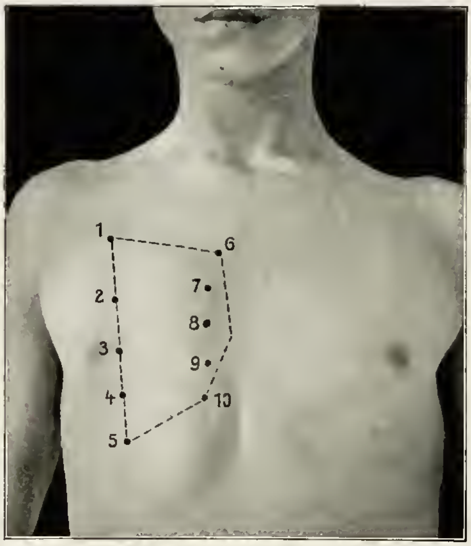


FIG. 119.—Injection for resection of second and fifth rib cartilages.

Resection of Cartilage of Second to the Fifth Ribs in the Fixed Dilated Thorax.—Over the second to fifth intercostal spaces mark two rows, each having five points of injection (Fig. 119). Of these the lateral row lies beyond the border of the cartilage of the ribs; the median row lies close to the sternum. From each of these points inject in the usual manner, 5 c.c. of a 1 per cent. novocain-suprarenin solution into the intercostal spaces; the field of operation is circuminjected in the direction

Fig. 120.—Patient after resection of second and fifth rib cartilages with the intercostal muscles for emphysema, under local anesthesia. The field of operation is covered with oiled silk. The base of the wound is formed by the pleura.

of the dotted line with 50 c.c. of a 0.5 per cent. novocain-suprarenin solution. The operation is painless and bloodless. Fig. 120 shows one of the patients during the operation. The rib cartilage is removed together with the intercostal muscles, according to Krueger. The base of the wound forms the pleura. On account of the deep respiratory movements the photogram is not clear; at any rate it will show what can be done with local anesthesia.

The same method of anesthesia is suitable in operations on the heart and pericardium. The author had only one opportunity to use it in pericardiotomy, and that for purulent pericarditis in a child.

He has for years operated for subphrenic abscesses which were to be opened through the thorax, a few lung abscesses, a few cases of circumscribed rib tuberculosis, and thoraeoplasty for small localized empyemas. The latter were not always satisfactory, for in old empyemas, as Schumacher has pointed out, the ribs are so crowded together and overlap one another to such an extent that the intercostal injections in the neighborhood of the field of operations are fraught with numerous difficulties. These difficulties do not arise when the injections are made close to the spinal column.

Operations on the Sternum.—The injection is made as far as it is necessary on both sides into the intercostal spaces, close to the sternum, with 5 c.c. of 1 per cent. novocain-suprarenin solution; the field of operation is then subcutaneously circum-injected with a 0.5 per cent. solution.

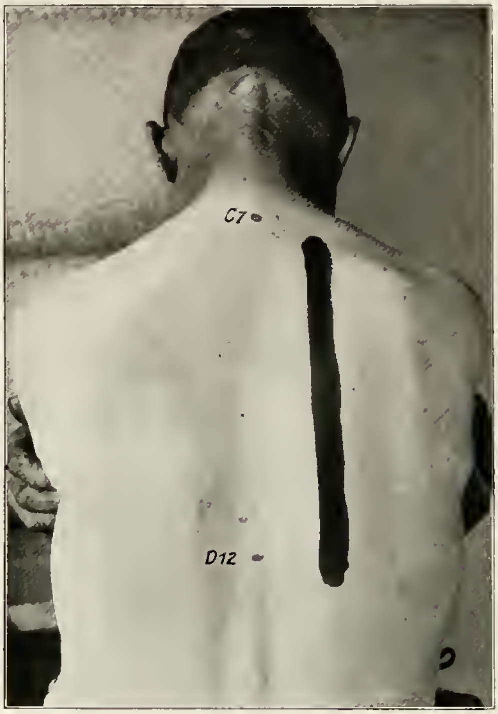


Fig. 121.—Subcutaneous line of injection for blocking the first to twelfth intercostal nerves.

The Central Blocking of the Intercostal Nerve.—Schumacher and Kappis have reported performing thoracoplasty with simple conduction anesthesia. Schumacher states that in 35 cases (resection of pieces of fourth to the eighth ribs) he had complete anesthesia in 20 cases, and in 15 cases a light general anesthetic was necessary. Kappis was able to remove the ninth and tenth ribs entirely, and the greater portion of the fifth to the eighth and the eleventh by means of a simple conduction anesthesia, induced by blocking the spinal nerves from the fourth to the eleventh dorsal vertebræ. In thoracoplasty (fourth to the sixth ribs) Hirschel injected not only into the baek but also anteriorly into the intercostal spaces besides eircuminjecting the area for the formation of Sehede's flap. He seems to have used the method as described by the

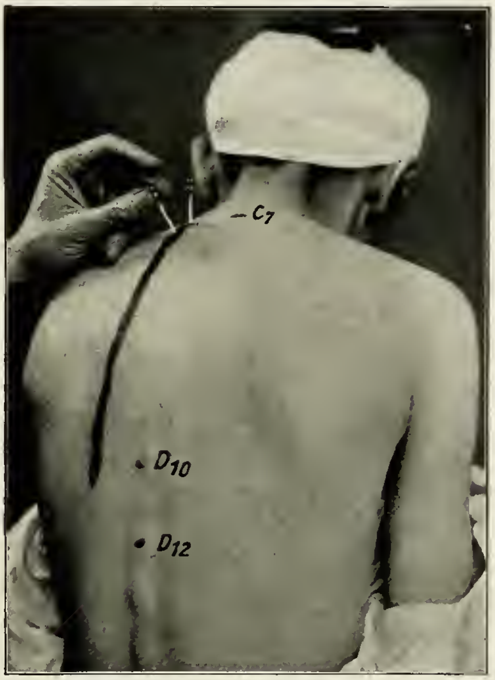


Fig. 122.—Blocking of first to tenth intercostal nerves for breast amputation. The upper needle is in the first intercostal space, the lower needle locates the second rib.

writer. It is not necessary in operations on the thorax to block close to the spinal column, in fact it is better to bloek along the lateral border of the erector spinæ, near the angle of the rib (Schumacher and Franke), which is about 5 cm. distant from the spinal line. Even in the shrunken thorax the intercostal spaces are easily accessible. The technique of the injection is as follows: It is assumed that all the nerves, or perhaps the intercostal nerves, are to be blocked. It is advisable, on account of the many points of injection, the position of which cannot previously be definitely determined, to deviate from the usual rule of marking them by means of wheals and follow Schumacher's plan. He infiltrates subcutaneously the entire strip in which the points of entrance are to lie with long needles from a few points with a 0.5 per cent. novocain-suprarenin solution (Fig. 121). The patient sits, leaning forward with shoulders drawn forward. A needle is inserted into the infiltrated strip, about on a level with the spinous process of the first dorsal vertebra and with its point the first rib is located. This is very easy in lean persons, but in fat or muscular subjects, some little time is required to find it. As soon as the rib is located, the operator feels his way along the under border and when the resistance of the bone is passed, the needle is pushed about 0.5 cm. deeper, and 5 c.c. of a 1 per cent. solution of novocain-suprarenin is injected. In order to find the location more surely leave the needle in position, place a second needle underneath the first, locate the second rib in the same manner and likewise inject the second intercostal space (Fig. 122). Then remove the first needle and place it on the third rib and make the injection into the third intercostal space, etc. If the upper ribs are not to be injected it is advisable to begin with one of the lower ribs which is more easily palpated. This is a very simple and reliable procedure, and is quickly performed. With a little precaution the puncturing of the pleura can be avoided, especially if care is taken not to insert the needle until the rib above has been felt.

After this injection is made, it is necessary to wait a little longer for the anesthesia to become fully effective than after the intercostal injections near the field of operation (about fifteen minutes). The intercostal spaces, the ribs, and the pleura, in the locality which has been injected, will be found insensitive as far forward as the sternum. For this reason it will not be necessary to make further intercostal injections in front. The limit of skin anesthesia is reached approximately in the area of distribution of the lowest intercostal nerve, which has been blocked, while the upper limit, as already shown on page 289, lies one or two ribs lower, irrespective of the overlapping of the cervical plexus. In front the skin anesthesia reaches almost to the median line. On the back it usually ceases where the points of injection lie, but very often the lateral injections also block the posterior branches of the thoracic nerves, in which case the skin anesthesia will reach almost to the spinal processes in the back. This statement can be explained by considering two cases in which it was possible to determine definitely the extent of skin anesthesia.

In one case of subphrenic abscess after appendicitis a 5 c.c. of 1 per cent. novocain-suprarenin solution was injected into each intercostal nerve, from the eighth to the twelfth respectively (Figs. 123 and 124, right side of body). The line shows the area of anesthetized skin, the posterior branches of the thoracic nerves also being blocked. The upper limit of anesthetized skin terminates abruptly at the tenth rib. As pieces of the tenth and eleventh ribs were to be resected in the posterior axillary line, it was necessary to widen the area of skin anesthesia for the incision by means of

Fig. 123.—Extent of conduction anesthesia after intercostal injections.

Fig. 124.—Extent of conduction anesthesia after intercostal injections.

subcutaneous injections. After that the operation was absolutely painless, as was also the splitting of the diaphragm and peritoneum and the exploring and draining of the large abscess.

In the second case it was necessary to make an incision into the seventh intercostal space, in order to remove a piece of scissors which had penetrated the cavity, resulting in pneumothorax. Into each nerve from 5. to 9. intercostal, 5 c.c. of a 1 per cent. novocain-suprarenin solution was injected (Figs. 123 and 124, left side of body). The line drawn indicates the extent of skin anesthesia. The operation was painless, without further injections. Since the intercostal arteries contract, following these injections, as a result of the action of the suprarenin, the blood-supply to the field of operation is lessened.

FIG. 125.—Subcutaneous line of injection for blocking the supraclavicular nerves.

In complicated extensive operations on the lower thoracic wall, downward from about the fifth intercostal space, absolute anesthesia of both the anterior and posterior thoracic walls can be obtained, almost to the median line, by a central blocking of a sufficient number of intercostal nerves with a moderately small amount of the anesthetic—60 c.c. of a 1 per cent. novocain-suprarenin solution for all of the twelve intercostal nerves. No other injections or circuminjections are necessary.

For operations on the upper part of the bony thorax, central blocking is not sufficient on account of the overlapping of the sensory innervation from the neck.

The supraclavicular nerves are especially easily blocked by subcutaneous injections of 0.5 per cent. novocain-suprarenin solution made in a strip which follows the clavicle and if necessary may run for a short distance on the spine of the scapula (Fig. 125). If the field of operation extends into the axilla, or supraclavicular space, then the brachial plexus must be blocked (see Chapter XVI). In order to exclude the nerve anastomoses from behind the cervical plexus; Franke recommends infiltration along the posterior border of the trapezius muscle. It is possible to anesthetize the entire half of the thorax and at the same time the entire arm with a moderate quantity of the anesthetic. Every indication points to the fact that the time is not far distant when almost the whole field of thoracic surgery will come under the head of local anesthesia. This will greatly simplify operations under differential pressure.

OPERATIONS ON THE BREAST.

It is a very easy matter to remove from the breast a well defined benign tumor, whether large or small, under local anesthesia. Two or four points of entrance are marked in the neighborhood of the field of operation, the tumor is lifted up from

Fig. 126.—Circuminjection of a fibroma of the breast.

the underlying structure (Fig. 126) with the left hand, and a pyramidal circuminjection of 50 to 75 c.c. of a 0.5 per cent. novocain-suprarenin solution is made. In lean women with small breasts the injection beneath and around the gland from several points will sometimes be sufficient for ablation of the breast. Inflammatory and especially phlegmonous conditions are better operated under ethyl chlorid or ether anesthesia.

Excision of a Cancerous Breast.—Occasional operations of this kind were formerly done under local anesthesia by Schleich, more recently by Chaput, Hirschel, Hohmeier and Eberle. Hirschel operated on 3 cases in lean women. They were not classical operations, as only small parts of the chest muscle were removed. Hohmeier also limited the use of local anesthesia to appropriate cases in lean women with small movable tumors.

Eberle has operated on 6 cases, some of them fat women. The most thorough injection was made beneath and around the mamma and the chest muscle, together with intercostal injections in the lateral and front wall of the thorax, with infiltration of the boundaries of the axilla and injections into the nerve bundles in the axilla. In this manner the author has for years attempted to carry out the classical breast amputations in lean patients; the anesthesia was satisfactory in most cases, but it is improbable that this method of local anesthesia can ever come into general use for amputations of the breast.

The amount of anesthetic necessary is great (200 to 300 c.c. of 0.5 per cent. novocain-suprarenin solution). The anesthesia is not at all reliable, the technique of the injection is awkward, and injections into the neighborhood of the diseased breast are not advisable and not permissible in the axilla in the presence of a carcinoma.

We now have the technique which had to be devised before such operations could be thought of. With a simple reliable conduction anesthesia, induced without coming into contact with the diseased parts, the very large field of operation which is necessary in a modern operation for carcinoma can be rendered insensitive. For this operation anesthesia of the brachial plexus above the clavicle (see Chapter XVI) outside of the axilla and the central blocking of a number of intercostal nerves is necessary.

The blocking of the brachial plexus is performed according to the method of Kulenkampff (10 c.c. of a 2 per cent. or 5 c.c. of 4 per cent. novocain-suprarenin solution). This is followed by the blocking of the first to the tenth intercostal nerves as described on page 290; (50 c.c. 1 per cent. novocain-suprarenin solution), and finally 75 to 100 c.c. 0.5 per cent. novocain-suprarenin solution are injected subcutaneously in a continuous small narrow strip, beginning at the acromion and following the clavicle along the median line, or alongside of it, then downward in a curve following the lower end of the thorax and finally continuing backward to the strip indicated for the intercostal injections (Fig. 127). This subcutaneous injection includes the supraclavicular nerves and the lower overlapping innervation from the other side.

After this injection has been carried out, which will take about fifteen minutes, an absolute anesthesia of the entire field of operation will be obtained and no further injections or circuminjections will be necessary. Fat persons need no more of the anesthesia than lean ones. At least twelve operations for carcinoma of the breast have been operated upon successfully in this way and the method will be found worthy of general acceptance.

Fig. 127.—Subcutaneous injection for amputation of the breast.

OPERATIONS IN THE AXILLA.

Superficial operations in the axilla are performed after injections under and around the field of operation. As soon as the operator penetrates deeper into the axilla it becomes necessary to block the brachial plexus and the five upper intercostal nerves, in order to obtain a complete anesthesia of the axilla.

CHAPTER XIV.

ABDOMINAL OPERATIONS.

The possibility of performing abdominal operations under local anesthesia depends upon a number of circumstances, which must be considered in each individual case. It is a fact which was assured after the introduction of the ether spray that anesthesia of the skin incision is usually all that is necessary for opening the abdomen, and for operations on the abdominal organs which have little or no sensation to pain. Bloch, who evidently had splendid material to work upon, has recently brought further proof that this is often the case. Local anesthesia with cocain and its substitutes has made wonderful progress; for now, even in sensitive patients, a real exclusion of sensation is possible, permitting the abdominal layers to be incised from skin to peritoneum with ease and comparative safety.

If the operation is to be performed in or upon the abdominal wall, as is the case in most operations for hernia, or if a simple incision through the abdominal wall immediately exposes the organ to be operated upon, and if further manipulation in the abdominal cavity is not necessary, then local anesthesia will be sufficient. Incisions into the stomach and bowel, the liver and gall-bladder and other abdominal organs are not painful. The sensibility of these organs is the same whether in an inflammatory or non-inflammatory state. On the other hand, painful sensations, called "abdominal sensations" (page 38), are produced by any traction on the bowel, or any touch or tearing of the parietal peritoneum, if not anesthetized. Pains are also often felt in tying off the mesentery, but usually not in tying off the omentum. The intensity of these sensations differs in each individual. In some patients it is possible, after incising the abdominal wall, to perform any abdominal operation desired without a complaint, Frequently, however, this is not the case. Usually any examination of the abdominal organs, the introduction of the hand into the abdominal cavity, the application and removal of compresses, the separation of adhesions, is so painful that further operation is not to be considered. Various efforts have been made to overcome these abdominal sensations. On page 38 is described one method, namely, by paravertebral conduction anesthesia. When this this has been successfully brought about, then not only the abdominal wall becomes insensitive but the abdominal muscles relax and abdominal sensations are absent. Kappis declares that for an operation in the upper abdominal cavity a bilateral blocking from the first to the third lumbar nerves, and from the fifth to the twelfth dorsal nerves, is necessary. Kappis was able in this way to perform resections of the stomach, gastro-enterostomies, gall-bladder operations and other laparotomies without pain. This is of great interest in that it proves that the vagus has absolutely nothing to do with the sensory innervation of these parts. These injections, however, greatly tax the patience of the surgeon as well as the patient, for it is necessary to have 22 points of injection, and into each of these at least 5 c.c. of 1 per cent. novocain-suprarenin solution (Kappis uses 1.5 per cent.) must be injected, requiring a comparatively large dose of the novocain. It is much easier to perform a unilateral paravertebral blocking. Laewen uses it for hernia operations and Finsterer for large unilateral abdominal operations, also operations in the lower abdomen. They succeeded in getting complete anesthesia in this way. Kappis declares that in operations on the appendix the abdominal sensations are present, a fact which the author has also observed. The use of this method is still in the experimental stage. Further efforts have been made to get rid of the abdominal sensations by making secondary injections, after the ordinary anesthetizing has been done, for example, into the broad ligament (Schleich) or into the mesenteriolium (Hesse), but complete success cannot be expected from this method.

The results obtained by the combination of local and general anesthesia are much more satisfactory. This method was first recommended by Schleich for abdominal operations, later practiced by von Mikulicz and more recently by Bakes and Laewen; it has also been warmly recommended by Finsterer.

The abdominal layers are made insensitive, followed by light general anesthesia in certain phases of the operation in which the abdominal sensations are to be expected. This procedure will be much more effective if the patient is previously prepared by the administration of morphium, pantopon or scopolamin. In the latter case general anesthesia can be omitted altogether. This method has been regularly used in abdominal operations on individuals who are greatly emaciated, for example, in stomach operations.

Reclus and Schleich anesthetized the abdominal layers in the line of the proposed incision. Schleich states that after layer infiltration had been made, and after cutting through the skin, the subcutaneous connective tissue, aponeurosis, muscles and fascia, a special infiltration of the peritoneum was necessary. This he describes in the following manner: "The contents of half a syringe is emptied into the deepest layers of the preperitoneal fat, which has been lifted up by hooks; the peritoneum is painlessly opened at this point, the finger is inserted and pressure is made against the peritoneum in the direction of the proposed incision, in order to elevate it, and then guided by the finger the needle is pushed forward, either sub- or intraperitoneally. Then by making pressure upon the syringe the operator can feel the peritoneum swell, and the peritoneal wheal raise against the finger. The spot thus distended is cut through and, guided by the finger, further infiltration is made and the peritoneum is cut through, step by step, upward or downward, according to the extent desired. At the same time it must be remarked in making this infiltration that if the peritoneum is inflamed, solution 1 must be used (Schleich solution 1, *i. e.*, 0.2 per cent. cocain solution)."

Reclus did not need this complicated, isolated injection of the peritoneum, because he used stronger cocain solutions than Schleich. After one effective injection of the anesthetic solution into the subserous tissue, the peritoneum, which receives its innervation from this tissue, naturally becomes insensitive just as the skin becomes insensitive after injections into the subcutaneous cellular tissue.

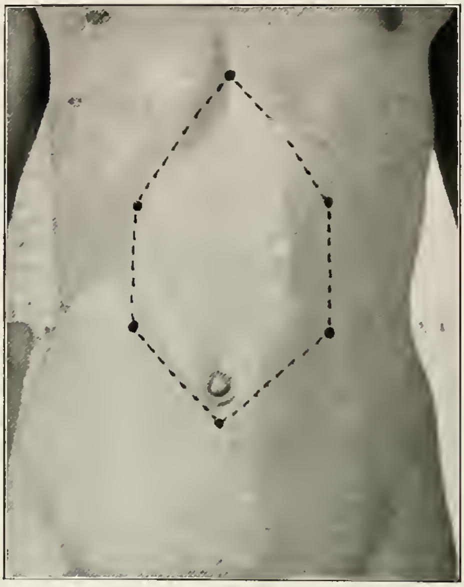


Fig. 128.—Injection for gastrostomy and the circuminjection of the upper abdominal region. (White.)

The anesthetic technique used at the present time for incisions of the abdominal wall is both simple and effective. The narrowness of the anesthetized zone obtained by Schleich's method and the short duration of the anesthesia were troublesome factors and prevented the general use of local anesthesia in abdominal operations. Even though these inconveniences can be avoided now, the advancement which has been made since Schleich's time in local anesthesia for abdominal operations, hernia excepted, is much less important than in many other operative fields.

Gastrostomy.—This is a splendid field for local anesthesia, because only the abdominal layers need be anesthetized; there are no abdominal sensations with which to contend, nor is there any need of additional anesthesia. Only a narrow anesthetized zone is necessary and the operation is of short duration. For this reason Schleich's anesthesia is specially suitable for this operation.

Two points of entrance are marked (Fig. 128), one close to the edge of the ribs, and the other at a point corresponding with the lower end of the contemplated incision. From these two points the abdominal layers are injected according to the plan of Fig. 29 (page 189). A long needle is inserted from each of these points perpendicularly, then obliquely, constant injection being made through the skin, subcutaneous cellular tissue and the rectus muscle into the preperitoneal tissue, and finally injection is made from point to point, just under the skin. This sounds dangerous, but, on the contrary, the operator can feel exactly which layer of the abdominal wall is being penetrated by the needle, and the resistance offered to the point of the needle by the sheath of the rectus muscle can be distinctly felt. For this procedure 40 to 50 c.c. of 0.5 per cent. novocain-suprarenin solution is needed. In these cases only the simple infiltration anesthesia is used, and it is scarcely necessary to mention that the method just described is a simplified and modified Schleich method.

Other Operations in the Upper Part of the Abdomen.—Of all the abdominal operations that can be performed under local anesthesia through a median incision the most suitable are the stomach operations in weak individuals, such as gastro-enterostomy, pylorus resections and some exploratory laparotomies, in which it is unnecessary to explore the entire abdominal cavity. But in these cases local anesthesia can only be used with some additional general anesthetic. In laparotomies where the abdominal wall must be stretched with retractors and where packing is necessary, anesthesia of the abdominal layers in the line of incision will not be sufficient. Naturally much better results are obtained, if as broad a strip of peritoneum as possible is anesthetized both to the right and left of the line of incision. This is easily accomplished by circuminjection. Five points of entrance are marked, as shown in Fig. 126. The four lateral points lie on the outer edge of the rectus; every line joining two points is infiltrated according to the scheme of Fig. 29 (page 189); 100 to 150 c.c. of 0.5 per cent. novocain-suprarenin solution is necessary.

Recently excellent results have been obtained by injecting subcutaneously a bilateral strip from the ensiform process to the external border of the rectus and under the rectus. Furthermore, both sides of the outer border of the rectus are injected downward subcutaneously and subfascially. A 0.5 per cent. novocain-suprarenin solution is used. Following this injection the abdominal layers become insensitive as far as the umbilicus and at the same time the recti become relaxed (Fig. 129).

Gastro-enterostomy is performed in the following manner: About one to one and a half hours before the beginning of the operation, 0.0005 scopolamin and 0.01 morphium are administered. The circuminjection of the upper abdominal region is next carried out as described. While the abdomen is being opened the patient receives some general anesthesia until the condition and position of the abdominal contents have been ascertained, the stomach and intestines have been packed off, after which the patient is not given any more general anesthetic. In abdominal operations, ether anesthesia, in connection with local anesthesia, has up to the present time been considered the most suitable. From recent observations, ethyl chlorid anesthesia, according to Kulenkampff,[1] can be recommended for this purpose.

FIG. 129.—Anesthesia of the abdominal wall for incisions above the umbilicus.

The ethyl chlorid is dropped from the customary glass tube upon several folded compresses which cover the mouth and nose of the patient. After a few inhalations the desired analgesia sets in, and the patient awakens immediately upon the removal of the inhaler. This form of anesthesia used in conjunction with local anesthesia is specially suitable on account of the quickness with which the analgesic effect is obtained and the absence of any irritation of the organs of respiration or the cortex of the brain. In resection of the pylorus the method is the same, but, as a rule, a second anesthesia is necessary in tying off the lesser omentum and sometimes for removing the packing.

There is no doubt that patients treated in this manner leave the operating-table in an incomparably better condition than if they had been subjected to a prolonged

[1] Kulenkampff: On the Analgesic Stage of Ethyl Chlorid Anesthesia, Beiträge zur klin. Chirurgie, 1911, Bd. lxxiii, 384.

general anesthesia. The freedom from danger of the anesthetic can in no way be better understood than by frequent observation of this procedure. Patients very ill with stenosis of the pylorus endure a resection of the pylorus without experiencing even a transient ill effect upon their general condition, and it is unnecessary to give salt infusions, etc. The author therefore heartily agrees with Bakes and Laewen who predict decided progress in operative technique by the use of combined local and general anesthesia. This progress will be due not so much to improvement in the technique of local anesthesia as to the more skilful use of the general anesthesia. This method of anesthesia is suitable for all abdominal operations of short duration and is particularly commendable in weak and debilitated patients, for in them results are better than in stronger persons who are able to fight against the anesthetic.

For operations on the bile-ducts general anesthesia is recommended because they are almost entirely intra-abdominal. On the other hand, simple local anesthesia is used to great advantage in opening abscesses of the liver and for echinococcus cysts. The infiltration is done as in gastrostomy, along the line of incision, no matter what direction the incision is to take.

Median Incisions in the Lower Abdomen.—There are only a few operations for which simple local anesthesia or the combined method can be considered, viz.: for evacuation of ascitic fluid of tuberculous origin, or occasional cases of extirpation of an ovarian tumor without adhesions. Usually it is only necessary to infiltrate in the line of incision from two points of entrance, one at the upper and one at the lower end of the small median incision, and to infiltrate first the preperitoneal and then the subcutaneous tissue with a 0.5 per cent. novocain-suprarenin solution.

Anesthesia of the Ileocecal Region.—The ileocecal region is circuminjected from four points, as shown in Fig. 130. The injection from point 2 toward point 1 is of special importance, because this area contains all the innervation supplying the field of operation. The infiltration along the line 1 to 2 should be performed according to the scheme in Fig. 27, a section of the tissues extending to the peritoneum. For the completion of the injection it is only necessary to infiltrate in the direction of the dotted line, passing the needle subcutaneously and under the aponeurosis parallel with the surface of the skin; 100 c.c., and in fat subjects 120 c.c. of 0.5 per cent. novocain-suprarenin solution will be required. The result is a complete anesthesia of the abdominal layers and of the parietal peritoneum as low as the ileocecal fossa.

This method is suitable for certain cases of appendicitis, cecostomy, and for closure of intestinal fistulæ. On the left side for making and closing an artificial anus the method is the same. For cecostomy, simple infiltration in the line of incision is sufficient. If there is much meteorism, it is well to observe the thinning of the abdominal layers, to avoid entering the abdomen with the point of the needle while making the subaponeurotic injection. Intestinal fistulæ and artificial ani can easily be circuminjected as far as the preperitoneal tissue, if a guiding finger is inserted into the bowel.

In operations for appendicitis, infiltration of the line of incision will not be sufficient. Hesse and Stenglein have reported on the use of local anesthesia in appendicitis. Hesse considers it suitable in (1) all cases operated in the interval between attacks, (2) mild chronic cases, (3) light or severe cases early in the first attack. In the following cases local anesthesia is contra-indicated (1) in practically all abscesses; (2) all cases in which a complicated pathological anatomy is to be expected.

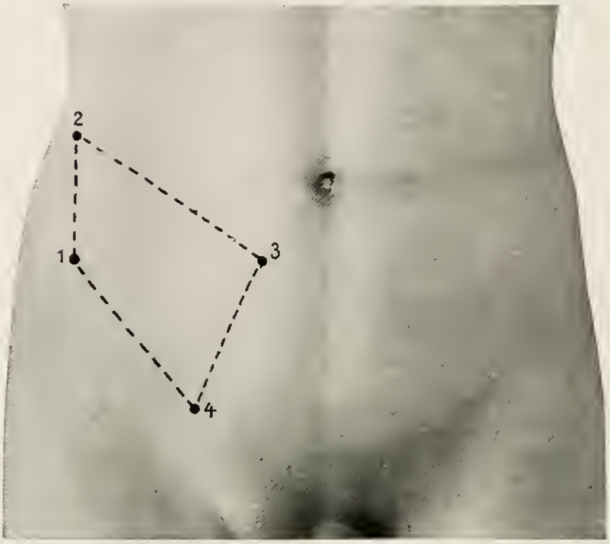


Fig. 130.—Appendectomy.

When the above-described circuminjection has been properly carried out, the incision through the abdominal layers, no matter in which direction the incision was made, as well as the stretching of the abdominal wound and the packing become painless. Localized abdominal sensations arise most frequently in the epigastrium whenever adhesions are separated, when traction is made on the cecum or when the mesenteriolum is ligated. Hesse advises that the mesentery be infiltrated before it is ligated, but this only lessens in small part the abdominal sensations. They are best controlled by morphium-scopalamin, as Stenglein suggests, or if necessary by the addition of ethyl chlorid anesthesia during the search for and the isolation of the appendix. The advantages derived from these combinations are not so apparent in appendicitis operations, as they are in stomach operations, inasmuch as the indications and contra-indications which Hesse mentioned, are often not recognized until the operation is in progress.[1]

OPERATIONS FOR HERNIA.

All things considered, it may be stated generally that local anesthesia or the combined method is of no special importance in abdominal operations, except stomach operations, and the few others above mentioned. In hernia operations the situation is entirely different, for here local anesthesia should be the method of choice, as it is suitable for all operations. The abdominal sensations in these cases are very slight. Since the introduction of cocain, local anesthesia has been considered particularly suitable for hernia operations and has been used with more or less success. Every author who refers to this subject gives favorable reports, and as early as 1889 Reclus used local anesthesia in the majority of hernia operations. He designates the operation for strangulated hernia "the triumph of cocain." He states that this is the anesthesia of choice, and in his judgment the use of general anesthesia is justifiable only under special conditions, such as herniæ of very large size, extensive adhesions, or the probability of complications.

Schleich's infiltration anesthesia was considered a step in advance for local anesthesia as the large doses of cocain used by Reclus were no longer necessary; but it is an undeniable fact that this progress, at least in inguinal and femoral herniæ, was made at the risk of producing an uncertain anesthesia. The branches of the ilio-inguinal, the spermatic, and the iliohypogastric nerves remain painful and capable of conduction, no matter how freely the tissues, in which they lie, are infiltrated with the Schleich solution. For this reason Cushing recommends that in operations for inguinal hernia the search for the nerve trunks which enter the field of operation should not be made until after the fascia of the external oblique muscle has been cut, and that they be blocked by an endoneural injection of a 1 per cent. cocain solution. Hackenbruch, starting out with an entirely different principle from Reclus and Schleich, injected the cocain-eucain solution in a fork-shaped or diamond-shaped area around the hernial ring.

All these methods have been superseded at the present time and are now of only historical value. They proved unreliable and difficult and their success depended too much upon the size of the hernia and other anatomical conditions. For this reason the use of local anesthesia for hernia remained in the hands of a few specialists.

[1] The writer confesses that after many attempts, some of them dating back a long time, he always returns to the same conclusion, that is, to perform operations on the appendix under general anesthesia without local anesthesia.

But there has been a great change since the advent of new anesthetizing solutions, with their simplified technique, and their greater reliability. In most of the surgical

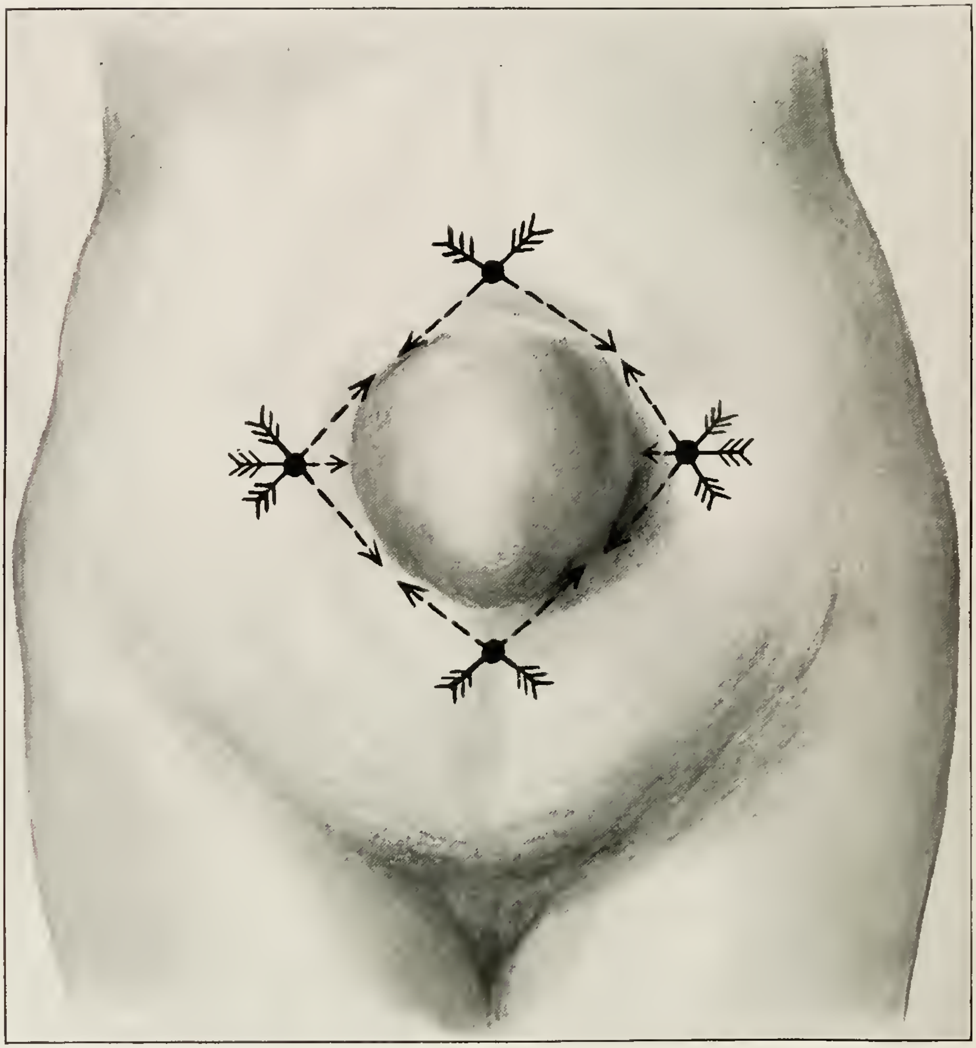


Fig. 131.—Anesthesia for umbilical hernia.

hospitals of Germany, hernias are now operated upon under local anesthesia according to the method described by Nast-Kolb, von Lictenberg, and Braun.

Statistical reports have been made on this subject by Hesse from city hospital at Stettin, where 218 hernia operations were performed from January 1, 1909, to September 15, 1910, of which 170 were performed under local anesthesia, and 48 under general anesthesia. In the hospital at Zwickau there were 397 cases operated for hernia from January 1, 1909, to October 1, 1911, and of these cases 345 were operated under local and 52 under general anesthesia. It has already been mentioned on page 171 that childhood presents no contra-indication to the use of local anesthesia in hernia operations; children are easily influenced, and if they can be induced to allow the injection, no further anesthesia will be required. During the operation it will, of course, be necessary for some experienced person to entertain the child.

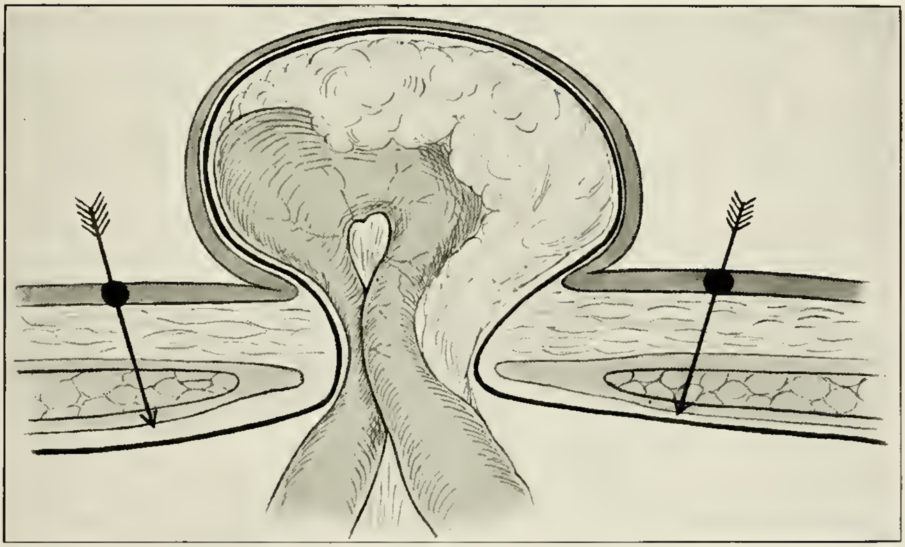


Fig. 132.—Cross-section of an umbilical hernia to demonstrate the extent of the deep injection.

Operations for Umbilical Herniæ, Hernia of the Linea Alba, and Postoperative Hernia.—The abdominal wall is anesthetized on the same principle as described for abdominal incisions above the umbilicus or ileocecal region. Four or more points of injection are marked. Surrounding the field of operation (Figs. 131 and 132) and proceeding from these the abdominal wall is circularly infiltrated down to the preperitoneal tissue with a 0.5 per cent. novocain-suprarenin solution. This is exceedingly simple and easily done in a reducible hernia, in which case the left index finger is introduced into the ring, and, guided in this way, the injection is made. After a little experience this can be done just as well in irreducible and strangulated hernia. In these cases, however, the operator must not expect to infiltrate the ring, for in irreducible hernia it is not accessible. He must rather aim to infiltrate a layer of the abdominal wall at some distance from the hernial swelling. This will cause the entire hernia to become insensitive. The greatest amount of anesthetic necessary in large umbilical herniæ in fat persons is 250 c.c. of a 0.5 per cent. novocain-suprarenin solution. Before undertaking a case of this kind it is necessary to know just how to guide the needle. In very fat persons it is advisable at first to infiltrate the skin and the subcutaneous connective tissue close to the hernial swelling; the aponeurosis is then exposed to the right and left of the hernial mass. The subaponeurotic injection can now be easily made as described; it is, however, necessary to wait until the peritoneum and hernial sac become insensitive. This method can be used in all cases of umbilical hernia, except when Menge's radical operation is required, in which case local anesthesia is not advisable.

Herniæ of the linea alba are anesthetized in the same way as the median incision for stomach operations (page 113), the size of the circuminjected area depending upon the extent of the field of operation. Most postoperative herniæ can be easily operated upon under local anesthesia by circuminjection.

Operations for Inguinal Hernia.—The object of the injection technique is to block the nerve trunks supplying the field of operation before they reach it, and to circuminject the field of operation. Neither of these manipulations alone would be sufficient. Fig. 133 explains schematically the innervation of the inguinal and femoral region. The external spermatic nerve, which is a branch of the genitofemoral, joins the spermatic cord at the internal ring, and accompanying it emerges from the inguinal canal on the under surface of the cord to be distributed to the cremaster muscle, tunica dartos, the skin of the scrotum or the labia majora, as well as the thigh in the region of the external ring.

The ilio-inguinal nerve lies above the spine of the ilium, between the oblique abdominal muscles; passing under the fascia of the external oblique it leaves the inguinal canal on the anterior surface of the hernial sac or the spermatic cord. Branches of this nerve supply the skin of the thigh, the scrotum and pubic eminence. The iliohypogastric nerve runs almost parallel with and a little higher than the former, between the oblique abdominal muscles, and in the inguinal region under the fascia of the external oblique muscle. It penetrates the anterior sheath of the rectus, in this manner reaching the subcutaneous connective tissues, innervating the skin of the inguinal region. The three nerves anastomose with one another; one or two of them may be absent, in which case they can be replaced one by the other. Bodine declares that the iliohypogastric nerve is the most constant one and not infrequently sends a branch through the inguinal canal, thus replacing a branch of the ilio-inguinal.

The ilio-inguinal and the external spermatic can also replace one another. The lumbo-inguinal, which is more deeply seated, is scarcely taken into consideration in operations for inguinal hernia. Cushing has called attention to the fact that if the three nerves first mentioned are cocainized at their entrance into the inguinal canal, the greater part of the field of operation will become insensitive.

FIG. 133.—Innervation of the inguinal and femoral region. 1, genitocrural nerve; 2, external spermatic nerve; 3, lumbo-inguinal nerve; 4, ilio-inguinal nerve; 5, iliohypogastric nerve; 6, anterior cutaneous branches of the twelfth intercostal nerve.

Method Used in Reducible Inguinal Hernia.—Two points of entrance are marked (Fig. 134). Point 1 lies three finger-breadths internal to the anterior superior spine of the ilium. Point 2 is exactly over the horizontal ramus of the pubes at the outer inguinal ring. From point 1 the muscular layer (arrow A) lying between the point of injection and the ilium is infiltrated according to Fig. 29 (page 190). About 20 c.c. of a 0.5 per cent. novocain-suprarenin solution is injected in the following manner (Figs. 135 and 136): The long needle is first entered perpendicular to the surface of the skin, then through the aponeurosis of the external oblique muscle and through the muscular layers of the internal oblique and transverse muscles; it is then withdrawn and inserted twice again, each time in a more oblique direction toward the spine of the ilium, until the point of the needle strikes the iliac bone. The thick muscular layer situated in this region must be infiltrated. This injection blocks the

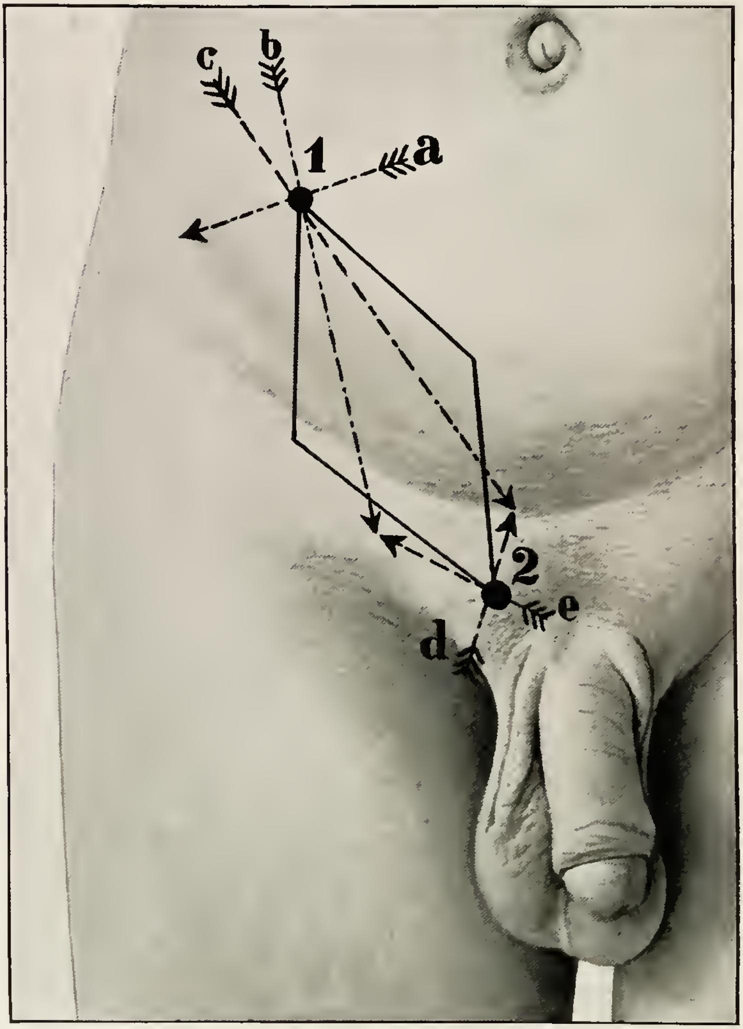


Fig. 134.—Injection for reducible inguinal hernia. The dotted lines indicate subaponeurotic injections, the continuous lines the subcutaneous injections.

ilio-inguinal and the iliohypogastric nerves. From point 1 further injection of 10 to 20 c.c. of 0.5 per cent. novocain-suprarenin solution is made under the aponeurosis of the external oblique muscle in a fork-shaped manner toward a point lying in the median line, laterally from the inguinal ring (arrows *b* and *c*).

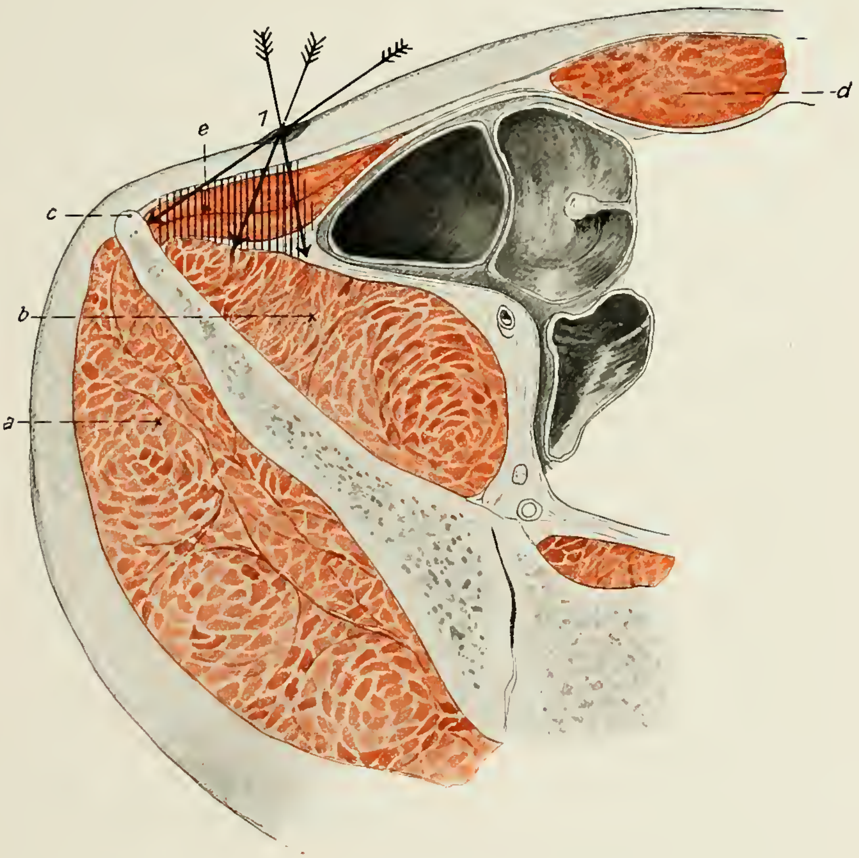


Fig. 135.—Cross-section of the abdomen at the level of the anterior superior spine of the ilium. (Made from frozen section.) *a*, gluteus muscle; *b*, iliac muscle; *c*, spina ilei; *d*, rectus abdominus muscle; *e*, external and internal oblique and transversalis muscles. The location of the trunk or branches of the iliohypogastric and ilio-inguinal nerves is shaded black. 1 is the point for injection.

From point 2 a deep injection of 10 c.c. of the solution is made in a fan-shaped manner, and with each injection the needle will strike the pubic bone. From point 2 further injections of 10 c.c. are made in a fork-shaped manner under the aponeurosis in the inguinal canal along the spermatic cord (arrows *d* and *e*). The skin incision is finally circuminjected subcutaneously in the form of a rhombus, 75 to 100 c.c. of 0.5 per cent. novocain-suprarenin solution being necessary for the entire injection. In double hernia both sides are injected before the operation is begun.

Method of Operation in Irreducible or Strangulated Inguinal Herniæ.—The position of the points of injection, as well as the subcutaneous and subaponeurotic or subfascial strip of injection is shown in Figs. 137 and 138. From point 1 the injections are made, as already described, toward the iliac spine, then follow the subaponeurotic injections toward points 2 and 3. These are followed by deep injections from points 2 and 3, the hernial mass being held up with the left hand, either to the outside or inside as the case requires. From both of these points, the needle must reach the pubic bone underneath the hernial mass. Further injections are made from points 2 and 3 under the aponeurosis into the inguinal canal, alongside the neck

FIG. 136.—Guidance of the needle for injections near the iliac spine in inguinal and femoral herniæ.

of the hernial sac. The final injection is a subcutaneous one between points 1, 2, 3, and a subcutaneous circuminjection of the whole scrotum and penis as the diagram shows. In very large herniæ 150 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. Reducible herniæ, with large sacs reaching to the base of the scrotum, are also better managed in the way just described, that is, by circuminjecting the entire scrotum.

Procedure in Femoral Hernia.—A glance at Fig. 133 will show that the field of operation for femoral hernia is mainly innervated by the same nerve trunks which played an essential part in the anesthesia of the field of operation for inguinal hernia operations. Anesthesia for femoral hernia is produced in the following manner (Fig. 139). There are four points to be marked by wheals. Point 1 occupies the same position as it does in operations for inguinal hernia, three finger-

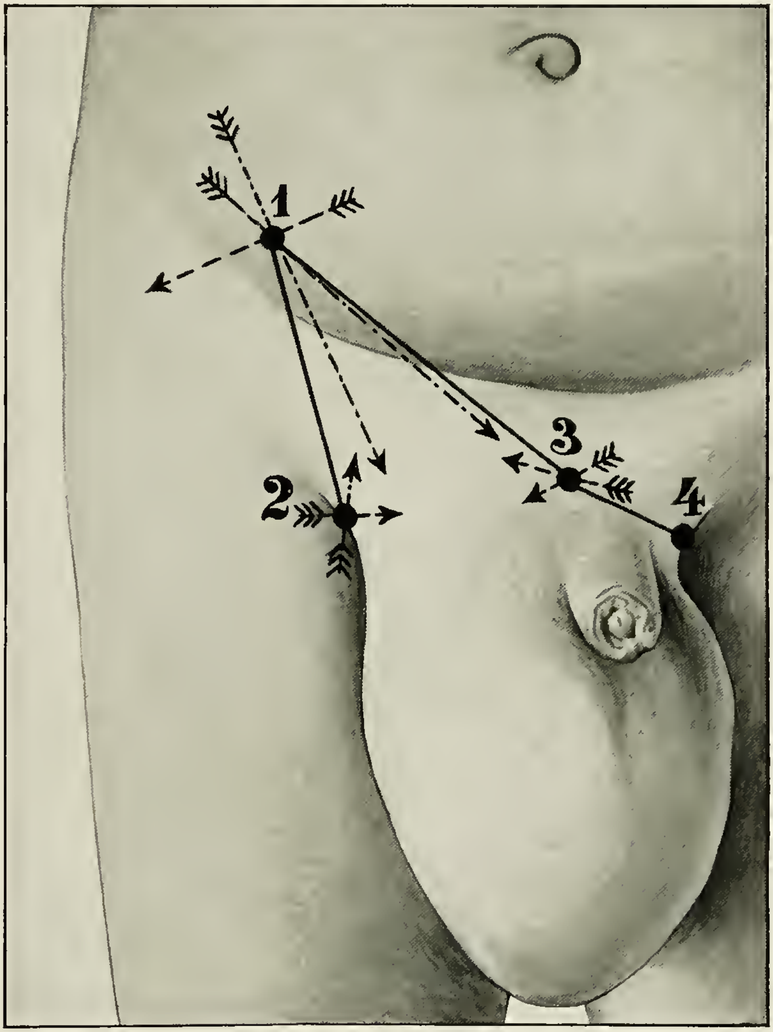


Fig. 137.—Injections for irreducible inguinal hernia or for reducible hernia with very large sacs. ——— subcutaneous, ... subaponeurotic injections.

breadths from the spine of the ilium toward the median line. Points 2 and 3 lie on each side of the hernial mass and at the ends of the incision to be made, which is parallel to Poupart's ligament. Point 4 lies underneath the hernial mass. We begin with the intramuscular injections from point 1, which should be directed toward the spine of the ilium as they were in the case of inguinal hernia, then a fork-

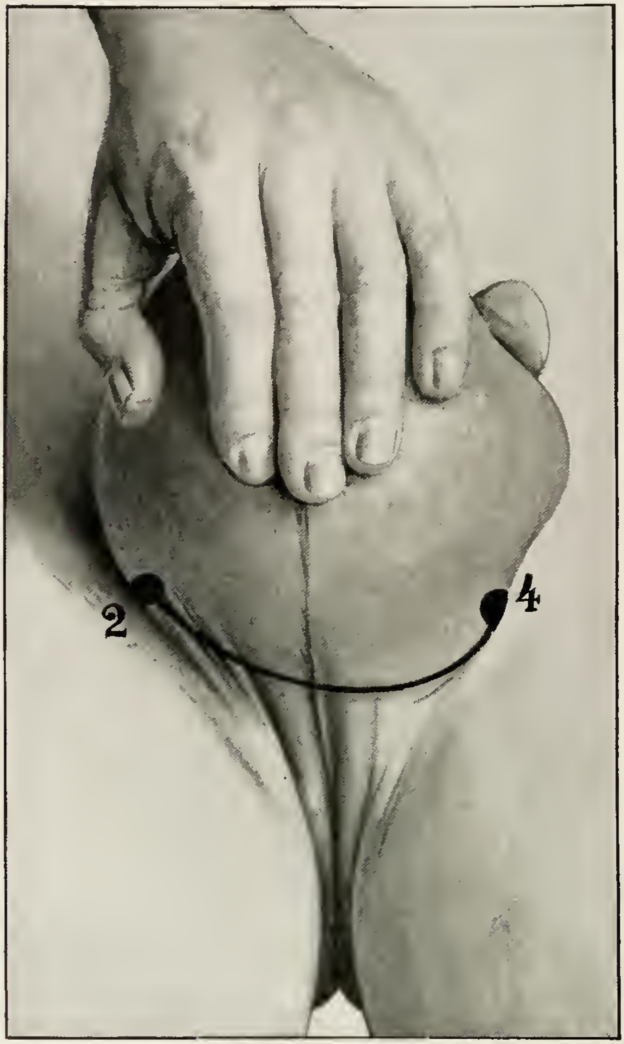


Fig. 138.—Continuation of the injection as shown in Fig. 137.

shaped, subfascial injection from point 1 is made, passing the needle on each side of the hernial sac as far as Poupart's ligament. From point 4, 10 c.c. of novocain-suprarenin solution is injected in the region of the neck of the hernial sac, as close to it as possible, and finally a subcutaneous circuminjection is made, as indicated by the line drawn in the diagram. The operations are entirely painless and no further injections will be necessary for the radical operation, even if the complication arises

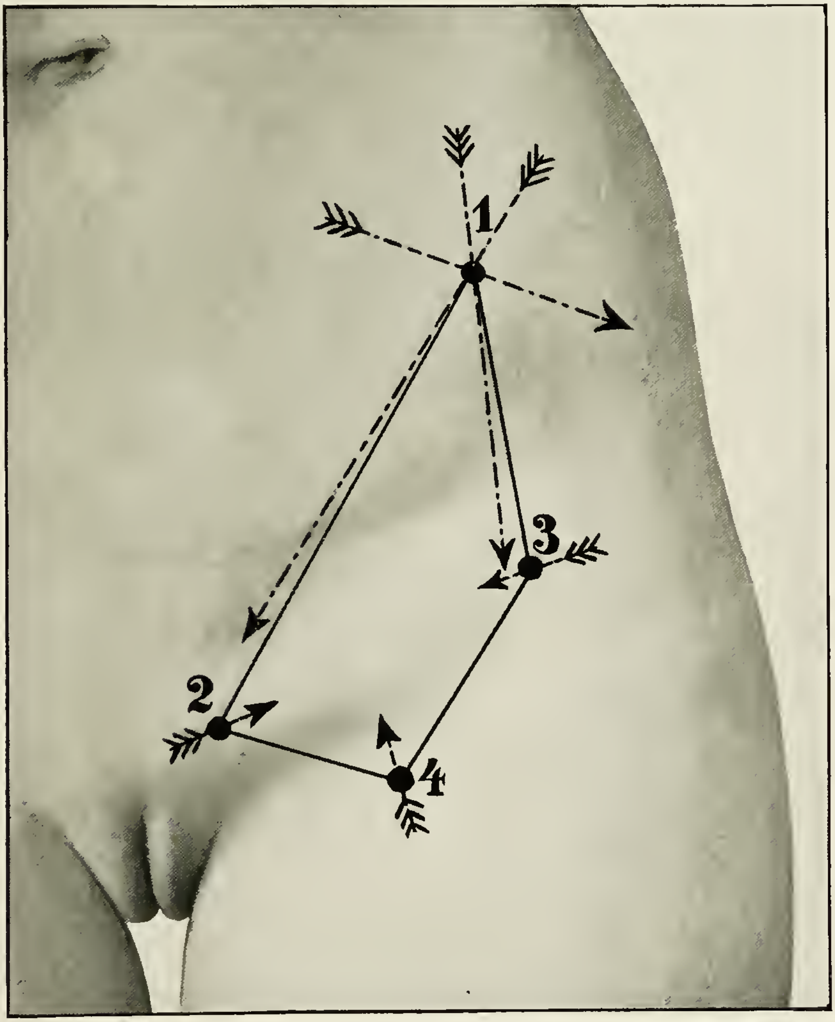


FIG. 139.—Anesthesia for femoral hernia.

which necessitates the cutting of Poupart's ligament upward. The same method used for inguinal operations can also be used for femoral hernia without any change. In the method of anesthesia the size and consistency of the hernia need not be taken into consideration, whether it be reducible or irreducible, strangulated or not. No difficulties are encountered in this anesthesia, except occasionally in obese and excitable patients. In the latter case morphium or morphium-scopolamin should be given. Other patients need not be prepared by the administration of any opiate. Abdominal sensations seldom occur except, perhaps once in a great while, when a hernial sac is separated and drawn out, and occasionally in gangrenous hernia when the mesentery is ligated. They are bearable, and only in exceptional cases is it necessary to use ethyl chlorid.

CHAPTER XV.

GENITO-URINARY AND RECTAL OPERATIONS.

The Innervation.—The innervation of the organs of the pelvis, and to some extent that of the external genitalia, is supplied by the pudic nerves, pelvic branches of the posterior cutaneous femoral, by spinal nerves, originating in the sacral plexus which accompany the sympathetic nerve bundles of the pelvic organs, and by the nerves of the coccygeal plexus. Their distribution in the perineum and the external genitalia can be seen from Figs. 140 and 141. The trunk of the pudic nerve emerges from the pelvis through the large ischiatic foramen, passes along the outer surface of the spine of the ischium to be divided into its branches, which again enter the pelvis between the tuberosity and the spine of the sacrum.

Fig. 142 shows the position of the nerve trunk on the outer surface of the spine of the ischium. Its branches lie in the ischiorectal fossa and supply the skin of the perineum, parts of the anus, the skin of the posterior surface of the scrotum, the urethra and corpora cavernosa, the penis, in females the labia minora, the greater part of the vagina, and a part of the labia majora. The pelvic branches of the posterior cutaneous femoral, and the nerves which pass through the inguinal canal supply the anal region and the perineum, the skin of the scrotum and the labia majora; the nerves originating from the coccygeal plexus also supply the anal region. The spinal nerves, known as the pelvic nerves, originate from the second, third, and fourth sacral nerves, run forward on both sides of the rectum, and in the female unite with the sympathetic ganglion (ganglion cervicale uteri, Fig. 143) which lies between the cervix uteri and the rectum. In the male, it lies laterally between the prostate and the rectum.

The pelvic nerve innervates the bladder, uterus, prostate and the upper part of the rectum, as well as the lower part of the pelvic peritoneum. The sympathetic ganglion itself takes no part in the sensory innervation of these parts.

CONDUCTION ANESTHESIA IN THE PELVIS.

Ilmer has recommended for operations on the female genitalia and for confinements that the trunk of the pudic nerve be blocked on both sides by injections of 5 to 10 per cent. cocain solution. The anesthesia used by him is absolutely unreliable and dangerous. Ilmer relies upon the methods of B. Mueller, which appear to be altogether theoretical and not at all based on practical experience. For example, an

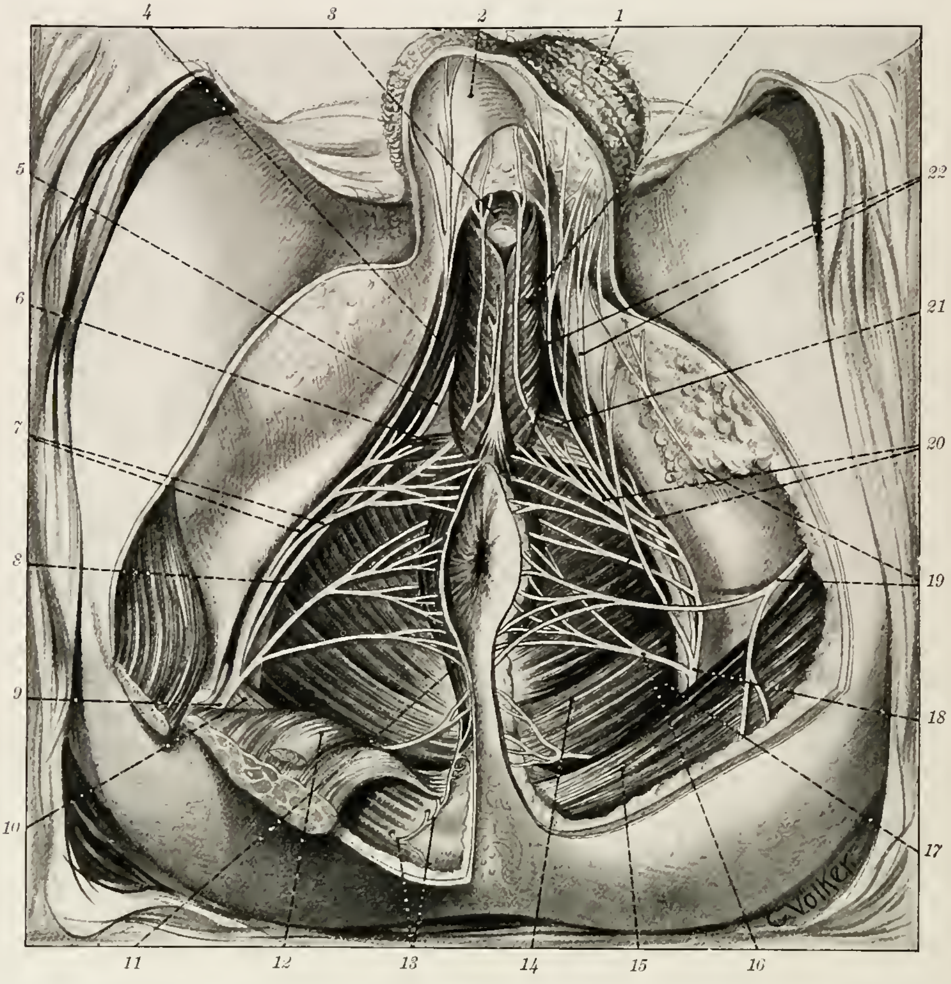


Fig. 140.—Nerves of the male perineum (after Toldt). 1, scrotum; 2, tunica dartos; 3, corpus cavernosum urethræ; 4, ischiocavernous muscle; 5, dorsalis penis nerve; 6, transversus perinei superficialis muscle; 7, perineal nerve; 8, dorsalis penis nerve; 9, pudic nerve; 10, ligamentum sacrospinosum; 11, sphincter ani externus muscle; 12, ligamentum sacrotuberosum; 13, anococcygei nerves; 14, levator ani muscle; 15, gluteus maximus muscle; 16, inferior hemorrhoidal nerve; 17, ischiorectal fossa; 18, perineal nerve; 19, perineal branches of posterior cutaneus femoris nerve; 20, branches of perineal nerve; 21, transversus perinei profundus muscle; 22, postscrotal nerves.

extensive anesthesia, which Mueller recommends should be done by blocking both pudic trunks, cannot be accomplished. Furthermore, the operator cannot always rely upon meeting the trunk of the nerve on the inner surface of the pelvis, because it is covered by the obturator fascia and divides before its entrance into the ischio-

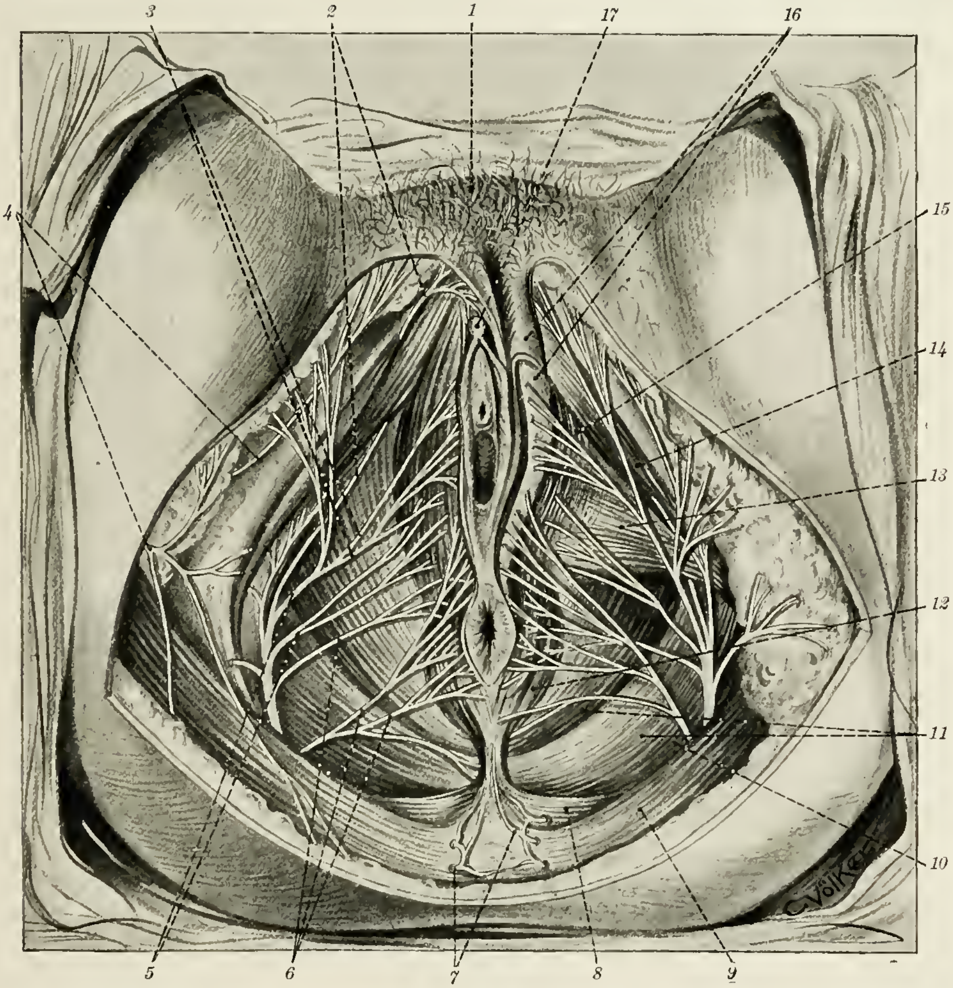


FIG. 141.—Nerves of the female perineum. (After Toldt.) 1, mons pubis; 2, dorsalis clitoridis nerve; 3, posterior labial nerves; 4, perineal branches of the cutaneus femoris posterior; 5, perineal nerve; 6, profundus hemorrhoidal nerve; 7, anococcygei nerves; 8, coccygeus muscle; 9, gluteus maximus muscle; 10, ischiorectal fossa; 11, levator ani muscle; 12, sphincter ani externus muscle; 13, transversus perinei profundus muscle; 15, ischiocavernous muscle; 15, bulbocavernosus muscle; 16, labium majus; 17, clitoris.

rectal fossa. For this reason Franke and Posner recommend that search be made for the nerve on the outer surface of the spine of the ischium (Fig. 142), where it lies in the loose connective tissue. Guided by a finger placed in the rectum, they insert a needle 15 cm. long from a point on the side of the anus, until the spine of the ischium is felt, and then direct the needle backward to the outer surface of the bone. It is sometimes difficult to feel the spine of the ischium and reach it with a needle when inserted so deeply. Blocking the trunk of the pudic nerve alone without the posterior cutaneous femoral, the coccygeal plexus, and the pelvic nerve, is of little value. It is much easier to exclude its branches by proper injections, as will be seen later.

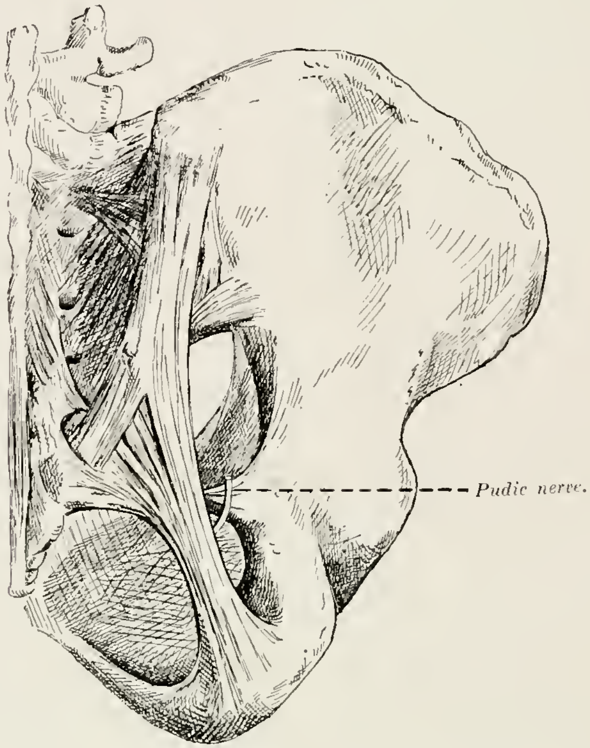


Fig. 142.—Position of the pudic nerve on the spine of the ischium.

The pelvic branches of the posterior cutaneous femoral are easily blocked, together with the branches of the pudic nerve, by injections into the ischiorectal fossa, and the coccygeal plexus is found by making an injection between the coccyx and the rectum. Franke and Posner attempted to locate the pelvic nerve by making injections in the region of the sympathetic ganglion of the cervix of the uterus (Fig. 143). For this purpose a needle 15 cm. long was inserted at a point in front and to the side of the anus, between the rectum and the prostate, as high as the region of the ganglion, injecting 15 c.c. of 1 per cent. novocain-suprarenin solution on both sides. In connection with the above-named injection of the trunk of the pudic nerve, and injections into the ischiorectal fossa, they were able to make painless perineal prostatectomies and one lithotripsy. It is, however, more important and technically much simpler

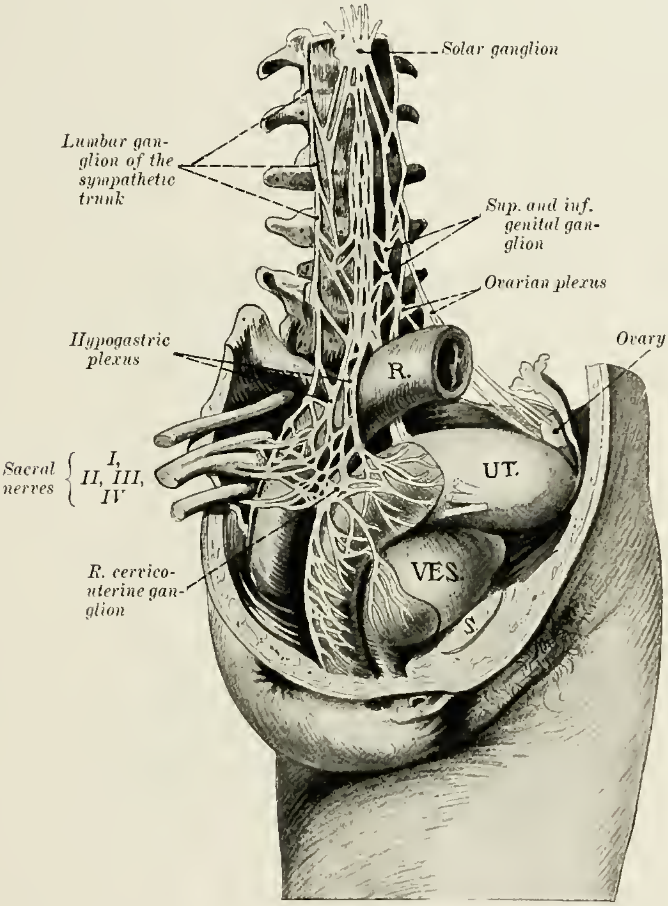


FIG. 143.—Innervation of the pelvic organs. (After Corning.)

to block the sacral nerves at their points of emergence from the sacral foramen. In this way the pelvic nerve, the entire pudendal plexus, and the posterior cutaneous femoral nerve are interrupted and a complete anesthesia of the pelvic organs and lower part of the pelvic peritoneum is obtained. This procedure we will call *parasacral conduction anesthesia,* deriving the idea from the paravertebral anesthesia of Sellheim and Laewen (page 314), in which the injection was also made into the nerve trunks as they leave the spinal canal.

The technique for parasacral injections is as follows: The two points of injection lie 1.5 to 2 cm. from the median line to the right and left of the sacrococcygeal articulation. Inspection of the inner surface of the sacrum shows that in the lower part, between the second and fifth sacral foramen, there is very little curvature to the bone, which makes it possible to push the needle forward in a straight line along the inner surface from the point mentioned to the second sacra foramen, without losing the contact between the point of the needle and the bone. Above the second sacral foramen the point of the needle must necessarily strike the bone and, therefore, cannot be inserted further. In the adult this point is 6 to 7 cm. distant from the point of entrance, not taking into consideration the soft structures.

FIG. 144.—Position of the needle for parasacral conduction anesthesia.

The patient is now placed in the lithotomy position and the needle inserted in a direction parallel with the inner surface of the lower half of the sacrum; with the point of the needle the edge of the sacrum is sought for. Feeling the way past the edge of the sacrum the needle is pushed along the inner surface of this bone parallel to its median plane until it strikes the bone at the depth mentioned. The entire distance from the second to the fifth sacral foramen is injected with 20 c.c. of a 1 per cent. novocain-suprarenin solution. No injection should be made until the contact with the bone is felt. The needle is now drawn back to the edge of the sacrum and is directed at a small angle toward the innominate line, always pushing it parallel to the median plane. In this direction the needle penetrates deeper than before, until it again strikes the bone above the first sacral foramen at a distance of 9 to 10 cm. from the point of entrance, the soft parts not taken into consideration; at this point 20 c.c. of 1 per cent. novocain-suprarenin solution is injected. The final injection of 5 c.c. of the solution is made between the rectum and the coccyx from the same point of entrance. The same injection is made on the opposite side; altogether 100 c.c. of the solution are required. Fig. 144 shows the method of guiding the needle as has been described. The needle must be 12 cm. long (No. 7, page 174). The author makes this injection without the aid of a guiding finger in the rectum, as the empty bowel is not easily injured and evades the needle. If the operator is doubtful on this point, then the position of the needle should be controlled by the finger, especially in making the injection to the first sacral nerve. We have used this method in prostatectomies, in operations for complete prolapse of the uterus, both with and without artificial fixation of the uterus, in extirpation and resection of the rectum for carcinoma, the rectum being painlessly dissected as far as the flexure.

The anesthesia extends higher up than Laewen's sacral anesthesia, and affects the same segments. In consequence of the blocking of the posterior cutaneous femoral nerve, the skin of the posterior surface of the thigh always becomes insensitive as far as the popliteal space. The sphincter ani is necessarily paralyzed. The urethral prostate and bladder are both totally insensitive. Anesthesia of the parietal peritoneum does not extend high enough for an extirpation of the uterus, for, as is well known, a high lumbar anesthesia is necessary for this purpose. That part of the peritoneum supplied by the sacral plexus alone is confined to the floor of the pelvis. Parasacral anesthesia is a most reliable form of anesthesia; more so than sacral and without secondary effects. This reliability is attributed to the fact that the course taken by the needle is determined by its point of contact with the bone.

KIDNEY OPERATIONS.

Laewen describes a pyelotomy for kidney-stone which was successfully performed under local anesthesia. From each of 4 points about 4 cm. from the median line he made paravertebral injections into the twelfth intercostal and the first to the third lumbar nerves, using 10 c.c. of 1 per cent. novocain-suprarenin solution and circum-injected the field of operation with a 0.5 per cent. novocain-suprarenin solution. The luxation of the kidney was the only part of the operation not entirely painless. For kidney operations Kappis recommends the simple paravertebral conduction anesthesia without the concomitant circuminjection. For this purpose the eighth dorsal to first lumbar nerves must be blocked; for operations on the ureter, the second and third lumbar nerves must also be blocked. Kappis states that since the development of this method almost all kidney operations are performed under local anesthesia at the Kiel clinic. (Concerning the technique of the paravertebral injections see page 279.) Encouraged by this statement, the author used Kappis' technique and removed successfully a large hypernephroma. The patient experienced no pain during this tedious operation, except on ligating the pedicle, whereupon several whiffs of ether

Fig. 145

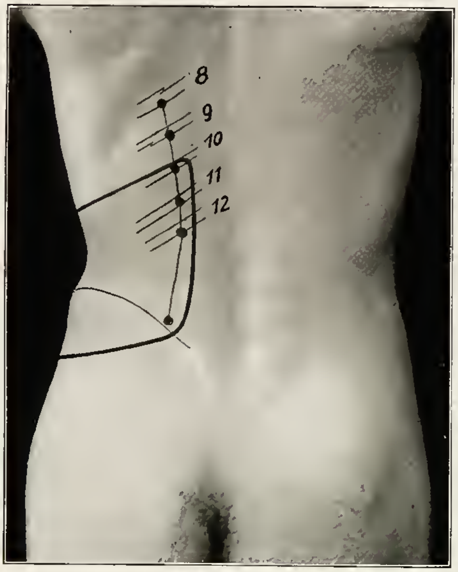


Fig. 146

Figs. 145 and 146.—Technique of anesthesia for kidney operations. The continuous line indicates the extent of anesthesia.

were administered. Three nephrotomies were performed in the following manner (Figs. 145 and 146): In each of the cases it was possible to determine the exact extent of the anesthesia. The eighth to twelfth dorsal nerves were each blocked with 5 c.c. of 1 per cent. novocain-suprarenin solution. The points of entrance were placed in a line continuous with the outer edge of the quadratus lumborum muscle. Another point was marked on the outer edge of the quadratus muscle at the crest of the ilium. From this point and the point marked for the twelfth dorsal, a strip of tissue extending to the kidney fat was infiltrated thoroughly with about 75 c.c. of 0.5 per cent. novocain-suprarenin solution according to Fig. 29 (page 189). No further injections or circuminjections were necessary, as the anesthesia of the skin was extensive, as shown in Figs. 145 and 146. The operations were absolutely painless, were performed upon lean persons, and the kidney was easily accessible. The luxation of the kidney was painless. There is, therefore, every reason to believe that local anesthesia will soon be used for kidney surgery.

ANESTHESIA OF THE MUCOUS MEMBRANE OF THE BLADDER AND URETHRA.

The application of a concentrated solution of cocain to so large an absorbing surface as the bladder and the male urethra is, as is well known, dangerous to life. Numerous patients have died from the effect of this unreliable method of cocain application. Sudden death has resulted from an injection into the urethra of 5 c.c. of a 1 per cent. cocain solution (Czerny). The secondary toxic effects of the drug administered in this manner are due to the concentration of the solution and not to the quantity used. Weak cocain solutions (0.1 to 0.2 per cent. in the bladder, 0.5 per cent. in the urethra) with the addition of suprarenin are absolutely safe and produce the same degree of anesthesia as concentrated solutions, if kept in contact with the mucous membrane a sufficient length of time.

Of the newer remedies, a combination of alypin and suprarenin is the best substitute for cocain. The application of a concentrated solution of this remedy is permissible, if used with caution. Garrasch has twice experienced severe poisoning (see page 120) following injections of 5 c.c. of 2 per cent. and 5 per cent. solutions of alypin into the urethra.

In order to render the mucous membrane of the bladder insensitive to the touch of instruments and for superficial operations the bladder should be filled with a 0.5 per cent. solution of alypin and suprarenin, and allowed to remain from fifteen to thirty minutes. If the mucous membrane of the bladder is not sufficiently cleansed before the solution is injected, if filled with blood, or if the mucous membrane is incrusted or covered with adherent mucous, it will be impossible to bring the solution sufficiently in contact with the mucous membrane to obtain anesthesia.

In intravesicular manipulations, made through the urethra, it is more important to anesthetize the more sensitive posterior part of the urethra than the mucous membrane of the bladder. In the male urethra the mucous membrane, when penetrable, is made insensitive in the following manner: A thin Nélaton catheter is introduced into the bladder and drawn back until the fluid ceases to run; 5 c.c. of a 1 per cent. alypin-suprarenin solution (for the proportion see page 180) is injected. At the same time the catheter is gradually withdrawn, the fluid thus being prevented from escaping, and the penis is tied off with a tape. The solution should remain in the urethra at least ten minutes or a quarter of an hour. This is absolutely necessary, the intensity and duration of the local anesthesia depending upon the length of time the solution remains in contact with the parts.

If the urethra is not passable, an anterior injection is made and the penis ligated. In strictures it is necessary to repeat the injection when the stricture has become passable. This procedure makes catheterization and dilatation of strictures entirely painless. In order to render the mucous membrane of the female urethra insensitive, all parts of the membrane, from the external orifice to the neck of the bladder, must be swabbed with a 2 per cent alypin-suprarenin solution, and the applications repeated for several minutes. The anesthesia thus produced will not be sufficient for extreme dilatation of the urethra which is sometimes necessary. Complete anesthesia can be obtained for this manipulation by circuminjection of the urethra with a 0.5 per cent. novocain-suprarenin solution.

FIG. 147.—Injection for suprapubic cystotomy.

Suprapubic Cystotomy.—Suprapubic cystotomy for stone in the bladder can be performed almost entirely under local anesthesia. After thoroughly washing the bladder, it is filled with a 0.5 per cent. alypin-suprarenin solution. Two points of entrance are marked (Fig. 147), and the injection is made by introducing a long needle at point 1, close over the symphysis, and directing it through the aponeurosis, in various directions, deep into the prevesical space and infiltrating this freely with 40 to 50 c.c. of a 0.5 per cent. novocain-suprarenin solution. The abdominal layers in the line of the incision are then made anesthetic by injecting from both points, as described on page 301. For this injection 20 c.c. more of the same solution are necessary. In most cases the wall of the bladder which is exposed above the symphysis is not sensitive to pain. In a few cases it is necessary to infiltrate the line of incision in the bladder more thoroughly before cutting, probably on account of the insufficient infiltration of the prevesical space.

OPERATIONS ON THE SCROTUM AND TESTICLES.

The skin of the scrotum and the tunica vaginalis communis receives its innervation for the most part from the perineum, from the subcutaneous terminal branches of the pudic nerve and the posterior cutaneous femoral. Above it is also supplied by branches of the ilio-inguinal and the external spermatic as they emerge from the inguinal canal. The two last named nerves alone supply the spermatic cord, the

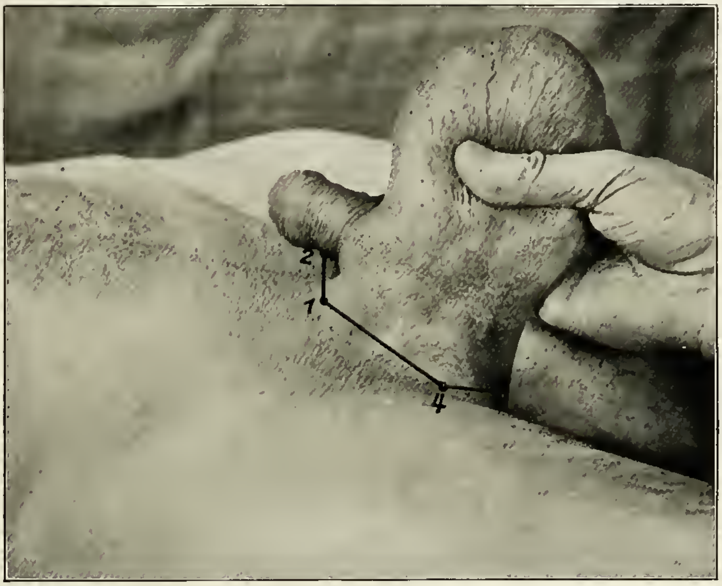


Fig. 148.—Circuminjection of penis and scrotum for operations upon the scrotum and testicle.

testicles and the tunica vaginalis propria. For the complete anesthesia of these parts the following injection is necessary. One point of entrance is marked on each side where the spermatic cord crosses the pubic bone, another is marked laterally where the scrotal skin emerges with the skin of the thigh (Fig. 148).

The next step is to produce anesthesia in the spermatic cord with its nerves. Reclus lifts the spermatic cord with two fingers of the left hand and injects the anesthetic into the cord (Fig. 149). It is not always possible to lift up the cord as, for example, in a large hydrocele that extends high up, for which reason the following method is

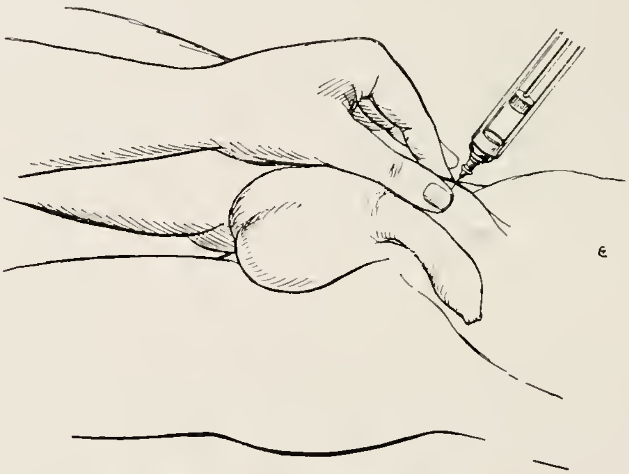


Fig. 149.—Injection into the spermatic cord. (After Reclus.)

Fig. 150.—Fan-shape injection upon the pubic bone for hydrocele.

preferable: A needle is inserted from point 1 toward the underlying pubic bone until the bone is felt with the point of the needle, and a bilateral fan-shaped injection of 5 c.c. of 0.5 per cent. novocain-suprarenin solution is made in three directions, perpendicular and lateral to the symphysis. In Fig. 150 the needles indicate the two last mentioned directions. In this way the spermatic cord cannot be missed. Finally, an extra injection of 10 c.c. of 0.5 per cent. novocain-suprarenin solution is

FIG. 151.—Injection in the inguinal canal for hydrocele.

FIG. 152.—Circuminjection of the posterior surface of the scrotum.

injected into the inguinal canal (Fig. 151), in this manner obtaining a reliable blocking of the nerves accompanying the spermatic cord. In bilateral operations this manipulation must naturally be carried out on both sides. These injections must be followed by a subcutaneous circuminjection of the entire scrotum, whether the condition be uni- or bilateral, made in a line connecting the four points of entrance (Fig. 148). Fig. 152 demonstrates the position of the needle for the subcutaneous injection from point 4 toward the perineum. In fat persons it is necessary to infiltrate freely the circular line of injection in layers, in order to block with certainty the posterior scrotal nerve. Not infrequently, 50 c.c. or more of 0.5 per cent. novocain-suprarenin solution is necessary for the circuminjection. This procedure is suitable for all operations on the scrotum and testicle and is also specially suitable for the radical operation for hydrocele and for ablation of the testes.

If these operations are performed through Kocher's inguinal incision the spermatic cord is immediately exposed at the beginning of the operation. If, after exposing the tunica and the testicle, it is found that the injection of the cord has not been successful, an accident which is very apt to happen to a surgeon who is not at once familiar with these methods, it will be necessary to inject a few drops of a 2 per cent. novocain-suprarenin solution into the spermatic cord in order to obtain the desired anesthesia.

OPERATIONS ON THE PENIS.

For a simple dorsal incision of the prepuce in phimosis it is only necessary to infiltrate the line of incision by an injection between the skin and mucous membrane. A very fine needle is inserted into the edge of the foreskin (Fig. 153) and passed between the skin and mucous membrane upward over the coronary sulcus, injecting along this line 1 to 2 c.c. of 1 per cent. novocain-suprarenin solution. Occasionally it is easier to make the injection from a point on the dorsum of the penis. The needle in this case is pushed forward subcutaneously to the edge of the prepuce.

Anesthesia of the entire prepuce for phimosis is produced as follows: The foreskin is drawn tensely over the glans and is held in this position by tying with tape. The anesthetic is injected subcutaneously and circularly into the coronary sulcus, and the tape is not removed until after the anesthesia has become complete. In cases of paraphimosis it is necessary to make a circular injection into the coronary sulcus, and one above the constricting band. Injections of suprarenin solution into the peripheral parts of the penis must be made with caution as the arteries supplying the prepuce are end arteries. If the novocain-suprarenin solution is injected too freely, the effect of the suprarenin may last too long, and a prepuce treated in this manner will be in a similar condition to a pedicled skin flap (see page 145). As a result of the contraction of all the arteries the tissues are unable

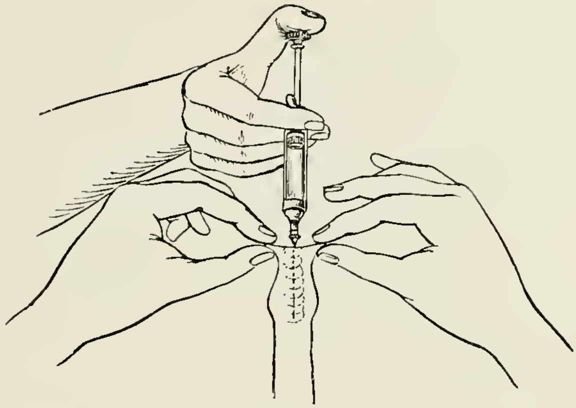


Fig. 153.—Injection for the dorsal incision of the prepuce.

Fig. 154.—Anesthesia of the entire penis.

to throw off the injected substances, or do it too slowly and in this way cause damage to the tissues. Damage of this character has been reported, but may be avoided by never injecting more than 1 or 1.5 cm. of 1 per cent. novocain-suprarenin solution into a penis. It is therefore advisable that the circular, peripheral injection into the penis be avoided and that the entire penis be made insensitive by injections at its base, even in operations for phimosis. If a circular subcutaneous injection of an anesthetic is made around the shaft of the penis, as described by Krogius, the glans and mucous membrane of the foreskin are often not made insensitive, giving rise to serious complaint in operations for phimosis. This is not the case if the injection is made close to the symphysis in the following manner (Fig. 154):

Anesthesia of the Entire Penis.—Two points of injection are made, one to the right and one to the left of the base of the penis, at a point where the spermatic cord crosses the horizontal ramus of the pubes. From these two points, with the penis drawn out and held in this position, a 0.5 per cent. novocain-suprarenin solution is injected. The needle is then passed as deep as the corpora cavernosa, circum-injecting them at the point where they emerge from the angle of the symphysis and unite with the shaft of the penis. From below the needle penetrates the scrotum, above it reaches the suspensory ligament of the penis. In fat persons long needles are necessary. A second injection just under the skin is then made corresponding with the dark line in Fig. 154. In an adult with a moderate amount of fat about 40 c.c. of 0.5 per cent. solution are required, a proportionately smaller quantity being used in children. The entire penis, skin, prepuce, glans, the pendulous portion of the urethra, and the corpora cavernosa, distal to the pubes, are rendered insensitive. This method is suitable for all operations on the parts named—for example, in amputations of the penis, plastic operations on the urethra (hypospadia glandis), urethral fistulæ and, as has been stated, for phimosis and paraphimosis.

For extirpation of inguinal glands in connection with amputation of the penis, see Chapter XVI.

OPERATIONS ON THE POSTERIOR PART OF THE URETHRA. EXTERNAL URETHROTOMY.

For years external urethrotomy for strictures and recent injuries have been performed almost without exception under local anesthesia in the following manner: In the median line in front of the anus one point is marked (Fig. 155) and an imaginary horizontal plane is drawn through this point. In the diagram this is shown by a horizontal line. This plane separates the anus and the rectum on one side from the bulbus urethræ and the prostate on the other. Laterally it passes through the ischio-rectal fossa on each side and meets the ascending ramus of the ischium in front of the tuberosities. This plane must be infiltrated with a 0.5 per cent. novocain-suprarenin solution. For this purpose the left index finger is inserted into the anus, and a needle

8 to 10 cm. long is inserted into the median plane between the bulbus urethræ and the anus, and a continuous injection is made, as high up as possible, between the rectum and the prostate. In the next two injections the needle is directed further to the right and left, reaching the lateral lobes of the prostate and rectum. In the next two injections it is passed within the transverse plane and always from the same point of entrance still more laterally, penetrating deeply into the ischiorectal fossa. In the last two injections the needle is directed almost transversely to the right and left, striking the ascending ramus of the ischium. The final subcutaneous injection is not made

FIG. 155.—Transverse infiltration of the perineum for external urethrotomy.

in the horizontal plane but as shown in Fig. 155 in the direction between the scrotum and the thigh, in order to block those nerves of the skin which might extend from the side to the perineum and the scrotum; about 75 c.c. of 0.5 per cent. solution is necessary. The course of the needle in deep injections is reproduced in Fig. 156.

All the branches of the pudic nerve and the posterior cutaneous femoral which supply the prostate, urethra and the external genitalia are blocked with certainty (see Fig. 140 (page 316). Franke and Posner have observed that the infiltration behind the prostate is an important factor in the blocking of the pelvic nerve. The perineum, the posterior surface of the scrotum, the entire urethra from the neck of the bladder to the external orifice and the prostate are rendered insensitive. The patient does not feel the entrance of the catheter and all operations performed in this region are painless. The perineal dissection of the prostate is usually not altogether painless, as violent pulling on the organs cannot be avoided. The method described has the same effect and is more reliable than Laewen's sacral anesthesia,

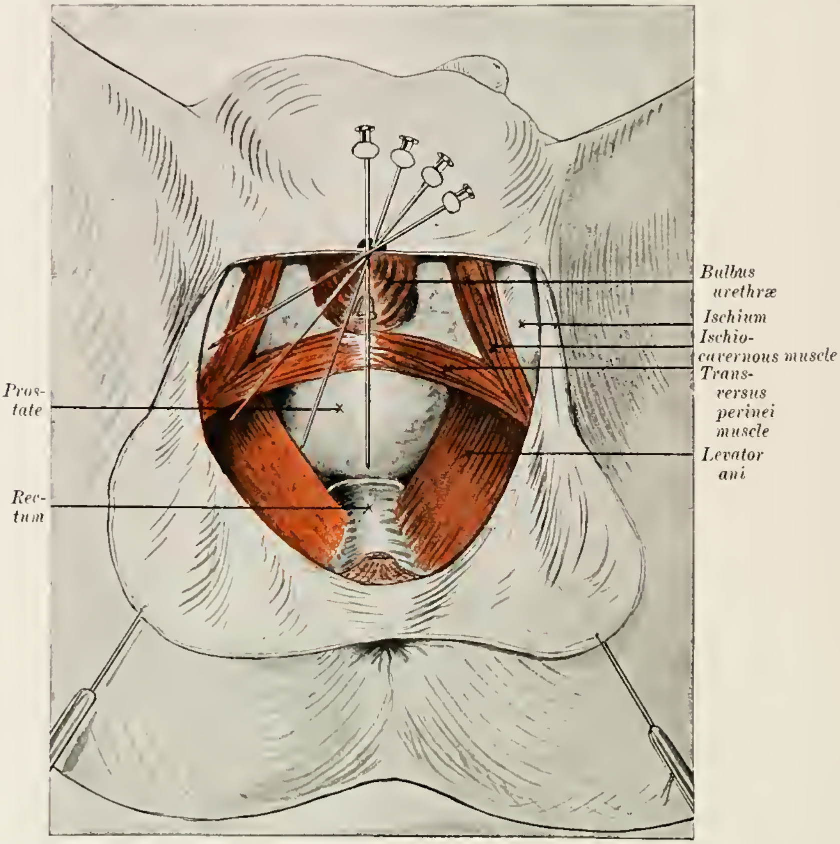


Fig. 156.—Transverse infiltration of perineum; position of needles.

and is preferable, as the anemia of the field of operation produced by the suprarenin is of great value. Only when the injections cannot be made behind the urethra and prostate, as in urinary infiltration and in abscesses, is sacral anesthesia to be preferred to direct anesthesia of the field of operation. Sometimes the method described is combined with anesthesia of the entire scrotum (page 325) for amputation of the penis, for the median splitting of the scrotum, and for sewing the urethra into the perineum, according to the method of Thiersch.

Prostatectomy.—Parasacral conduction anesthesia (page 320) is the most suitable for performing the perineal or Wilms prostatectomy. Suprapubic prostatectomy is performed in the following manner: The patient usually receives 1 cg. of morphin preceding the anesthesia, which is the same as for "sectio alta" (page 324). The shelling out of the prostate is done under ether or ethyl chlorid anesthesia. After opening the bladder Payr circuminjects the prostate through the bladder. The circuminjection is, however, more satisfactory if it is made from the perineum, as advised by Colmers. It is a mistake to prepare the patient with heavy doses of veronal, pantopon, or scopalomin, as recommended by Colmers. In aged patients these opiates must be used very cautiously, and are not at all necessary in prostatectomies. In abdominal operations, where abdominal sensations are to be avoided, the previous preparation of the patient with opiates is permissible.

VAGINAL OPERATIONS.

While the older reports of Reclus and Schleich regarding the use of local anesthesia for vaginal operations did not seem to find favor among gynecologists, nevertheless they have recently begun to use local anesthesia in this field as well as in general surgery. Among the gynecologists Freund (1904) was the first to interest himself in local anesthesia. In colporrhaphies he recommended subcutaneous and submucous injections of 1 c.c. of 1 per cent. eucain solution with the addition of suprarenin to be introduced at each point for both anterior and posterior operations. For plastic perineal operations and colporrhaphies Fisch and Wagner have also found local anesthesia satisfactory. Henrich, a pupil of Freund, also Fisch, Wernitz, and Kraatz have used local anesthesia for operations on the cervix, for dilatation of the cervix and for curettements. Wernitz used unsuitable remedies (1 to 2 per cent. cocain solution) and, as was to be expected, experienced cocain poisoning. Fisch brought the modern novocain-suprarenin solution to the attention of gynecologists. Ruge reported two total vaginal extirpations under local anesthesia. Reclus had described such an operation sometime before, but his case was one of prolapse of the uterus. Reference has already been made to anesthesia of the pudic nerve (page 318). Sellheim very appropriately remarks that conduction anesthesia of the pudic nerves can be much more reliably obtained by injecting large quantities of the solution to various depths and in various directions, in the neighborhood of the nerves as they emerge from the ischiorectal fossa. If we further add that Mathes and Schmidt are warmly in favor of repairing perineal tears under local anesthesia and that Thaler has successfully emptied the gravid uterus under local anesthesia, we will have about exhausted the literature upon the subject. It cannot be said that much has been done in this field, if these reports are to be compared with the progress that has been made in the use of local anesthesia in general surgery.

Operations on the Labia.—Large and small cysts and solid tumors of all kinds, both on the labia majora and minora, should always be removed under local anesthesia, according to the general rules given in Chapter X. For the removal of the tumor shown in Figs. 157 and 158 there were three points of entrance marked. Point 1 on the perineum, point 2 laterally, and point 3, which is not visible in the diagram,

Fig. 157

Fig. 158

Figs. 157 and 158.—Extirpation of a tumor of the labia majora.

is placed above the tumor. From these three points 40 c.c. of 0.5 per cent. novocain-suprarenin solution were injected, part under the tumor, and a part used for the subcutaneous circuminjection, made in the direction of the dotted line. In case of a malignant tumor it is more advisable to anesthetize the entire vulvar orifice, which method will be described later.

Repairing Recent Perineal Tears.—For repairing recent perineal tears it is advisable to inject under and around the entire wound with a 0.5 per cent. novocain-suprarenin solution. According to Mathes the points of entrance are placed in the mucous membrane of the vagina, which is already insensitive, or the injection is made according to Schmidt from the wound surface into the rectovaginal septum. Schmidt estimates the amount necessary for this operation to be 60 to 70 c.c. of 0.5 per cent. novocain-suprarenin solution.

Anesthesia of the Vulvar Orifice.—The injection technique corresponds exactly with that described on page 331 for external urethrotomy in the male. Accordingly, one point of injection is marked in the median line in front of the anus; an imaginary line is drawn in a horizontal plane, which separates the vagina from the rectum and laterally meets the tuberosities of the ischium. This plane should be infiltrated with 0.5 per cent. novocain-suprarenin solution. A needle 8 to 10 cm. long is inserted (No. 5 or 6, page 174) and passed in the median line between vagina and rectum almost to the peritoneum. It is then drawn back as far as the subcutaneous connective tissue and directed a little more to the right and the left, always remaining in the horizontal plane mentioned, and again deeply inserted between rectum and vagina. In guiding the needle in the third direction, the point reaches still farther to the right and left, deep into the ischiorectal fossa, and with the fourth injection the point of the needle reaches the tuberosities of the ischium. The principle of these injections is shown in Fig. 156.

The first injection is made with a guiding finger in the vagina or rectum. Care must be taken not to infiltrate the plane immediately under the mucous membrane of the vagina, but as close as possible to the wall of the rectum. During the insertion of the needle constant injection should be made. A final subcutaneous injection will be necessary just as in the male, not in the horizontal plane but in a direction between the thigh and labia majora. Altogether 75 to 100 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. The injection blocks those branches of the pudic nerve and of the posterior femoral cutaneous (see Fig. 141, page 319) which pass to the front. Therefore, the parts made insensitive are the perineum, the vulvar orifice, the posterior part of the labia majora, the labia minora, the urethra and the clitoris. This method is suitable for plastic operations on the perineum, operations on the labia minora, about the meatus of the urethra and for rectovaginal fistulæ.

Anesthesia of the Vulvar Orifice, Including the Labia Majora (Fig. 159).—In this case the horizontal infiltration of the perineum just described should be used. Two extra points of injection are marked beneath and inward from the outer inguinal ring. From these points the subcutaneous tissue around the pubic eminence and at the side of the labia majora is freely infiltrated toward the injection already made in the perineum with a 0.5 per cent. novocain-suprarenin solution. By this means the nerve branches which come from the side and above are blocked, especially those coming from the inguinal canal and spreading out into the labia majora. Altogether 125 to 150 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. In operations for carcinoma of the vulva with removal of glands this method should be used (see Chapter XVI).

Operations for Prolapse.—In order to obtain complete anesthesia in operations for prolapse, vaginal injections will be found to be indispensable. The transverse perineal infiltration is unreliable in affecting the sensibility of the posterior pelvic peritoneum, and does not affect the bladder at all. For example, in a case of anterior and posterior colporrhaphy with large cystocele, the injection of 0.5 per cent. novocain-suprarenin solution is made in the following manner: The anterior lip of the

Fig. 159.—Anesthesia of the introitus vaginæ, including the labia majora.

cervix uteri is held by a volsellum and the prolapsed part is drawn forward. A needle from 8 to 10 cm. long is inserted close over the portio and the solution (20 c.c.) is injected in a fan-shaped manner upward between the bladder and the cervix (Fig. 160), but not submucously. From a point close beneath the opening of the urethra injections of 10 c.c. each are made to the right and left under the mucous membrane. This last injection is particularly serviceable in producing a more marked anemia. The portio of the uterus is drawn to the right, and 15 c.c. are injected into the left parametrium; the same injection is made into the right parametrium, the neck of the uterus being drawn to the left. Then a volsellum is hooked into the posterior lip of the cervix and 20 c.c. are injected from a point just behind the portio in a fan-shaped manner between the vaginal mucous membrane and Douglas' cul-de-sac. The prolapsed part is replaced, after which the previously described horizontal perineal injection is made. For the whole injection about 200 c.c. of a 0.5 novocain-suprarenin solution will be necessary. The operation is totally painless, even when patients have received no opiate. It is advisable, however, for psychic reasons to give a little morphin or morphium-scopolamin.

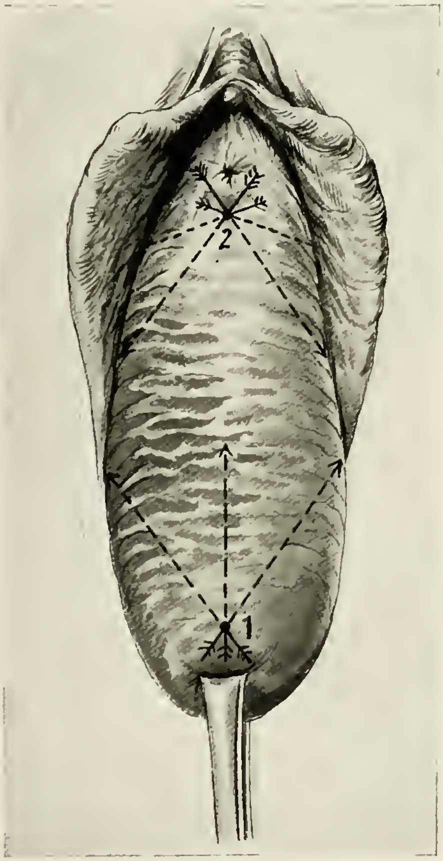


Fig. 160.—Anterior colporrhaphy.

This method has been used for a sufficient length of time to prove its advantages over all others. It is more reliable, less dangerous, and has the advantage of producing a satisfactory anemia and should be given preference over other methods of anesthesia, such as pudic nerve anesthesia, sacral and lumbar anesthesia. Lumbar anesthesia is certainly contra-indicated for the previously mentioned operations.

For posterior colporrhaphy alone, the horizontal perineal infiltration together with injections into the posterior vaginal vault are sufficient. For anterior colporrhaphy alone, the anterior injections are sufficient in themselves, provided the vaginal entrance is not too sensitive.

Parasacral anesthesia is particularly suitable for prolapse operations, but it lacks the advantage of the anemia obtained from the suprarenin in the injections just described.

OPERATIONS ON THE UTERUS.

Henrich, Fisch, and Kraatz infiltrate the portio vaginalis and the cervix with the anesthetic. Kraatz's method is to insert the needle into four points placed as near as possible to the outer border of the portio, directing it parallel with the cervical canal to the lowermost part of the body of the uterus; he injects 5 c.c. of 0.5 per cent. novocain-suprarenin solution at each point, using altogether 20 c.c. The controlling index finger feels the injected fluid as it forms a swelling above the vaginal fornix.

All operations confined to the portio and cervix, even dilatation, can be performed. It will be noted here as elsewhere that there is little bleeding from the arteries on account of the effect of the suprarenin, and therefore any bleeding, even though it appears slight, must be stopped by suture.

Dilatation of the cervix is painless, but curettement is more or less painful in proportion to the sensitiveness of the patient or the quantity of the sedative that has previously been administered. Severe traction on the uterus which is transmitted to the pelvic peritoneum remains more or less painful. It is therefore essential that further experiments be made in order to decide whether it is not more advisable to render the entire organ as well as the pelvic floor insensitive by parametric injections in all cases of uterine operations.

With the exception of Wernitz whose injections were purposeless and insufficient, Ruge was probably the first to make parametric injections. He describes them in the following manner: A needle is inserted from 4 to 5 cm. into the parametrium to the right and left of the uterus. It is at once directed slightly to the side in order to block the nerves which enter the parametrium, as far as possible from the uterus, in order to obtain as extensive an anesthesia of the pelvic floor as possible. On each side 10 c.c. of 1 per cent. novocain-suprarenin solution are injected. In the same manner 5 c.c. of the solution are injected 2 to 3 cm. deep into each of two points on the anterior and posterior vaginal vault. Altogether about 40 c.c. of 1 per cent. novocain-suprarenin solution will be required. This emphatically proves the progress made by local anesthesia. Wernitz injects 2 to 4 cm. of 1 to 2 per cent. cocain solution, a quantity of anesthetic much too small to produce an efficient anesthesia in this region and he has even experienced cocain poisoning with this small amount. Ruge can inject a ten times larger quantity of an anesthetic, which is just as effective without secondary complications, and it is even possible to double the amount of 1 per cent. novocain-suprarenin solution without bad results. It may be possible in this manner to make the entire pelvic floor with the uterus and its surroundings insensitive; this occurred in two of Ruge's cases. Absence of pain is imperative for all uterine extirpations and most vaginal laparotomies. In making these injections it is necessary to use very fine needles in order to avoid injury. We know that there is no damage done in accidentally penetrating the subclavian or carotid artery and the same is probably true of the ureter and uterine artery. Furthermore, the general directions (page 180) should be followed, namely, to first insert the needle without the syringe in places where injury might be done, and avoid making injections in those places where blood flows from the needle. All injections must be made while the needle is in motion. If the patients are young women with tense vaginæ, some method of anesthetizing this part for uterine operations must be employed. It may be possible to obtain sufficient anesthesia of the vagina by making superficial application of the anesthetic solutions of alypin and suprarenin. The perineal injection described above certainly makes the vagina sufficiently insensitive for any amount of distention.

Thaler performed vaginal hysterectomies and the emptying of gravid uteri at an early stage in nine women with complete anesthesia and very little bleeding; 0.5 novocain-suprarenin solution was injected in the following manner: After emptying the bladder a volsellum was hooked into the anterior lip of the cervix and 10 c.c. of solution were injected beneath the mucous membrane of the vaginal vault where the transverse anterior colpotomy incision was to be made. The needle was introduced superficially (0.75 to 1 cm. deep). Injections of 12 c.c. of the solution were made into the parametrium both to the right and left of the uterus to a depth of 1 to 1.5 cm. In a large uterus, after splitting the anterior cervix to the internal os, an additional injection of 10 c.c. of the solution was made directly into the wall of the uterus in order to increase the local effect of the suprarenin upon the muscles of this organ. It was not necessary to prepare the patient by the administration of an opiate. The way has been paved, and in a few years we will probably be able to say more in favor of local anesthesia in gynecology.

OPERATIONS IN THE ANAL REGION.

Local anesthesia for operations on the anus is worthy of more consideration than it has received in the past, for such operations can easily be performed without general anesthesia. Reclus and Schleich (the former as early as 1889) have again and again called attention to the fact that the anal region is particularly suitable for performing operations under local anesthesia, and it was not without special reasons that Schleich selected an anal operation for demonstration at the German Congress of Surgeons in 1894. To one who is unfamiliar with this subject there is something surprising in seeing the painlessness of a forced dilatation of the anus and the excision of hemorrhoids without a general anesthetic. It is, therefore, all the more remarkable that anal operations are still being performed under general or lumbar anesthesia.

Fig. 161.—Circuminjection of anus and rectum.

Dilatation of the Anus; Operations for Hemorrhoids; Operations for Anal Fistulæ.—Before beginning operations of this kind it must be remembered that the bilateral blocking of the trunk of the pudic nerve will not be sufficient to produce anesthesia of the anus, neither will the filling of the ischiorectal fossa with a 0.5 per cent. novocain-suprarenin solution be sufficient; even though the latter procedure causes a more reliable blocking of the branches of the pudic and posterior femoral cutaneous nerves which supply the anus than is produced by the uncertain injection of the trunk of the pudic nerve.

The further innervation of the rectum and anus through the coccygeal plexus and pelvic nerve must also be taken into consideration. Laewen's sacral injection produces a splendid relaxation of the sphincter ani and anesthesia of the anal region. Unfortunately it is not reliable and a better method is in circuminjecting the anus. In some operations about the anus, the anemia produced by the suprarenin is of great

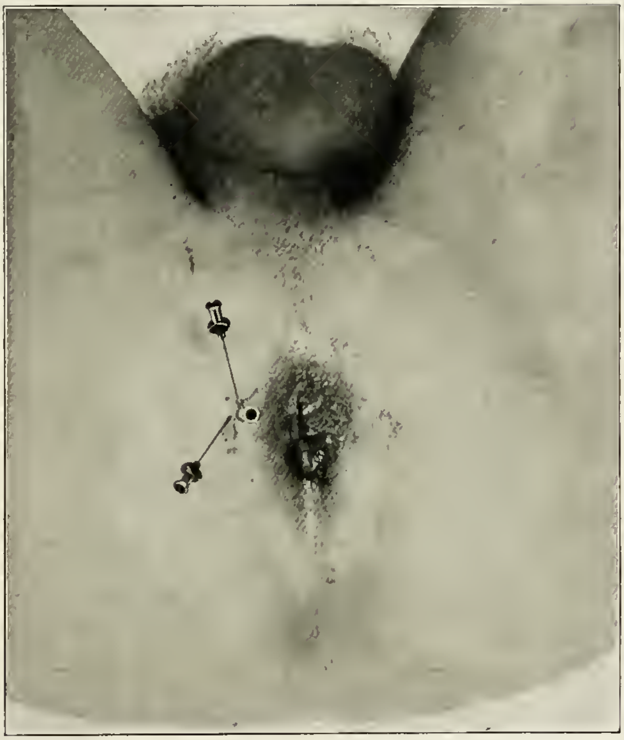


Fig. 162.—Position of needle for circuminjecting the rectum.

value, for example, in the Whitehead method of excision of hemorrhoids. The typical circuminjection of the anus, the principle of which was first described by Reclus, is performed in the following manner: Four points of entrance are marked in the region of but not too close to the anus, perhaps 2 to 3 finger-breadths distant from the anal orifice (Fig. 161). From these points a 0.5 per cent. solution of novocain-suprarenin is injected with a needle 10 cm. long. The needle is first inserted perpendicularly at one of the lateral points, parallel with the wall of the rectum, penetrating the sphincter and the levator ani. The needle is partly withdrawn and again passed deeply to its full length, in a more oblique direction toward the anterior and posterior walls of the rectum. The direction taken by the needle is very well shown in Fig. 162. At least 5 c.c. of 0.5 per cent. novocain-suprarenin solution is continuously injected with each insertion of the needle. The same injection is made into the three other points marked, so that at least 60 c.c. of the solution would be used for the entire injection. The circuminjection of the anus is made from one point to the other in two different layers, one injection into the sphincter and the other into the subcutaneous tissue (Fig. 159). For this 20 c.c. more of the solution will be used, making altogether 100 c.c., and 125 c.c. in fat persons. These injections can be made without inserting the finger into the rectum. Occasionally, when the position of the needle seems doubtful, it may be controlled with the finger. Anyone who is inex-

FIG. 163.—Para-anal injection under guidance of the finger.

perienced should make the deep injections with the aid of the guiding finger as shown in Fig. 163. In the deepest injections the point of the needle should be felt under the rectal wall, above the sphincter. In women the anterior injection is controlled through the vagina. If in anal fissure the finger cannot be introduced on account of intense pain, it is well to follow the advice of Reclus and previously make the mucous membrane insensitive by inserting cotton tampons soaked in an anesthetic (2 per cent. alypin-suprarenin solution). An experienced person can dispense with this method. The sphincter relaxes in a very few minutes after the circuminjection and can be dilated, excised, or cauterized as much as desired.

In complicated cases of rectal fistula where the extent cannot be exactly estimated, it is advisable to proceed as in operations for hemorrhoids, and circuminject the entire anus, in which case the points of entrance should be so located that the fistulous tract is situated within the circuminjected area. In simple, direct fistula, where the probe passes directly into the rectum and in which the inner opening can be felt, and dilatation of the sphincter is not necessary, a simpler method can be used. Three points of entrance are marked along the outer opening of the fistula (Fig. 164) and the needle is inserted into each of these points and from them continuous injection is made down to the mucous membrane of the rectum, under the guidance of a finger, close to the inner opening, and finally a subcutaneous and submucous injection is made in the direction of the dotted line. Sometimes the outlet of the fistulous tract lies far from the anus, and it is almost impossible to determine the extent of the

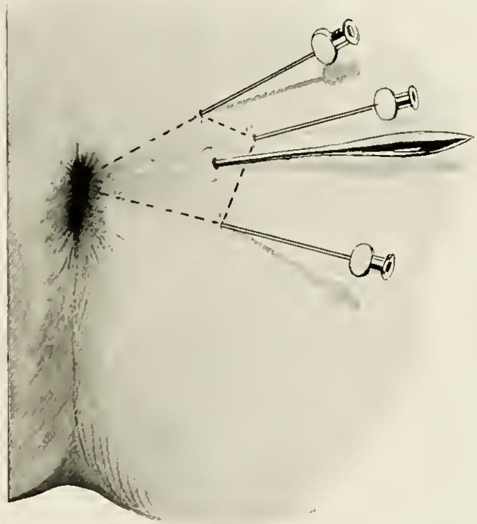


Fig. 164.—Technique of injection for simple rectal fistula.

operative field. In such cases circuminjection is not applicable and sacral or parasacral conduction anesthesia is more suitable. The latter is also an excellent method of anesthesia for hemorrhoidal operations, but it lacks the advantage of the anemia produced by suprarenin, which is so valuable in the Whitehead operation for hemorrhoids. Periproctitic abscesses are best opened under ether or ethyl chlorid anesthesia.

The Excision of a Carcinomatous Rectum.—Excisions and resections of carcinomatous rectums under local anesthesia with the aid of parasacral injections (page 320) have been practised for so short a time that it is impossible as yet to determine the general usefulness of this method.

CHAPTER XVI.

OPERATIONS ON THE EXTREMITIES.

THE USE OF LOCAL ANESTHESIA FOR THE REDUCTION OF FRACTURES AND DISLOCATIONS.

Local anesthesia can be used in various ways for fractures and dislocations of the extremities. Conduction anesthesia is suitable for these cases just as for other operations. Kulenkampff's plexus anesthesia is of the greatest importance in this connection, because it brings about in a simple manner such complete motor and sensory paralysis of the arm and the shoulder muscles that a more favorable condition cannot be imagined. Another method is the direct injection of an anesthetic between the fractured ends or into the dislocated joint as recommended by Lerda and Quénu. As early as 1885 Conway attempted to produce anesthesia in 3 cases of fracture of the radius by injecting cocain solutions between the broken ends of the bone. Furthermore, Reclus relates one case of fracture of the tibia in which he injected a cocain solution at the point of fracture, in order to facilitate the transportation of the patient. He states that the fracture immediately became painless. There are no other case reports on this subject in the older literature. The first comprehensive reports were made in 1907 and 1908 by Lerda and Quénu, the former reporting 30 and the latter 15 fractures in different parts of the body which were painlessly replaced after injections of cocain.

After establishing the diagnosis, injections of an anesthetic solution are made from various points and in different directions toward the ends of the fracture. If there is a marked dislocation of the broken ends, particularly in the long axis of the bone, injection must be made at each end of the broken bone. In limbs having two bones each fracture must be treated separately. In joint fractures, additional injections must be made into the joint.

Lerda and Quénu used a 0.5 per cent. cocain solution; one added suprarenin, the other omitted it. Conway increased the effect of the cocain by ligating the extremity. We now use a 1 per cent. novocain-suprarenin solution. The points of entrance are previously prepared by painting with iodin. The result of this injection is very surprising, almost immediately after the injection the pain subsides, and a few minutes later the fracture becomes entirely insensitive. The muscles relax as in general anesthesia.

Conway was the first to call attention to the use of intra-articular injections for dislocations (replacements of a dislocated elbow). In 1909 Quénu reported 5 cases of luxation which were painlessly replaced in this manner (two shoulder dislocations, 1 elbow, and 1 thumb luxation, and one ischiatic dislocation of the hip). The injection technique is very simple. The anesthetic (1 per cent. novocain-suprarenin solution) is injected both at the proximal and distal ends of the dislocated bones. Shortly after the injection the limb which was rigidly fixed becomes movable and painless and the muscles relax. Occasionally active movements and pressure on certain spots, the latter corresponding to the muscular attachments, remain painful. For such cases Quénu advises that more of the anesthetic be injected at the painful spot.

The following table shows the author's experience with local anesthesia in 51 simple fractures and luxations:

	Plexus anesthesia.	Other conduction anesthesia.	Local injections.
Typical fracture of radius	1	..	3
Fracture of forearm	7	..	1
Dislocation of elbow	.	..	1
Supracondyloid fracture of upper arm	4	..	1
Dislocations of shoulder	10	..	5
Dislocations of the foot	.	2	..
Fracture of ankle	..	3	7
Fracture of leg	..	1	1
Posterior dislocation of tibia	..	..	2
Dislocation of hip-joint	..	..	2
	22	6	23

In 23 cases local injections were made and only in one case of fracture of the tibia did they prove unsuccessful. In all other cases there was complete anesthesia, and the fractures were easily and painlessly reduced.

In fracture of the radius 10 c.c. novocain-suprarenin solution were injected both from the extensor and radial side to the seat of fracture and some into the wrist-joint. In cases of fracture of both bones of the forearm 10 c.c. was injected into each point of fracture. In dislocations of the elbow an injection of 5 c.c. was made from behind through the triceps, and to the upper end of the joint of the forearm, and also freely around the lower end of the humerus. In a case of supracondyloid fracture of the upper arm, with dislocation, 20 c.c. were injected from behind in various directions about the seat of fracture and into the elbow-joint.

In 5 cases of forward dislocation of the shoulder 10 c.c. were injected through the deltoid muscle from without into the joint cavity, and the same quantity was injected around the luxated head of the humerus. In 7 fractures of the ankle, 15 c.c. were injected around the fractured fibula at the internal malleolus and into the ankle-joint.

In 2 cases of posterior dislocation of the tibia, 35 to 40 c.c. were injected from before and from both sides to the joint ends. The intra-articular injections for dislocation of the femur mentioned by Quénu are most interesting. One of two cases of this character, a recent anterior dislocation of the hip in a very strong miner, about forty-five years of age, was performed under this method as follows: From two points in the gluteal region 25 c.c. of a 1 per cent. novocain-suprarenin solution were injected with a long needle to the head of the femur, which could be palpated and felt with the needle, and 20 c.c. of the solution into the joint cavity. The dislocated head of the femur cannot be used as a landmark for inserting the needle

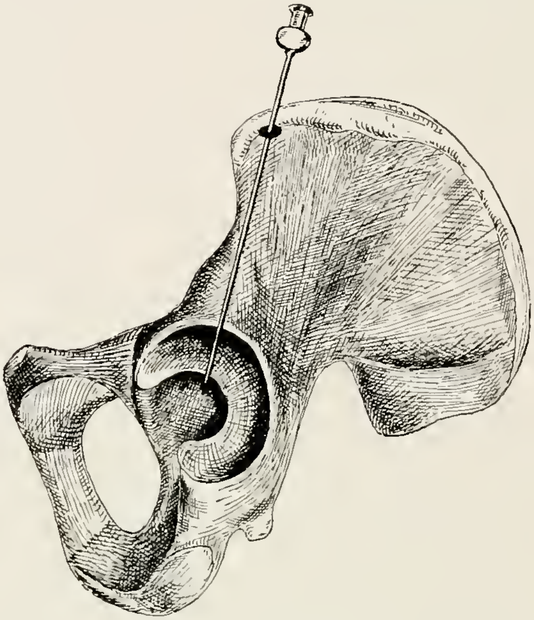


Fig. 165.—Injection into the hip-joint for dislocation.

into the joint cavity owing to its changed relative position to the cavity. The pelvic bone must be used as a guide. A point close behind the anterior superior spine of the ilium (Fig. 165) was selected for the entrance of the needle which was 10 cm. long, holding a bony pelvis next to the patient as a guide. The point of the needle was passed along the bone and immediately into the joint cavity, from which bloody synovial fluid was removed. Almost immediately after the injection the leg which was rigid before became movable and after ten minutes was easily replaced. The patient felt no pain in his hip, but later complained of the firm grip of the persons who were replacing the bone. The other case was an obturator dislocation of thirty-six hours' duration in a strong, stable boy aged seventeen years. Again 25 c.c. of the solution were injected into the joint cavity, 25 c.c. around the head of the femur, which could be felt under the pubic bone, and 10 c.c. more into a spot on the outside which had remained very sensitive. Ten minutes after the first, and five minutes after the second injection the bone was easily and painlessly replaced. No bad results have been reported from the use of local anesthesia in fractures and dislocations, everything points to its surprising advantages. The only remote danger in using the local injections for fractures and dislocations is the possibility of infection. Such a danger is so improbable at the present time that surgeons daily inject into the body large quantities of such solutions, and therefore there is no reason why they should not be also injected between fractured ends and into the joints.

There is one precaution which must always be observed in making these local injections, that is, the points of entrance should never be placed where there is an abrasion of the skin, or where it is crushed, thinned, or soiled. In such cases the local injections are best supplanted by the plexus anesthesia of Kulenkampff, which is so serviceable in dislocations of the shoulder. A shoulder dislocation of four weeks' standing can be replaced with ease under plexus anesthesia.

Local injections are specially recommended for fractures of the lower extremity. Lerda and Quénu also used them frequently for this purpose. The advantages derived from the use of local anesthesia in the treatment of fractures are so evident that they only need to be mentioned.

It is a decided technical advantage to be able to make cases of elbow and forearm fracture painless without a general anesthetic, and then to be able to examine the patient under the Röntgen screen and leisurely decide upon the best method for replacing the limb and the best position in which to place it. The annoying and sometimes dangerous excitability of the anesthetized patient is avoided and bandages are more easily applied.

Dislocations are much more easily replaced than when patients have had general anesthesia. If plexus anesthesia is used, this fact is readily explained by the more complete relaxation of the muscles. Intra-articular injections decidedly facilitate the replacement of dislocations. Mention should be made of the communication of Payr, who filled the luxated joint with 80 to 100 c.c. of 0.5 per cent. novocain-suprarenin solution in order to release the capsule and at the same time prepare a way for the dislocated bone.

OPERATIONS ON THE UPPER EXTREMITY.

The Sensory Innervation.—The brachial plexus supplies the entire sensory innervation of the arm as far as the shoulder-joint, and merges into a thin nerve trunk after leaving the opening in the scalenus muscle. In the axilla the upper intercostal nerves supply part of the sensory innervation, and one of them, the medial brachial cutaneous,

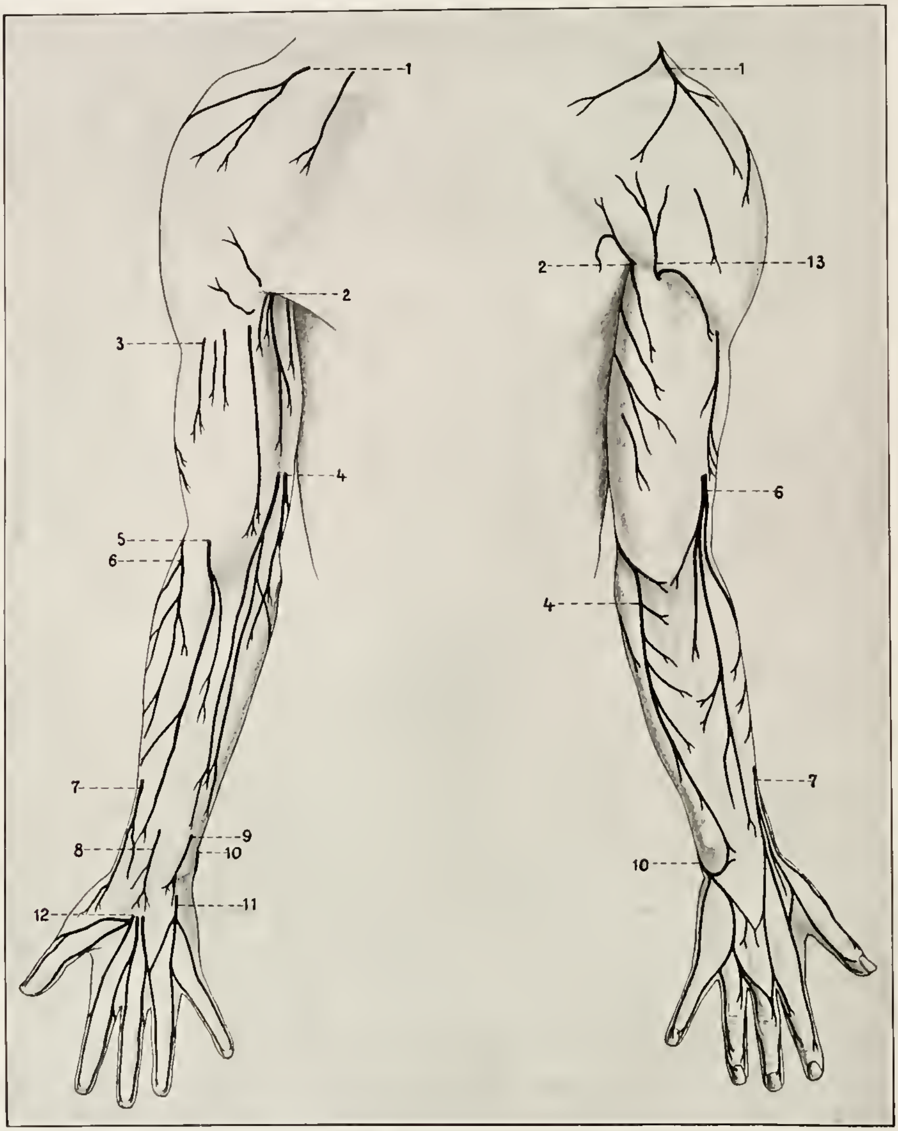


Fig. 166.—Sensory innervation of the upper extremity: 1, supraclavicular; 2, medial brachial cutaneous; 3, anterior brachial cutaneous; 4, medial antibrachial cutaneous; 5, lateral antibrachial cutaneous; 6, dorsal antibrachial cutaneous; 7, superficial radial; 8, palmar branch of median nerve; 9, palmar branch of ulnar nerve; 10, dorsal branch of ulnar nerve; 11, ulnar nerve; 12, median nerve; 13, lateral brachial cutaneous.

supplies also a part of the skin of the upper arm. On the other hand, the skin of the shoulders is innervated from the cervical plexus by the supraclavicular nerves. Fig. 166 shows the sensory nerves of the upper extremity as they emerge from the fascia under the skin and their peripheral distribution. It is well to compare this with the scheme of Fig. 171 (page 354).

The details of the innervation will be considered and described only so far as they are concerned in the technique of the anesthesia.

Anesthesia of the Brachial Plexus.—Crile's method (page 162) of interrupting the brachial plexus, after freely exposing it just above the clavicle, has the disadvantage of all such procedures, and therefore has not become popular. Hirschel was the first author who was able to report upon the possibility of anesthetizing the entire arm (which was an impossibility before the introduction of suprarenin) by making the injection to the plexus through the skin.

He selected the axilla for his point of entrance. As high up in the axilla as possible a pad is bound to the thorax by two elastic bands in order to obtain a congestion of the vessels for the purpose of slowing the process of absorption. The arm is strongly abducted, the axillary artery fixed with the fingers of one hand, and the needle inserted as far up under the pectoralis major as possible, in the direction of the long axis of the arm. Injection must be made as soon as the needle is entered, which will cause the vessels to slip away from the needle and thus prevent injury.

Several syringefuls of the solution are injected around the median nerve above and around the ulnar nerve anteriorly. One further injection is still necessary underneath the artery, about the insertion of the latissimus dorsi where the radial nerve is encountered. In this manner the artery is circuminjected and with a little caution any lesion to the artery or vein can be avoided. Hirschel first reported three injections successfully carried out in this way, and later reported 25 cases, and at the same time mentioned the fact that he considered the constriction of the vessels unnecessary; 30 to 40 c.c. of 2 per cent. novocain-suprarenin solution are sufficient for this anesthesia. Soon after Hirschel's first report, Kulenkampff also reported 25 cases of successful anesthesia of the brachial plexus. For blocking he chose the spot where the plexus lies on the first rib, lateral to the subclavian artery, and made the first experiments upon himself. The location of the plexus can be very definitely determined, being bounded on the inner side by the subclavian artery whose pulsations can be felt below by the first rib and anteriorly by the clavicle. The subclavian vein lies to the outer side.

The daily use of the plexus anesthesia, according to Kulenkampff, has proved this procedure to be a typical, harmless, very simple, and, at the same time, reliable method of anesthesia. It is suitable for all operations on the upper extremities and especially for the replacement of shoulder dislocation, for which purpose it is undoubtedly far superior to Quénu's method mentioned above. When it is used for operations on the upper extremity, general anesthesia is altogether superfluous. Kulenkampff has recently given an accurate account of the experience gained in his first 160 cases. The anatomical relations of the point of injection are shown in Kulenkampff's diagram (Figs. 167 to 169). Fig. 167 shows the position of the first rib, when viewing the supraclavicular region from the side. It should be noted how it apparently rises perpendicularly above and behind the clavicle. This is of importance, as it represents the lowest point to which the properly guided needle

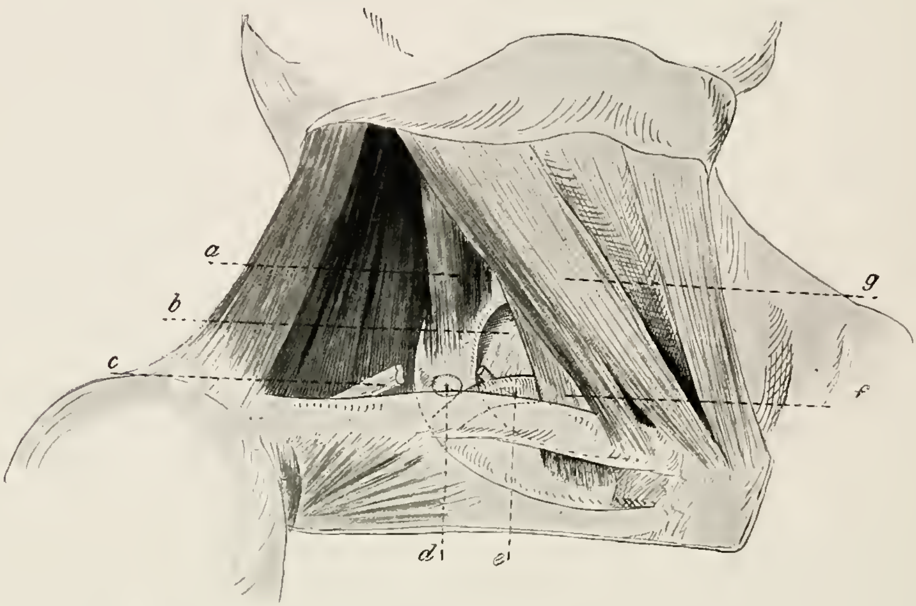


Fig. 167.—Relation of first rib and subclavian artery to the clavicle (Kulenkampff). *a*, scalenus medius muscle; *b*, apex of lung; *c*, omohyoid muscle; *d*, wheal; *e*, subclavian artery and its branch the transverse colli; *f*, scalenus anticus muscle; *g*, sternocleidomastoid muscle.

can penetrate. The operator does not experience that uncomfortable feeling of inserting the needle to a great depth, without feeling any resistance and not knowing the location of the point of the needle. The first rib crosses the clavicle at about its centre, which is the spot where the most important wheal must be placed. In the median line the arch of the subclavian artery is also recognized, as it extends above the clavicle and above this the pleural arch makes its appearance, which is otherwise covered by the brachial plexus. Furthermore, the scalenus anticus is recognized on the outer edge of the sternocleidomastoid muscle and the obliquely ascending omohyoid is seen to the outer side of the first rib. It is cut off here, in order to show as plainly as possible the direction taken by the rib. Fig. 168 shows the relative

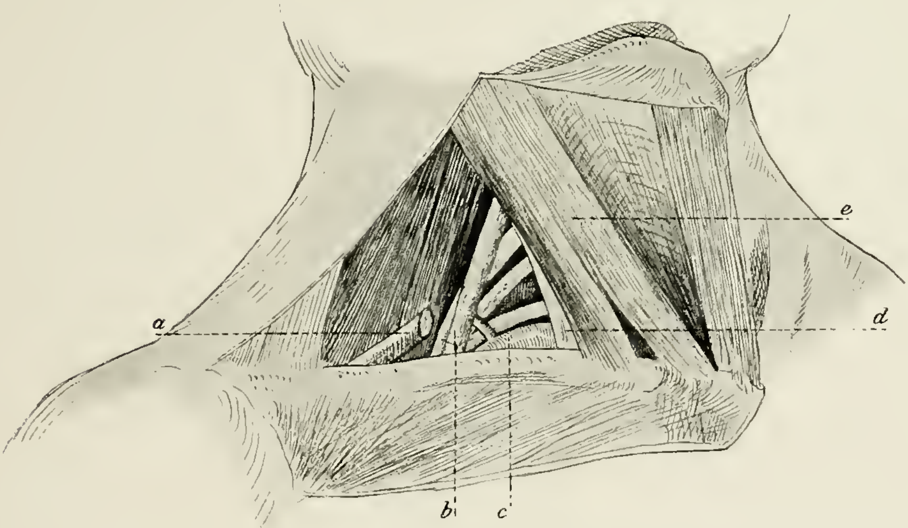


FIG. 168.—Relation of the brachial plexus to clavicle and subclavian artery (Kulenkampff.) *a*, omohyoid muscle; *b*, brachial plexus (partly schematic); *c*, subclavian artery with the transverse colli; *d*, scalenus anticus muscle; *e*, sternocleidomastoid muscle.

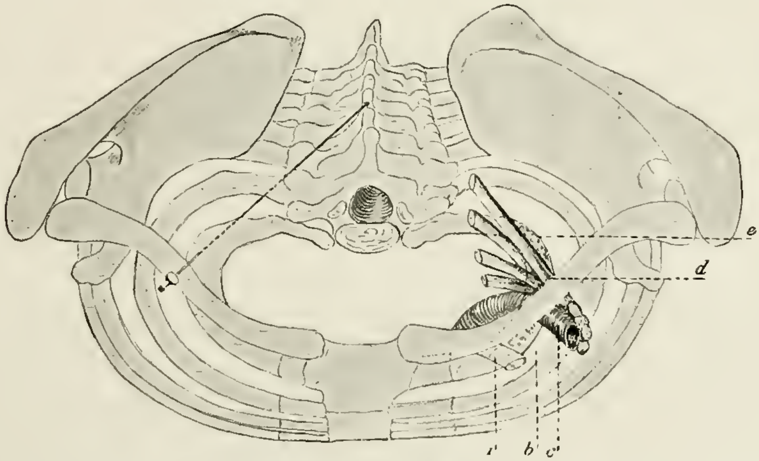


FIG. 169.—Bony thorax from above (Kulenkampff) showing the relation of the plexus and subclavian artery to the clavicle on one side, and the position of the needle on the other. *a*, subclavian vein; *b*, attachment of the scalenus anticus muscle; *c*, subclavian artery; *d*, brachial plexus surrounding the artery in a sickle-shaped manner; *e*, attachment of the scalenus medius muscle.

positions as they appear after the removal of the skin, superficial and deep fascia. The transversus colli artery is seen, as it usually passes in the midst of the closely overlapping nerve trunks. Fig. 169 shows how the needle should be introduced in order to reach the first rib. Depending upon the angle at which the cervical vertebræ approach the sternum, a projection of the axis of the needle would strike the second to fourth spinous process of the dorsal vertebra.

On the opposite side the plexus, artery, attachment of the scalenus muscle, and the vein are shown particularly with reference to the sickle shape of the cross section. It also shows how the artery is surrounded by nerve trunks immediately under the clavicle. It can be readily seen that a needle inserted close to the artery must pass between the nerve trunks and that if it is properly inserted it will, without fail, transmit the pulsation of the artery. The diagram shows the narrow slit of the scalenus muscle somewhat more plainly than Figs. 167 and 168.

Fig. 170.—Plexus anesthesia. (After Kulenkampff.)

The technique of the injection is as follows: It is advisable whenever possible to have the patient in the sitting posture while being anesthetized (Fig. 170). The patient needs no previously administered opiate, but he should certainly be informed of the paresthesia, which radiates to the fingers and which will arise when the needle penetrates to the plexus, and he should be instructed to state when he feels these sensations. This is the only way to positively determine when the needle has reached the right spot. The next step is to palpate the subclavian artery, which is done by making gentle pressure with the finger. In many cases the pulsation is visible more often to the right than to the left, which may be explained by varying anatomical relations. A wheal is placed directly outward from the spot where the artery disappears behind the edge of the clavicle. The spot almost without exception will correspond to the middle of the clavicle. At this same point, as a rule, a downward prolongation of the external jugular vein, which is usually visible, also crosses the clavicle. Here we insert a fine needle 4 to 6 cm. long, without syringe, in the direction which it should take to strike the spinous process of the second or third dorsal vertebræ (Fig. 169). The plexus lies rather close to and under the fascia. As soon as the needle touches it, radiating paresthetic sensations are complained of in the fingers supplied by the median nerve which lies superficially, and of the radial nerve which lies deeper and posterior to the median nerve. If at a depth of 1 to 3 cm. the first rib is felt, it indicates that the plexus must lie more superficially. If paresthesia is not obtained at once, it must be sought by slightly changing the position of the needle. Very often from an unnecessary anxiety about the subclavian artery the needle is inserted too far outward. If blood flows from the needle, its direction must be changed. As soon as paresthesia occurs, attach the syringe to the needle and inject 10 c.c. of a 2 per cent. novocain-suprarenin solution. If paresthesia evidences itself in the region supplied by the median nerve, a part of the solution should be injected a few millimeters deeper. Finally, 10 c.c. more are injected so as to be distributed in the immediate surroundings, the direction of the needle being very slightly changed during this injection.

The operator should not make the injection before the paresthesia occurs. If there is a pronounced paresthesia of the median as well as of the radial nerve, it indicates that a complete sensory and motor paralysis of the arm will occur after one to three minutes. It is usually necessary to wait ten to fifteen minutes, but if after this length of time the paralysis is not complete, it will be advisable to make another injection of 5 to 10 c.c. of 4 per cent. novocain-suprarenin solution. Paresthesia will not be felt after this latter injection and results are more or less uncertain.

Very soon after the injection the upper arm can be ligated to arrest hemorrhage without any discomfort to the patient. For this purpose use Perthe's compressor. Ligation is usually necessary, because, after blocking the brachial plexus, the arm becomes more or less hyperemic as in Haidenhain's experiment. The evident contrary action of suprarenin in not causing contraction of the subclavian artery is similar to the observations made on extremities after section of the nerves.

The number of failures which will result will depend upon the experience of the surgeon. Kulenkampff reports that in 100 cases anesthetized by eight different surgeons, in 4 cases it was found impossible to cause paresthesia and, therefore, the injections were ineffective. In 19 other cases some areas supplied by certain nerves were not completely blocked, but in most cases the operations could be performed.

The extent of the anesthesia following the injection is shown in Fig. 171. There is always a motor paralysis of the axillary nerve. It is, therefore, rather surprising that the skin which is innervated by the sensory part of the axillary nerve, as is

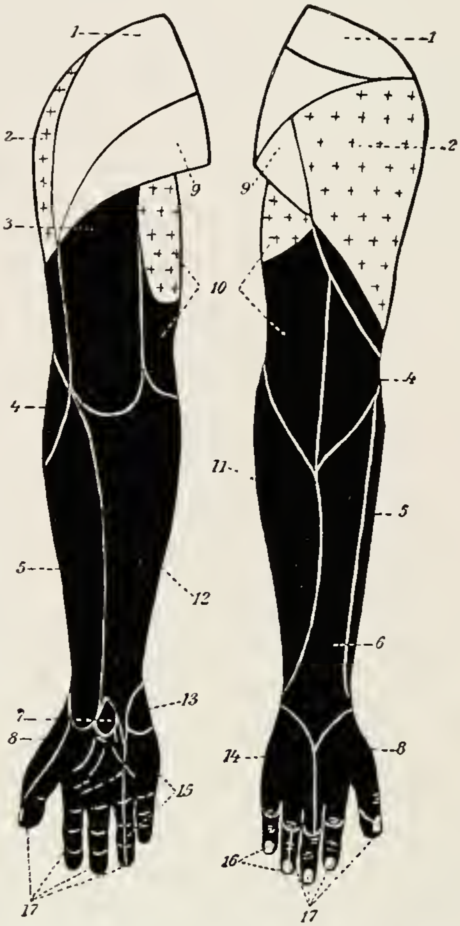


FIG. 171.—Sensory tracts of upper arm (after Toldt) and the effect of blocking the brachial plexus (after Kulenkampff). ■ anesthesia; + + hyperesthesia or not paralyzed; □ not paralyzed: 1, supraclavicular nerves; 2, lateral brachial cutaneous (derived from the axillary nerve); 3, cutaneous branch of the anterior brachial (derived from the medial antibrachial cutaneous); 4, posterior brachial cutaneous (derived from the radial); 5, lateral antibrachial cutaneous (derived from the musculocutaneus; 6, dorsal antibrachial cutaneous (derived from the radial); 7, medial palmar branch; 8, superficial branch of the radial; 9, lateral cutaneous branch (derived from the intercostal); 10, medial brachial cutaneous; 11, ulnar branch of the medial antibrachial cutaneous; 12, volar branch of the medial antibrachial cutaneous; 13, palmar cutaneous branch of the ulnar; 14, dorsal branch of the ulnar; 15, superficial branch of the ulnar; 16, digital volar (derived from the ulnar); 17, digital volar (derived from the median).

taught in text-books on anatomy, is never rendered insensitive but is either hypesthetic or not affected at all. From this observation it is probable that innervation of these parts must take place from other nerves, probably the supraclavicular. The anesthesia produced will last from one and a half to three hours. In 160 cases Kulenkampff observed no injury at the point of injection and no post-operative pains. It is possible to puncture the subclavian artery during this injection but this accident is absolutely free from danger.

Plexus anesthesia is indicated in all surgical operations about the arm, whether they be bloodless or bloody, except those which can be more readily treated by local injections. Most of the operations for which we use the plexus anesthesia are severe injuries to the hand and phlegmons of the hand and forearm. To these may be added all amputations, disarticulations, and resections of the upper extremity and reduction of fractures and dislocations.

A painless disarticulation of the shoulder-joint can be performed after blocking the terminal branches of the supraclavicular and intercostal nerves, by making a circular infiltration with a 0.5 per cent. novocain-suprarenin solution of the subcutaneous connective tissue at the shoulder-base, extending transversely through the axilla and over the shoulder.

Jenkel, Finsterer, Borchers and Siebert, have reported favorable results obtained with Kulenkampff's plexus anesthesia. As a result of plexus anesthesia Borchers observed a motor paresis of the arm which lasted four weeks, but, as the author himself asserts, this was probably due to the fact that the upper arm had been too tightly ligated. Hirschel considers his injection into the axilla far more reliable than those made in the supraclavicular fossa. He thinks the latter very suitable for shoulder operations or for the reduction of shoulder dislocations, but believes they cannot be relied upon for hand and finger operations—which does not correspond with either our experience or that of Borchers.

Anesthesia of a Finger, According to Oberst.—This anesthesia is based upon the fact that the nerves supplying all the fingers lie in the subcutaneous connective tissue of the first phalanx (page 158). Fig. 172 shows schematically a cross section of the first phalanx. The main nerve trunks are indicated by black dots. The most important nerves lie toward the volar surface, close to the flexor tendons. These nerves divide high up into branches which extend to the dorsal side, innervating the extensor surface of the second and third phalanges. Under the skin of the extensor surface are two fine nerve branches which, as a rule, do not extend beyond the first phalanx.

The anesthetic must be injected into the region of these nerve trunks. For this, two points of entrance will be necessary, which should be situated on the side of the finger more toward the extensor surface (Fig. 172, 1, 2) where the skin is least sensitive. The injection is begun by making a wheal at one of the points of entrance with a very fine sharp needle. The needle is then inserted transversely to the long axis of the finger (in Fig. 173, 1 and 2, the position of the needle is indicated by arrows) injecting

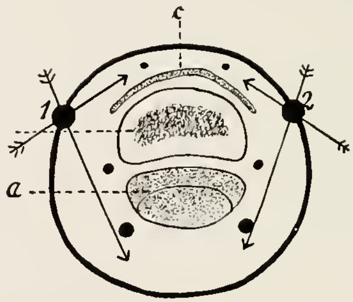


Fig. 172.—Anesthesia of Oberst. Schematic cross-section of the base of a finger. 1 and 2 points for injection. *a*, flexor tendon; *b*, bone; *c*, extensor tendon. The nerves are indicated by black dots. The arrows indicate the direction of the needle.

Fig. 173.—Injection of the finger, according to Oberst.

the solution under the skin of the flexor surface. The needle is now removed and again inserted into the same spot, now insensitive, in order to inject beneath the skin of the extensor side. The solution, which should saturate the subcutaneous connective tissue in a circular manner, ought to be so distributed that the flexor side receives a little more than the extensor side. Inject 2 to 2.5 c.c. of a 2 per cent. novocain-suprarenin solution. It is necessary to wait until the tip of the finger has become insensitive to the prick of a needle, which usually occurs in five minutes. The finger is then totally insensitive and any operation, either bloody or bloodless, can be performed (reduction of luxations). This method is suitable for felons when they do not extend beyond the middle phalanx. Oberst's method of ligating the finger before making the injection of the anesthetizing solution is unnecessary owing to the addition of the suprarenin. The finger arteries are end arteries, therefore the injection of suprarenin into the finger must be made cautiously. Even if the subcutaneous connective tissue of the finger is filled with a dilute suprarenin solution, all its arteries will contract and it is with difficulty that the suprarenin is eliminated. The condition is similar to that of a pediculated skin flap (Fig. 174) or the prepuce (page 329).

This is undoubtedly responsible for the disturbances and secondary pains, which are frequently noticed after finger anesthesia. These disturbances are not observed when the injection is carried out according to the Oberst method—namely, ligating the finger before injecting 1 to 2 c.c. of 0.5 per cent. cocain solution. They can also be avoided if the injection is made as close as possible to the base of the finger, where the blood supply is more abundant, and if the subcutaneous connective tissue is not too tensely infiltrated with an injection of too large a quantity, as 10 c.c. of 0.5 per cent. novocain-suprarenin solution. It is therefore preferable to use a small quantity of 2 per cent. novocain-suprarenin solution in the manner described. Unilateral injections made only to the flexor or only to the extensor surface are seldom used. Small furuncles on the extensor side of the first phalanx can easily be made insensitive by a fork-shaped injection (Fig. 172) on the index finger.[1]

Anesthesia of One Finger and the Surrounding Part of the Hand.—The introduction of suprarenin has made it possible to work out several methods of injection which will include the palm and which would otherwise be possible only by ligating the arm, a process which takes up much time and is very disagreeable to the patient, and, therefore, could never become popular.

In order to make one finger with the neighboring part of the palm or back of the hand insensitive, two points of entrance are marked on the back of the interdigital folds (Fig. 174) 1 and 2, or 2 and 3.

For the thumb and fifth finger the points of entrance are placed respectively on the outer or inner edge of the hand. From these points a 0.5 or 1 per cent. novocain-

[1] Inasmuch as the fingers and toes are supplied by end arteries, I would suggest that novocain be used without the addition of suprarenin, and that the circulation be interrupted by a narrow elastic band in order to avoid any evil effects resulting from the prolonged constriction of the vessels from suprarenin.

suprarenin solution is freely injected subcutaneously in a direction toward the points *a* and *d* in the palm and *b* or *c* on the back of the hand. Fig. 175 demonstrates the direction of the needle for injections of the palm from one of the interdigital folds. Points of entrance should never be placed in the palm, as the skin is too hard and

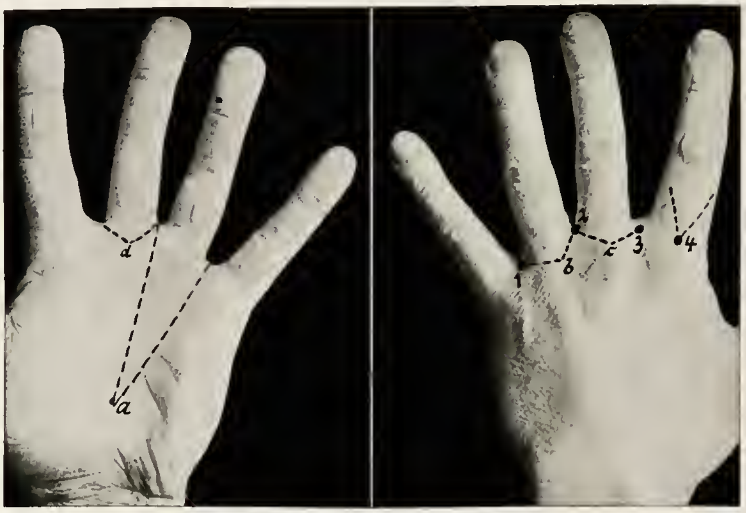


Fig. 174.—Fork-shaped injection of the index finger. Anesthesia of a finger with portions of palmar and dorsal surface. (Third and fourth fingers.) 1 to 4 indicates points for injection.

Fig. 175.—Method of introducing a needle through an interdigital fold to the hand.

sensitive. The operation should not be begun until the anesthesia has extended to the tip of the finger under consideration. A free infiltration of the solution mentioned can be made without the precaution which is usually necessary for injection of the fingers.

Disarticulation of the Middle Finger at the Basal Phalanx. Operations on the Third Metacarpal Bone.—Four points of entrance must be marked (Figs. 176 and

Fig. 176

Fig. 177

Figs 176 and 177.—Disarticulation of the middle finger and thumb at the base. Operations upon a metacarpal bone.

177); two of them in the interdigital fold, two on the back of the hand to the right and left of the third metacarpal bone and over the spaces between the bones. Two injections are made from points 3 and 4. Fig. 178 shows a cross-section through the

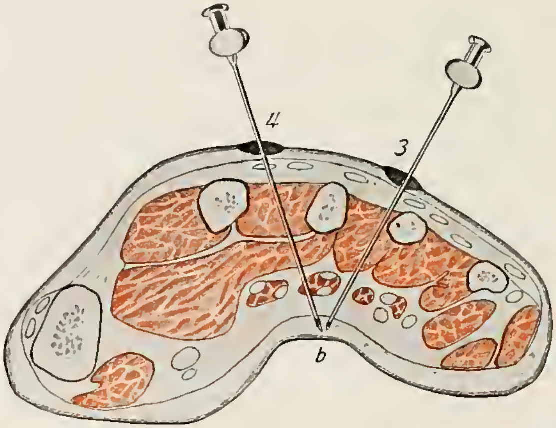


FIG. 178.—Cross-section through the middle of the hand. Direction of the needle in the interosseous spaces. 3, 4, and *b* correspond to similar points of Figs. 176 and 177.

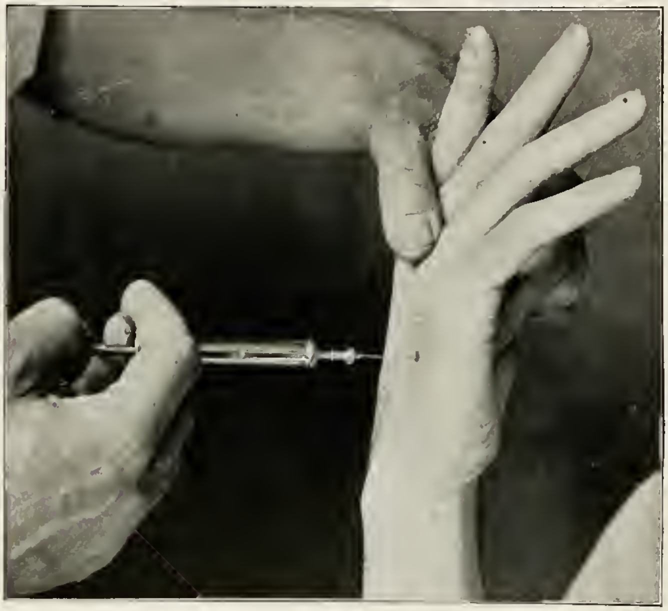


FIG. 179.—Method of injecting an interosseous space.

palm, and indicates the direction which the needle must take. For this injection the operator places the tip of his left index finger into the patient's palm and inserts the needle at points 3 and 4, making constant injection directly through the space which lies between the bones, until the point is felt beneath the skin of the palm at point (*b*). Fig. 179 demonstrates the technique of this injection. For each of the two injections 5 c.c. of 0.5 per cent. novocain-suprarenin solution will be required. These injections are followed by the infiltration of the subcutaneous connective tissue from points 1 and 2 toward point *b* in the palm, and on the back of the hand toward points 3 and 4. Finally, points 3 and 4 are joined by a subcutaneous injection. Altogether 30 to 40 c.c. of 0.5 per cent. novocain-suprarenin solution are required. The anesthesia is completed when the tip of the middle finger has become insensitive. The finger can now be disarticulated, with or without removing its metacarpal bone. It is unnecessary to ligate the hand. This same method is used for operation on the third metacarpal bone.

FIG. 180 FIG. 181

FIGS. 180 and 181.—Anesthesia of two fingers with part of the hand.

The Disarticulation of the Thumb at the Basal Phalanx. Operations on the First Metacarpal Bone (Fig. 174).—The injection between the bones is begun from point 6 and the needle is inserted until felt under the skin of the palm at point *a*. On account of the thickness of the soft parts 10 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. The next step is a subcutaneous injection from points 5 and 7 in the palm toward point *a* and on the back of the hand toward point 6. It is unnecessary to ligate the arm. About 50 c.c. of 0.5 per cent. novocain-suprarenin solution are necessary. This procedure shows at once that it is possible to make the thenar eminence insensitive without penetrating the sensitive skin of the palm. This method can also be used for anesthesia of the fifth finger and its metacarpal bone.

Anesthesia of Several Fingers and Parts of the Palm (Figs. 180 and 181). Points 1, 2, 3 are used for anesthesia of the second and third fingers and are marked by wheals. The injection in the interosseous spaces should be made from point 2 toward point *a* and a subcutaneous infiltration is made from points 1 and 3 in the palm toward point *a* and on the back of the hand toward point 2. The points of entrance, 4, 5, 6, are used in the same manner for anesthetizing the fourth and fifth fingers at the same time. If necessary, parts of the palm can be included in the anesthetized area by placing the points of injection 2 or 6 closer to the fingers or the wrist, as the case may be; 50 c.c. of 0.5 per cent. novocain-suprarenin solution are necessary.

Fig. 182

Fig. 183

Figs. 182 and 183.—Anesthesia of a part of the palm.

Operations on Soft Parts of the Palm.—The technique of the anesthesia of the thenar and hypothenar eminences by circuminjection has already been described in connection with disarticulation of the thumb. Every other part of the palm can be treated in the same way. The points of entrance (usually two) should always be placed on the side of the hand and on the back of the interdigital folds. For example, we will select a field of operation which is limited to the soft parts of the palm, above the index finger (Figs. 182 and 183). In this case the points of entrance are marked 1 and 2. From both of these points a free injection of 30 to 40 c.c. of 0.5 per cent. novocain-suprarenin solution is made toward point *a* in the palm. In case of phlegmon of the hand, injections near the diseased parts must be avoided. Preferably they should be rendered insensitive by plexus anesthesia. Abscesses are opened more quickly and better under ethyl chloride anesthesia, as recommended by Kulenkampff.

Operations on the Soft Parts of the Back of the Hand.—In this region operations are usually aseptic, such as the treating of injuries, extirpation of ganglia, hygromata, and tumors. The field of operation is circuminjected with 0.5 per cent. novocain-suprarenin solution. Fig. 184 shows a number of possibilities for circuminjection. In most cases it will only be necessary to circuminject three sides of the field of operation in a fork-shaped or U-shaped manner, since the innervation to the field of operation is derived exclusively from the arm. A three-sided circuminjection of the field of operation is usually sufficient to produce peripheral anesthesia. If the circuminjection is first made under the tendons and then subcutaneously, the anesthesia will not be limited to the skin and subcutaneous connective tissue. For aseptic operations on the back of the hand it is, therefore, never necessary to administer a general anesthetic.

Fig. 184.—Anesthesia of the soft parts of the back of the hand.

Blocking the Ulnar Nerve at the Elbow.—This nerve blocking was introduced by Krogius and is easily done and very reliable, as can be demonstrated on one's own arm. The nerve which usually lies above the inner condyle of the humerus is plainly felt as it rolls between the fingers, the pressure causing the patient to complain of a peculiar sensation. The nerve is then fixed with the thumb and left index finger and the needle is inserted into it through the subcutaneous cellular tissue and fascia. At the moment when the point of the needle touches the nerve and penetrates it the patient again experiences the same paresthesia as is felt when pressure is made on the nerve, which indicates that the needle is in the proper place for the injection of the anesthetizing solution. It must be remembered that in some few persons, when the forearm is bent, the trunk of the ulnar nerve is situated in front of and not behind the inner condyle and only slips behind when the arm is extended; a subcutaneous

Fig. 185

Fig. 186

Figs. 185 and 186.—Anesthesia following the blocking of the ulnar nerve at the elbow.

or subfascial injection in this position will naturally be ineffective. Figs. 185 and 186 show the extent of the anesthesia which, as a rule, occurs immediately after the injection. This shows the adaptability of this form of anesthesia for operations on the fifth finger, the hypothenar eminence, the ulnar edge of the hand, and the fifth metacarpal bone.

For disarticulation of the fifth finger and other operations in this region there is no simpler method of anesthesia. During this operation ligation is necessary and should be applied before the operation to the forearm above the wrist, where it does not annoy the patient.

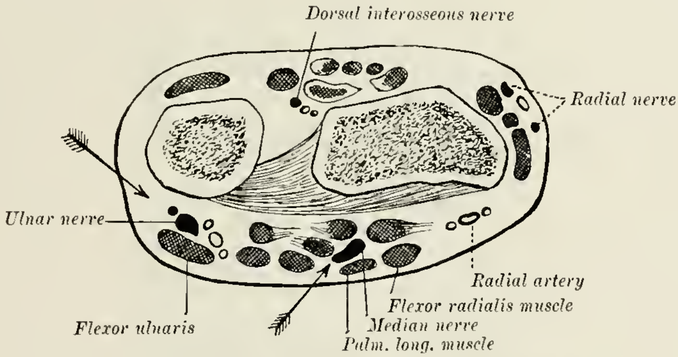


Fig. 187.—Cross-section through the forearm above the wrist-joint.

Anesthesia of the Whole Hand.—The following nerves extend from the forearm to the hand: the ulnar, median, and interosseous, all of which lie in the deep fascia, and the terminal branches of the radial nerve which are placed subcutaneously. Fig. 187 is a cross section through the forearm just above the wrist. The two arrows indicate the direction in which the needle should be inserted for blocking the median and ulnar nerves. In order to block the median nerve, a point of entrance (Fig. 188) is marked toward the ulnar side, close to the tendon of the palmaris longus. The needle is inserted through the fascia underlying the tendon mentioned. Search is then made until the point of the needle strikes the nerve trunk. The patient should be requested to say when radiating paresthetic sensations are felt; 5 c.c. of 2 per cent. novocain-suprarenin solution are then injected and 5 c.c. of the same solution are injected from the ulnar edge of the forearm above the pisiform bone and under the flexor ulnaris. Finally, the subcutaneous cellular tissue around the forearm is infiltrated from the same point and possibly 2 or 3 others, and on the extensor side the subfascial tissue is also infiltrated between the tendons down to the interosseous ligament with 50 to 60 c.c. of 0.5 per cent. novocain-suprarenin solution.

Operations on the Forearm.—The skin and subcutaneous connective tissue of the forearm to the lower third is exclusively innervated by long subcutaneous nerves which emerge from the fascia above the elbow (medial, lateral and dorsal antebrachial cutaneous nerves, Fig. 164). Consequently the infiltration of a transverse strip of the subcutaneous cellular tissue of the forearm results in anesthesia extending more or less peripherally from the point of injection, and if the subcutaneous cellular tissue is infiltrated circularly close above or below the elbow with a 0.5 per cent. novocain-suprarenin solution, the anesthesia will extend to the lower third of the forearm in every direction. This method has no more practical value than

Fig. 188.—Points for injecting the median and ulnar nerves above the wrist-joint.

the more easily accomplished blocking of the individual nerve trunks mentioned. Conduction anesthesia of the lateral antebrachial cutaneous nerve, as it emerges from above the elbow on the lateral edge of the biceps and passes into the subcutaneous cellular tissue, has a historical value, for Corning in 1885 observed for the first time in a human being the peripheral extension of skin anesthesia following an injection of cocaine made at the point of emergence of this nerve.

In anesthetizing for operations the following observations should be made: Operations on the upper two-thirds of the forearm, limited to the skin and the subcutaneous cellular tissues, are circuminjected with a 0.5 per cent. novocain-suprarenin solution in a U-shaped manner (Fig. 184). The unilateral innervation of this region makes circuminjection unnecessary. In the lower third of the forearm the U-shaped circuminjection should always be made subfascially, because it is here that the nerves emerge (Fig. 166). This fact might possibly frustrate the result of a purely subcutaneous circuminjection. All circumscribed tumors can be circuminjected according to Fig. 30 (page 192) in a pyramidal or cup-shaped manner. Large anesthetic areas on the extensor surface of the lower third of the forearm can be obtained in the following manner (Fig. 189): Two points of entrance are marked at the same height on the extensor side of the forearm at a point corresponding to the palpable edge of the ulna and radius. Between these points all the soft parts of the extensor side, first the muscles and then the subcutaneous cellular tissue, are infiltrated transversely to the long axis of the arm with 40 to 50 c.c. of 0.5 novocain-suprarenin solution. From both these points of injection strips should be injected subcutaneously to the wrist and, when necessary, to the fingers, for which purpose more points of entrance may be required. It is unnecessary to ligate the arm during the operation. This

Fig. 189.—U-shaped injection of the forearm and back of hand.

method can be used for the treatment of any injury to the soft parts and for extirpation of tumors, hygromata, and tendon-sheath tuberculosis in this region.

A corresponding method on the lower half of the flexor side of the forearm is carried out a little differently on account of the ulnar and median nerves. The two points of entrance are again marked on the side of the forearm and are connected by infiltration across the forearm, at first close to the bone and interosseous ligament and then by infiltration of the subcutaneous cellular tissue. It is unnecessary to infiltrate all the muscles, in fact that is hardly possible, and does not result in a blocking of the ulnar and median nerves. If the field of operation lies within the area supplied by the ulnar nerve, this nerve should be blocked at the elbow (page 363), and if it lies in the territory of the median nerve this nerve should be sought at the upper end of the incision and blocked by intraneural injection, just as soon as it is exposed, during the operation. It will be necessary to ligate the arm during this operation and, therefore, anyone who is familiar with plexus anesthesia, will prefer it in this case. Phlegmons, bone operations, extensive operations on the soft parts of the upper half of the forearm, and amputations are performed under plexus anesthesia.

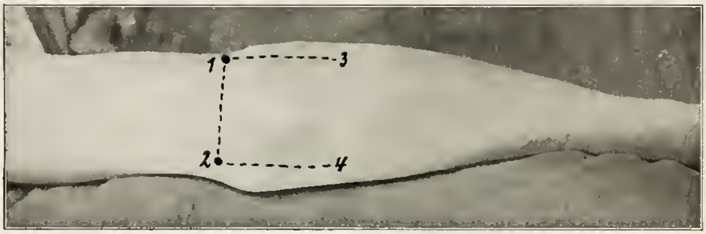


Fig. 190.—Horseshoe shape injection of the elbow-joint.

Operations on the Elbow.—A U-shaped infiltration of 40 c.c. of 0.5 per cent. novocain-suprarenin solution into the subcutaneous cellular tissue of the back of the elbow from two points of entrance (Fig. 190, 1 and 2) will be sufficient for extirpation of an olecranon bursa. For suturing a fractured olecranon process, two extra points of injection should be marked (Fig. 185, 3 and 4). An injection of 20 c.c. of 0.5 per cent. novocain-suprarenin solution is first made into the elbow-joint beneath the outer or inner condyle. From each of the points 1 and 2, 10 c.c. of the solution are injected under the triceps tendon and from each of the points 3 and 4, 10 c.c. are injected into the inner and outer muscles covering the ulna. Finally a U-shaped subcutaneous injection is made.

In order to perform an aseptic arthrotomy (for removal of loose bodies in joints) 20 c.c. of a 0.5 per cent. novocain-suprarenin solution are injected into the joint and the capsule and the subcutaneous cellular tissue is infiltrated in the line of incision. For resections and disarticulations it is better to use the plexus anesthesia, which excels venous anesthesia in simplicity and comfort both for the patient and the physician.

Operations on the Upper Arm.—Anesthetizing local injections only must be considered for superficial operative procedures. Simple subcutaneous circuminjections are not always successful, owing to the numerous and irregular points of emergence of the nerves (Fig. 166). Therefore, it is always necessary to make a complete pyramidal or encasing circuminjection of the field of operation (page 191). In order to make the skin of the entire outer surface of the upper arm sufficiently insensitive for the removal of Thiersch's grafts or Kraus's skin flap, the entire subcutaneous cellular tissue should be infiltrated in layers as far as it is necessary with a 0.5 per cent. novocain-suprarenin solution in the same manner as will be described for the thigh. Complicated operations on the upper arm, bone operations and dislocations should be performed under plexus anesthesia.

Operations in the Shoulder Region.—Large lipomata of the shoulder region are very easily removed under local anesthesia. A number of points of entrance should be marked around the tumor. From these points the whole base of the tumor is systematically circuminjected with long needles. Finally the points of entrance are joined by subcutaneous injection strips; 0.5 novocain-suprarenin solution is the proper anesthetic to be used. Large lipomata will frequently require from 200 to 250 c.c. of the solution. Operations on the shoulder-joint are best performed under plexus anesthesia, according to the method of Kulenkampff. Methods have already been mentioned for disarticulations of the shoulder-joint. For this purpose the plexus must be blocked and besides this the subcutaneous cellular tissue at the base of the limb (*i. e.*, from the acromion process across the axilla) must be circularly infiltrated with a 0.5 per cent. novocain-suprarenin solution. Under local anesthesia and by the anterior incision of Langenbeck the auther has often resected a joint and reduced by operation irreducible axillary dislocations of the humerus and twice has operated for fractures of the upper end of the humerus. Besides blocking the brachial plexus the line of incision is freely infiltrated with 0.5 per cent. novocain-suprarenin solution, whereby the bleeding is decidedly lessened. A shoulder-joint may be resected either by a posterior incision, according to Kocher, or by the deltoid incision, which is preferred in complicated cases. For the last mentioned incision the same method is used as described for disarticulations. For Kocher's incision it will probably be necessary to block the lower branches of the cervical plexus according to Kappis, or from the side (page 268) by infiltration toward the transverse processes of the cervical vertebræ. For all these operations we can certainly dispense with general anesthesia. For performing minor operations on the clavicle, for example, the chiseling of a disturbing callus (Fig. 191), the entire bone must be circuminjected from two points of entrance in a trough-like manner, according to the diagram shown in Fig. 32 (page 192).

FIG. 191.—Trough-shape circuminjection of the clavicle.

OPERATIONS ABOUT THE LOWER EXTREMITY.

Sensory Innervation.—The foot and leg are supplied by the sciatic and anticrural nerves entirely, while a great number of other nerves are concerned in the sensory innervation of the upper thigh, some of which reach the thigh directly from the pelvis. The most important of these are the obturator posterior and lateral femoral cutaneous, while the others, the iliohypogastric, ilio-inguinal, genitocrural, and the superior gluteal supply the innervation of the skin at the base of the thigh.

Figs. 192 and 193 schematically show the points of exit of the sensory nerves and their peripheral distribution to the lower extremity.

Conduction Anesthesia of the Thigh.—The conditions for anesthesia of the lower extremity by central conduction anesthesia are much more unfavorable than they are for the arm, for in the arm the main nerve trunks originating from the cervical plexus form a single cord, while in the lower extremity at least five nerves must be blocked separately. Blocking the lateral cutaneous femoral, which innervates the skin of the upper thigh, was described by Nyström in 1909. This nerve emerges close beside and medial to the anterior superior spine of the ilium under Poupart's ligament (Fig. 194). Running for a short distance downward under fascia lata, it penetrates it in one or more places, and thus reaches the subcutaneous cellular tissue and the skin. In order to block the trunk of the nerve, Laewen suggests that a point of entrance

Fig. 192

Fig. 193

Figs. 192 and 193.—Scheme of sensory innervation of the lower extremity: 1, iliohypogastric; 2, lateral femoral cutaneous; 3, lumbo-inguinal; 4, anterior femoral cutaneous; 5, obturator; 6, lateral sural cutaneous 7, saphenous; 8, superficial peroneal; 9, sural; 10, deep peroneal; 11, superior gluteal; 12, inferior gluteal; 13, posterior femoral cutaneous; 14, medial sural cutaneous; 15, tibial cutaneous branch; 16, tibial.

be marked two finger-breadths inward and downward from the anterior superior spine of the ilium (Fig. 195). From this point an injection is made transversely outward as well as below and beyond the spine. Two injections consisting of 2.5 c.c. of 2 per cent. novocain-suprarenin solution each are made, one under the fascia and the other under the skin. The nerve will then be blocked. Nyström advised this method for the removal of epithelial grafts from the outer side of the upper thigh.

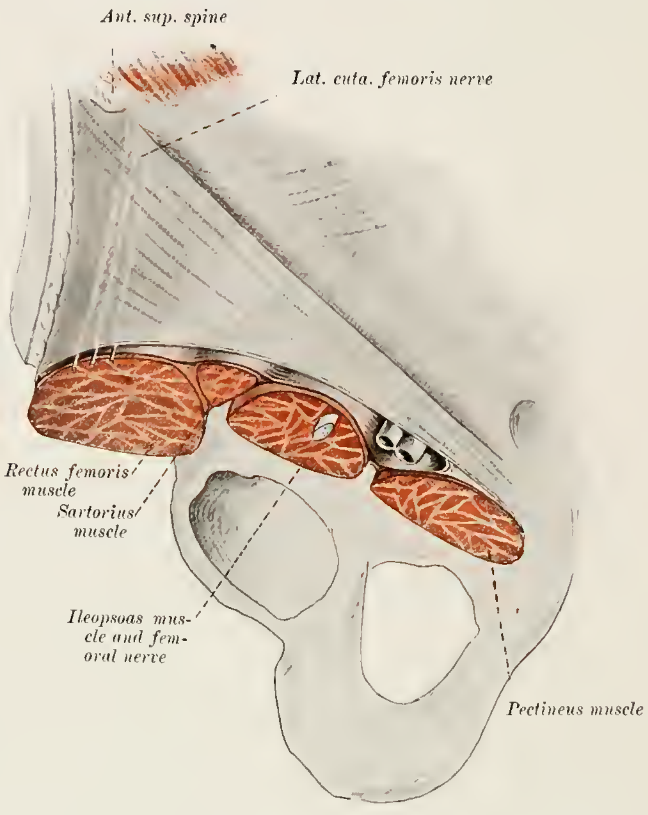


Fig. 194.—Cross-section through the thigh below Poupart's ligament.

Unfortunately it is unreliable, a fact which Laewen has also noted, because the extent of skin anesthesia resulting from the injection is so variable and often very small. Laewen therefore advises that besides the nerve mentioned, the anterior crural nerve should also be blocked. This nerve lies a little outward from the femoral artery, and is separated from it by a strip of fascia (ileopectineal ligament) and, as a rule, by a layer of iliopsoas muscle. It frequently does not lie close under the fascia lata, but deeper in a connective tissue septum of the muscle mentioned. These conditions are shown in Fig. 194. Laewen therefore gives the following directions: The pulse of the femoral artery should be palpated under Poupart's ligament. The fingers of the left hand should remain upon the artery, so as to be constantly assured of its position. A point of entrance is marked just under Poupart's ligament about 1 to 1.5 cm. outward from the spot where the pulse of the artery is palpable (Fig. 195). From this point a fine needle is inserted perpendicularly and the fascia lata, which is easily felt, is penetrated; 5 c.c. of 2 per cent. novocain-suprarenin solution should be injected, inserting the needle 0.5 to 1 cm. deeper during the injection. To this should be added that the point of the needle must touch the nerve.

Fig. 195.—Points for injection. 1, for the lateral femoral cutaneous; 2, for the femoral.

At the moment when the nerve is touched a very characteristic contraction of the muscles of the thigh is noted, and if the injection is then made, the blocking will be completed in a few minutes. The most striking feature is the motor paralysis of the quadriceps femoris muscle. In this case Laewen's novocain-bicarbonate solution is unnecessary. While the blocking of the crural nerve alone has as little practical significance as the blocking of the lateral femoral cutaneous alone, nevertheless the blocking of both nerves conjointly furnishes a very large anesthetic field which is very constant in extent. The limit of the field of anesthesia is shown by Figs. 196 and 197.

Laewen recommends his method especially for removal of epithelial grafts, for which purpose it gives surprisingly good results. In this manner he was also able to remove painlessly a large lipoma from the rectus femoris muscle. The simultaneous blocking of the anterior crural nerve and the lateral femoral cutaneous is a simple method, and one that can be generally used for all suitable cases. On the other hand, those nerves which emerge from the pelvis and are distributed to the thigh are reached with difficulty.

Fig. 196

Fig. 197

Figs. 196 and 197.—Extent of anesthesia after blocking the lateral femoral cutaneous and femoral nerves.

Crile exposes the sciatic nerve and blocks it by endoneural injection (page 161). The blocking of this nerve through the skin is difficult and unreliable. The nerve trunk lies deeply seated in the gluteal region, slightly median to the middle of the line joining the trochanter major, and the tuberosity of the ischium. Laewen, to whom special credit is due for his thorough investigations, aims to palpate the nerve in this spot in lean persons, and injects from two points of entrance, one of which is situated 2 cm. outward from the tuberosity of the ischium, the other 3 cm. inward from the trochanter.

Perthes aims to reach the nerve trunk in the gluteal fold. Jassenetzki-Woino chooses a point which is determined by the intersection of a horizontal line through the greater trochanter and a vertical line through the outer edge of the tuberosity of the ischium. It is immaterial where the point of entrance is made, but what is important, and should not be omitted, is to reach the nerve trunk with the point of the needle, which is indicated by radiating, paresthetic sensations felt in the toes. The importance of observing these paresthetic sensations has been shown in connection with the brachial plexus. If according to the method of Laewen a 4 per cent. novocain-suprarenin solution is injected as soon as the paresthesia occurs, the result is almost always a blocking of the nerve trunk. Whether or not this blocking is more reliable with the aid of a Perthes needle the future must decide.

Fig. 198

Fig. 199

Figs. 198 and 199.—Anesthesia of the great toe. (After Oberst.)

The posterior femoral cutaneous nerve lies beneath the gluteal fold, close under the fascia in the middle of the posterior surface of the thigh and is located here with comparative ease. Laewen attempted to locate it higher up where it is deeply situated close behind the sciatic nerve. The obturator nerve, according to Laewen, cannot be located near the place where it emerges; therefore he aims to block it by subcutaneous and subfascial semicircular infiltration on the inner surface of the thigh.[1]

Laewen repeatedly succeeded in making the whole leg anesthetic, by blocking all these nerves. The necessary doses of novocain (2.1 g.) are large and the method is too complicated to be of any practical significance. Laewen himself expressed this opinion.

[1] Perthes succeeded in puncturing the nerve with his irritating canula (Reizkanüle), from the region of the spine of the pubes at the obturator foramen. See also the later work of Kappis and Babitzki.

Anesthesia of the Toe, According to Oberst.—The method is the same as used for the fingers (Figs. 198 and 199). On the great toe two points of entrance are marked on the edge a little more toward the extensor side. From these points injections are made under the skin of the flexor side, as indicated by the dotted line. On account of the prominence formed by the extensor tendons, it is more convenient to make the injection under the skin of the extensor side from a third point, situated in the middle of the extensor side. 3 to 4 cc. of 2 per cent. novocain-suprarenin solution are necessary. For the other toes the points are marked in the interdigital spaces as in Fig. 200.

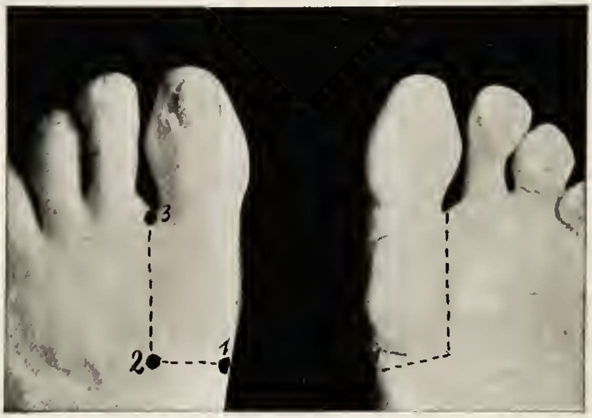


Fig. 200.—Disarticulation of the great toe. Hallux valgus operations.

Disarticulation of the Great Toe.—Hallux Valgus Operation (Fig. 200).—There are three points of entrance to be marked; the first is in the median line on the border of the foot, the second on the back of the foot over the first interosseous space; the third in the first interdigital fold. The first injection is made into the interosseous space, and is carried out just as in the hand. The needle is inserted and infiltration is made through the interosseous space, until the applied finger feels the point of the needle under the skin of the sole. Then follows the subcutaneous injection from points 1 and 3 in the direction of the dotted line: 40 to 50 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. The operator should wait until the whole toe becomes insensitive. Ligation is not necessary for disarticulation.

Disarticulation of the Third Toe.—Operations on the Third Metatarsal Bone (Fig. 201).—Four wheals are placed as in the corresponding operation on the hand; two lie on the extensor side of the interdigital folds, two on the back of the foot over the second and third interosseous spaces. The needle is pushed forward from points 1 and 2, injection being made into the spaces between the bones until the needle is felt under the skin of the sole at point *a*. Then follow injections from points 3 and 4 under the skin of the sole toward point *a*, and under the skin of the back of the foot toward points 1 and 2. Finally, subcutaneous injections are made between points 1 and 2; 50 c.c. of 0.5 per cent. novocain-suprarenin solution are necessary.

Fig. 201.—Disarticulation of the third toe.

Operations on the Back of the Foot.—The technique of the anesthesia is the same as for the back of the hand. There is nothing to add to that which has already been stated on page 362.

Tenotomy of the Tendo-Achillis (Fig. 202).—A point of entrance is marked to the right and left of the tendo-Achillis, and the field of operation is infiltrated in a trough-like manner, according to Fig. 31 (page 191). In adults and older children it is possible to perform operations on the tendo-Achillis under local anesthesia. These cases are, of course, always exceptional, as the other therapeutic measures associated with tenotomy usually require further anesthesia.

Anesthesia of the Entire Foot.—For extensive operations on the bones and soft parts of the foot always observe the following directions: Five nerves pass from the calf of the leg to the foot, the tibial, saphenous, sural, and superficial and deep peroneal (see Figs. 192 and 193). Blocking the tibial behind the internal malleolus produces anesthesia of the region designated in Figs. 203 and 204, and the

Fig. 202.—Tenotomy of the tendo Achillis.

Fig. 203

Fig. 204

Fig. 205

Fig. 206

Fig. 207

Fig. 208

Figs. 203 to 208.—Anesthesia of foot following conduction anesthesia. Figs. 203 and 204, tibial is blocked behind the inner malleolus; Fig. 205, subcutaneous injection of a semicircle above the inner malleolus; Figs. 206 and 207, subcutaneous injection of a semicircle above the outer malleolus; Fig. 208, injection of the deep peroneal nerve.

blocking of the deep peroneal is shown in Fig. 208. If an anesthetic is subcutaneously injected in a transverse strip above the internal malleolus, the terminal branches of the saphenous nerve will be blocked, and anesthesia of the skin area, shown in Fig. 205 is obtained. In the same manner a strip injected above the outer malleolus will block the superficial peroneal and sural, and anesthesia of the area shown in Figs. 206 and 207 is obtained.

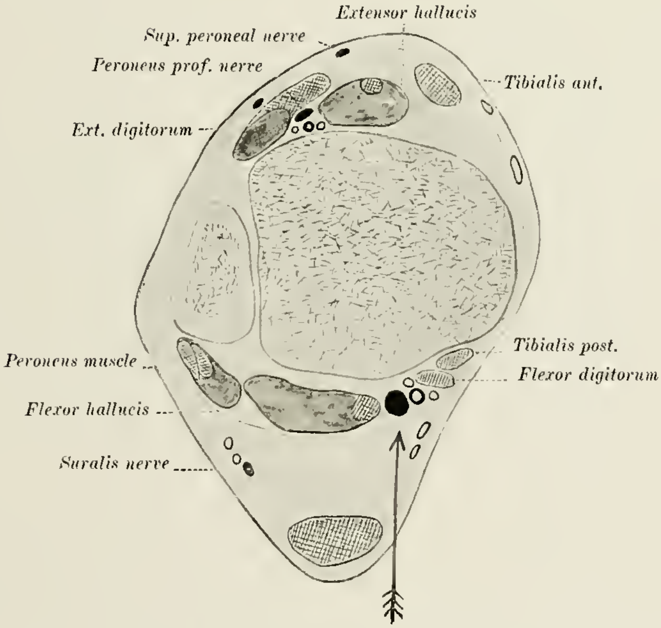


Fig. 209.—Cross-section of the leg above the ankle-joint. (After Braun.) The arrow indicates the method of injecting the tibial nerve.

It is very easy to block the tibial at the designated spot. Fig. 209 shows a cross-section through the lower leg just above the ankle. The arrows indicate the direction taken by the needle in reaching the nerve trunks. The point of entrance lies high up, where the inner malleolus is thickest, about 1 c.c. distant from the tendo-Achillis. From this point the needle is inserted directly forward until the posterior surface of the tibia is felt. Continued search must be made until the patient, who has been previously instructed, announces that paresthesia is felt, radiating to the toes. If blood flows from the needle, it must be drawn back a little, and reinserted more to the side. As soon as the paresthesia is felt, 5 c.c. of 2 per cent. novocain-suprarenin solution are injected and after a few minutes the blocking of the nerves will be noted.

The method is as follows: several points of entrance are marked—one at the point mentioned, behind the inner malleolus; the others, usually four, are marked at the same height all around the lower leg. The tibialis is blocked by an injection of 5 c.c. of 2 per cent. novocain-suprarenin solution as described above, and the subcutaneous cellular tissue of the lower leg is then infiltrated from the other points of entrance as is also the tissue lying between the tendons and the anterior surface of the tibia. The latter is done in order to block the deep peroneal. Finally the fat which lies behind the tendo-Achillis is infiltrated with 50 to 75 c.c. of 0.5 per cent. novocain-suprarenin solution.

This excellent method is used in performing operations on the sole of the foot and the metatarsal and tarsal bones. We have performed amputations according to the methods of Lisfranc, Chopart, Pirogoff, disarticulations at the ankle-joint, resections in the region of the tarsus and operations for the correction of club foot in older children. This method, which is naturally contra-indicated in cases of phlegmon, has never failed us. For amputation it is not necessary to ligate the extremity, because the arteries bleed so little under the influence of the suprarenin.

Operations on the Leg.—It is necessary to thoroughly inject under and around the field of operation of the leg, even if it be superficial and confined to the skin and subcutaneous cellular tissue. A simple subcutaneous circuminjection is unreliable. The anastomotic peroneal nerve and the saphenous nerve which supply the skin of the leg are easily blocked, the former in the popliteal space, beside the head of the fibula, the latter by infiltrating a strip of the subcutaneous cellular tissue which extends laterally from the tuberosity of the tibia to the middle of the calf of the leg. A 0.5 per cent. novocain-suprarenin solution is used. This blocking has little practical value because the blocking of the third nerve supplying the tibia, namely, the tibial, in the popliteal space is unreliable and difficult, and the blocking of the two first named nerves alone only renders a small area insensitive. Bier's venous anesthesia (page 164) is suitable for complicated aseptic operations and amputations of the leg.

Operations About the Knee.—For anesthesia of a prepatellar bursa, four points of entrance must be marked, situated as shown in Fig. 210. A subcutaneous injection alone in the direction of the dotted line would not be sufficient, so before making this injection it will be necessary to push the needle forward from each point of entrance and infiltrate in various directions to the edge of the patella; or, if this is not possible on account of the size of the tumor, the capsule of the knee-joint must be infiltrated from the side and the quadriceps from above; 75 to 100 c.c. of 0.5 per cent. novocain-suprarenin solution will be necessary. Extirpation of the bursa, in aseptic or slightly infected cases never requires a general anesthetic. The use of local anesthesia, however, should be avoided in a perforated bursa with a phlegmonous condition of the surrounding parts.

Ganglia in the Popliteal Space.—Ganglia should always be extirpated under local anesthesia. The tumor must be carefully circuminjected with a 0.5 per cent. novocain-suprarenin solution from four points of entrance. At first the injection should be very deep, and then subcutaneous. If during the operation one of the large nerve trunks should come into view, it must be blocked by an endoneural injection of novocain-suprarenin solution.

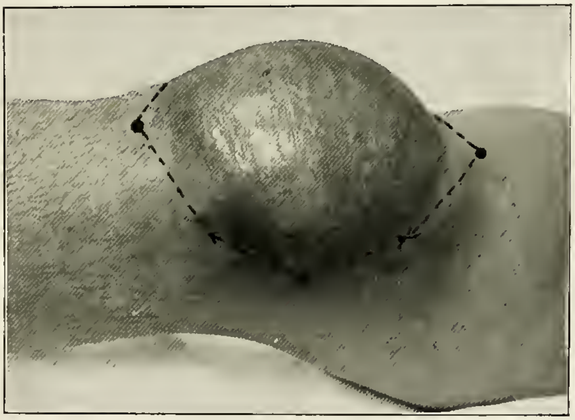


FIG. 210.—Anesthesia for housemaid's knee.

Operations on the Knee-joint.—Anesthesia for aspiration of the knee-joint is carried out according to the rules given on page 189. The synovial membrane is very quickly made insensitive by filling the joint with a 0.5 per cent. novocain-suprarenin solution, which also relieves the contractions induced by the pain. For cases of erosion of the joint or where adhesions exist within the joint, this is not a suitable method. On the other hand, in performing aseptic arthrotomies of the knee-joint for movable cartilages and for meniscus operations, local anesthesia is most suitable. The joint is filled with 20 c.c. of 0.5 per cent. novocain-suprarenin solution and from two points of entrance (Fig. 211, 1 and 2) the joint capsule and subcutaneous cellular tissue are infiltrated in the line of incision (according to Fig. 27, page 187) with the same solution. The operations are always painless, even if it is necessary to open the joint wide.

For many years the author has sutured fractures of the patella without exception under local anesthesia. The points of entrance are practically the same as for prepatellar bursæ (Fig. 210) only the lateral points lie a little farther back. As much of a 0.5 per cent. novocain-suprarenin solution is injected into the joint as it will hold without causing too much pressure and the fluid is distributed by gentle flexion and extension movements. This causes a part of the fluid to flow between the fractured parts of the patella, producing an anesthetic effect similar to that in hollow bones (page 381). Finally the joint capsule and the subcutaneous cellular tissue are infiltrated in the direction of the dotted line (Fig. 211). For this operation 100 to 150 c.c. of 0.5 per cent. novocain-suprarenin solution are necessary. In most cases this operation is painless. Resections of the knee-joint are better performed under venous anesthesia.

Fig. 211.—1 and 2, arthrotomy of the knee-joint; 3 and 4, resection of the saphenous vein.

Supracondylar Osteotomy of the Femur.—The operation for genu valgum (unilateral and bilateral) should be performed under local anesthesia. Four points of entrance are marked as indicated in Fig. 212. From these points the needle is directed to the bone, passing in front of and behind the bone during the process of injection. The infiltration is only made immediately around the bone at the place where the osteotomy is to be performed. The muscles need not be infiltrated. For this 100 c.c. of 0.5 per cent. novocain-suprarenin are used. After this has been done, two more points are marked at the ends of the incision to be made, and from them the line of incision is infiltrated to the bone (Fig. 29, page 189). The bone can then be exposed in the usual manner and severed partly by aid of the chisel and the remainder by breaking. The patient must be prepared for this latter act, so that he will not be frightened by the cracking of the bone.

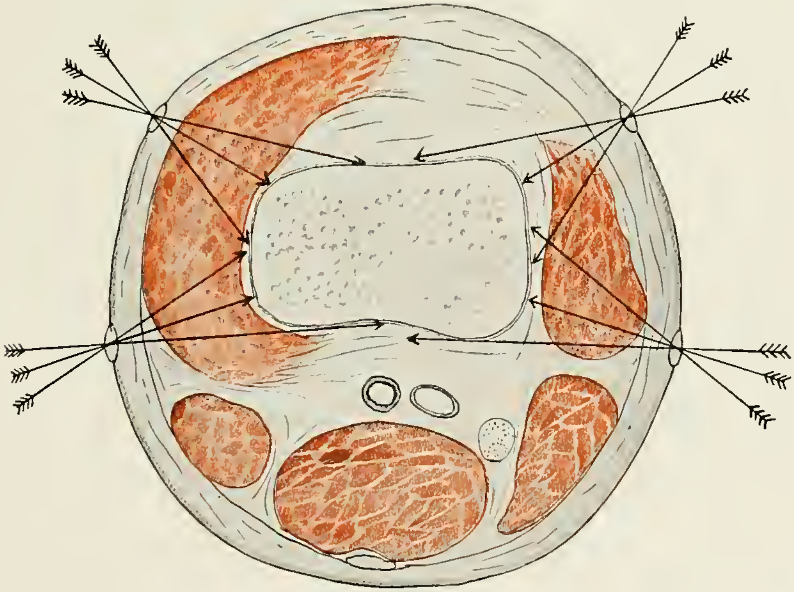


Fig. 212.—Supracondylar osteotomy of the femur.

Operations on the Soft Parts About the Femur.—Aseptic fields of operation of almost any size can be rendered insensitive by pyramidal, trough-shaped, or similar forms of circuminjection, but the simple subcutaneous circuminjection may fail even in very superficial operations on account of the numerous points of exit of the nerves (Figs. 192 and 193).

Operations on the Saphenous Vein.—If only a narrow anesthetized zone is necessary, as is often the case in the ligation of vessels or for the inducing of venous anesthesia, then the infiltration should be made in the line of incision. A wheal should mark each end of the proposed incision, and 0.5 per cent. novocain-suprarenin solution should be injected into the line of incision under and beside the vein, and the points of entrance should be joined by a subcutaneously injected strip. If a portion of the vein is to be resected according to the method of Trendelenburg, it will be necessary, in order to gain a larger anesthetized field, to make a rhombic infiltration at first under and around the vein, and then a subcutaneous one. Fig. 211 illustrates this method at the spot where varicose veins should always be resected, that is at the upper end of the vein, where it enters the femoral. The technique of anesthesia is the same as that just described.

FIG. 213.—Injection for removing Thiersch grafts.

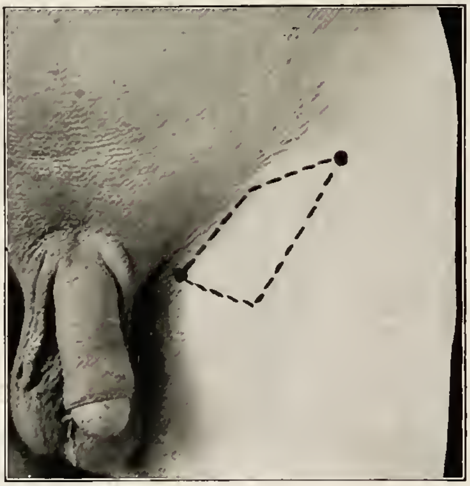


FIG. 214.—Circuminjection of the inguinal region.

For the removal of long Thiersch epithelial grafts it is advisable to infiltrate the entire outer surface of the thigh subcutaneously with 0.5 per cent. novocain-suprarenin solution. For this purpose a number of points of entrance are marked in the order shown in Fig. 213, and injection of 0.5 per cent. novocain-suprarenin solution is made from each point in various directions and an even distribution of the solution into the subcutaneous cellular tissue can be obtained by gentle massage.

The extirpation of lymphomata of the inguinal and femoral regions can very easily be made painless by circuminjecting the tumor with 0.5 per cent. novocain-suprarenin solution in some such manner as indicated in Fig. 214. The needle should be inserted from all sides, pass under the tumor, and should penetrate the region of the fossa ovalis below and also laterally under the fascia of the pectineus muscle and the rectus femoris and above under Poupart's ligament. For the curettement of diseased lymph glands the same method is necessary. For bilateral removal of all the fatty tissues with the glands, in the groin, use local anesthesia and circuminject in the manner shown in Fig. 215. It is also necessary to make a subfascial injection, especially under the fascia of the external oblique muscle in the region of the skin overlying Poupart's ligament.

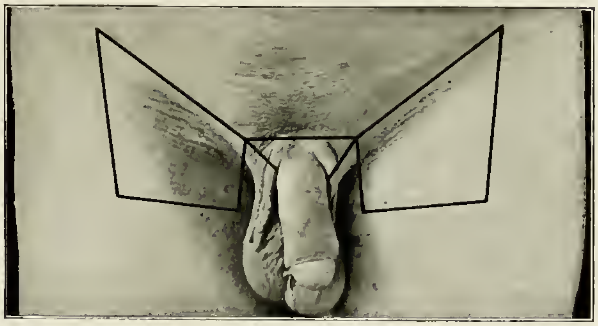


Fig. 215.—Circuminjection for amputation of penis with removal of glands.

The diagram illustrates the manner in which a circuminjection around the root of the penis for penis amputation (page 330) can be added. For such extensive anesthesia not less than 200 c.c. of 0.5 per cent. novocain-suprarenin solution will be required.

INDEX.

F

G

J

K

L

M

U

V

W

Y

Z