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A PRACTICAL DISCUSSION OF SPINAL ANESTHESIA

Senior Thesis
by
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PREFACE

In this monograph I have attempted a survey of the literature of historical and recent date on the subject of Spinal Anesthesia. I have summarized this into a practical discussion of the subject and have made no attempt to show its superiority or inferiority to other forms of anesthesia. The subject matter has been derived entirely, with due credit and acknowledgment, from those authors listed in a selected bibliography at the close of the paper.
INTRODUCTION

Like many great discoveries, spinal anesthesia resulted from an accident. J. Leonard Corning was the first to produce anesthesia by the intraspinal method. He did it accidentally, however, while giving a supposed therapeutic extraspinal injection of cocaine. In giving the history I have very briefly described the evolution of anesthesia in general in order to bring out the similarity of the discovery of spinal anesthesia and other anesthetics.

Due to prevalent misconceptions, this method was slow to receive its merited position in anesthesia. Throughout the discussion the importance of a safe and well understood technique and the constant personal care for the patient have been stressed. The technique given, in principle, is that predominantly used by most of the important workers in this field.

Complications during operation and postoperatively have been discussed in detail and are generally agreed upon by most authors. Applicability and selection of patients are still points of considerable argument. Spinal anesthesia, as other anesthesia, has its good and bad points. Perhaps it is best to place its choice with the surgeon. That evidence which gives the surgeon most peace of mind, knowing his patient as he should, will decide its applicability.
"And the Lord God caused a deep sleep to fall upon Adam, and he slept; and He took one of his ribs, and closed up the flesh instead thereof." It has been claimed that in the "deep sleep" which the Creator "caused to fall upon Adam" is the germ of the idea of anesthesia that has come down to us from the dim ages of the past. It is probable that primitive man used digital compression of the carotid arteries to produce anesthesia, as the inhabitants of some countries do today. This method was practiced by the Assyrians before performing the operation of circumcision. Curiously, the literal translation of the Greek and Russian terms for the carotid is "the artery of sleep". (1)

The ancient Egyptians are believed to have used Indian hemp and the juice of the poppy to cause a patient to become drowsy before a surgical operation. Pliny (1) relates that they applied to painful wounds a species of rock brought from Memphis, which was powdered and moistened with sour wine. This is the first record we have of local anesthesia with carbonic gas. It is probable that the "wine mingled with myrrh", which, according to St. Mark, was offered to Christ before he was nailed upon the cross, was indeed a narcotic draught, given with the object of lessening his sensibility to the agony.
The earliest reference to anesthesia by inhalation is contained in the works of Herodatus, who states that the Scythians were accustomed to produce intoxication by inhaling the vapor of a certain kind of hemp which they threw upon the fire. This was probably cannabis indica, or Indian hemp.

During the fifteenth century, several new drugs had been introduced and used as an inhalation, in mixed form. The following is the composition of the sleeping sponge, and the method used. "Take of opium, of the juice of the forest mulberry, of the seeds of lettuce, of the seeds of dock, which has large round apples, and of the water-hemlock, each an ounce. Mix all these in a vessel, and then place it in a new sponge; let the whole boil until the sponge consumes it all. Place the sponge in hot water for an hour and let it be applied to the nostrils of him who is to fall asleep." The sleep produced was so profound it often continued for several days. (1)

Local anesthesia was not unknown during the middle ages, and Cardow recommends the inunction of a mixture consisting of opium, celandinici, together with oils. Crushed seeds of poppy and henbane were applied as a plaster to parts about to be cauterized. Local anesthesia was also produced by freezing. During the seventeenth and eighteenth centuries
the interest in anesthesia began to wane and few allusions are made to it until late in the eighteenth century. Thus from the dawn of creation, anesthesia for surgical operations had been practiced to some extent, but, owing to the uncertainty of the potency and action of the powerful narcotics and palliatives administered and the danger attending their use when exact science was unknown, the practice seemed likely to fall into oblivion. At last a series of brilliant discoveries in chemistry created a new epoch in the history of anesthesia.

The chemical era of anesthesia, brought about the discoveries of Priestley about 1767. These led up to the plan of administering gases and vapors of definite composition through the lungs. In course of time, nitrous oxide, which had been discovered by Priestley in 1776, was introduced by Humphery Davy as an inhalant, and he discovered to his great delight that it relieved pain. About this time, Professor Thompson of Glasgow was accustomed to amuse his students annually by allowing them to inhale ether and nitrous oxide until they were intoxicated. It is an extraordinary fact that, even in the face of such experiments, no one among the investigators who stood at this time on the brink of so great a discovery ventured over the threshold. The things that are the most apparent may be the longest buried, and so with the discovery of efficient anesthesia. (2)
In 1844, however, Dr. Colton, a pupil under Turner of London, delivered a lecture at Hartford, Connecticut. Several demonstrations for the amusement of the audience were done. Dr. Wells who was in the audience induced a Dr. Riggs to be the operator and extract a tooth while under the influence of the nitrous oxide. This was done and, as Wells stated, without pain. Wells then demonstrated its use several succeeding times. He was asked to address a class at Massachusetts General Hospital, at which time his experiment was not successful, and the whole thing was denounced as humbug. He became disappointed, his death occurring, due to this, at thirty-two. To Wells, however, belongs the credit for having first shown the practicability of producing insensibility by nitrous oxide and establishing the principle of anesthesia.

In 1828, Faraday had called attention to the anesthetic properties of ether. In 1839, Clarke and Morton began amusing their friends by the use of ether, just as nitrous oxide. Morton began studying the more serious side of the unconsciousness brought on by ether, and finding his conclusions similar to those of Wells, he had opportunity to use ether on several extractions. These proved to be very successful and he obtained permission to test his new anesthetic on a surgical patient at Massachusetts General Hospital. The operation was a success and soon after (1846) a meeting was held in Boston to decide on a name for the "sleep producing"
substance. Morton himself chose the name "letheon", but subsequently Dr. Oliver Wendell Holmes suggested "anesthesia" for the condition and "anesthetic" for the agent.

Chloroform as a substance had been known for some time. It also passed through a series of more or less amusing experiments, before Waldie and Simpson became aware of its practical uses. In 1847 Simpson first used chloroform anesthesia with success and reported the same to the Medico-Chirurgical Society of Edinburgh. The advent of chloroform gave an impetus to other investigators, and during the last fifty years such agents as methyl chloride, ethyl bromide, ethylene and amylene have been produced, many of which have been abandoned because of some defect or other.

Local anesthesia has already been alluded to as probably the earliest form of complete anesthesia. In 1884, Carl Koller of Vienna demonstrated the effects of cocaine as a local anesthetic. The alkaloid was isolated by Gädeke from the leaves of Erythroxylon Coca in 1855. Koller undertook a series of experiments on animals in which he found complete anesthesia of the eye lasting, on an average, ten minutes following the introduction of a two per cent. solution. The immense value of such an anesthetic in ophthalmic operations was universally recognized. Soon other alkaloids came out and found ready use, especially in dental work.
With the development of local anesthetic substances, we also see the beginning of spinal or subarachnoid anesthesia. Corning (5) was the first to begin such experimentation. He found that when a certain quantity of a remedy, say strychnine, is thrown under the skin of a frog, certain functions of the spinal cord are profoundly affected. The animal is thrown into violent convulsions and assumes a rigid attitude. Such action may be produced by direct injection of the substance into the sheath of the cord or injection under the skin.

He continued his experiments to determine whether local medication of the spinal cord was within range of practical achievement. The drug made use of was the hydrochlorate of cocaine. The injection of twenty minims of a two per cent. solution of cocaine between the spinous processes of the inferior dorsal vertebrae of a young dog should produce effects similar to a transverse myelitis or total hemisection of the cord. This was not injected into the membranous coverings of the cord, since Corning assumed that the small vessels running down between the spinous processes enter the spinal canal, join the more considerable vessels of the plexus spinalis interna, and thus produce anesthesia of the cord substance. The above having been done, a few minutes later there was a marked evidence of weakness in the hind legs but
no evidence of feebleness in the anterior extremities. Upon testing the sensibility, there was no reflex action whatever in the posterior extremities. Similar effects were produced on pinching or pricking the limbs. After a lapse of about four hours, the dog seemed to have recovered and walked about without difficulty.

Corning then performed a second experiment on a man, using thirty minims of a three per cent. solution of cocaine into the space situated between the spinous processes of the eleventh and twelfth dorsal vertebrae. He then injected another thirty minims in the same manner eight minutes later. In twenty minutes there was definite anesthesia of the lower extremities, the lumbar regions, the penis and scrotum. An hour or more after injection, sensibility was still impaired to a marked degree but otherwise he seemed none the worse for his experiences.

The only constitutional symptoms complained of were headache and slight vertigo. At no time was there nausea. Some tingling sensations and numbness persisted the following morning.

Corning concluded that such medication might be of therapeutic advantage in many morbid conditions of the cord or even certain branches of surgery.

Spinal anesthesia may be said to have truly begun with Nierman (6) who, in 1859, discovered the alkaloid of coca
leaves, to which the name cocaine was given. In 1862 Schroff found that cocaine had local analgesic properties. Koller, in 1884, suggested its employment for surgical purposes.

Corning, however, plays a conspicuous part in the early history and his experimental work was the first recorded showing its practical use. Corning was influenced by the work of Harley who showed that a poison such as strychnine, injected under the membrane covering of the cord, can act only through the intermediation of the blood vessels. Corning concluded: "In order to obtain these local effects, it is necessary first to inject the solution in the vicinity of the cord; second, to select such a spot as will insure the most direct possible entry of the fluid into the circulation about the cord in a given area".

Quinke (6) discovered, three years later, independent of Corning's work, that it was possible to remove the spinal fluid after lumbar puncture without danger to the patient.

Following the work of Corning and Quinke, many men experimented to learn the effect of medicinal fluids upon the spinal cord. It was natural that someone should propose the injection of such substances through lumbar puncture.

Sicard (6), in 1894, published a report of a series of experiments in which he injected into the subarachnoid space various substances as normal salt solution, morphine, and
tetanus toxin, and later reported on cocaine when introduced into the subarachnoid space through the intercranial or spinal route.

In 1894, Corning published an account of his method of irrigating the cauda equina with medicinal fluids. While doing this he became impressed with the desirability of introducing the remedies directly into the spinal canal. Corning's studies, however, made no impression despite the fact that he suggested the surgical application of the method. No one took the hint until Bier (3) of Keil demonstrated its worth and published the results of his labors.

Bier (3) established the surgical application of spinal anesthesia. Lumbar puncture after the method of Quinke was employed. The skin was rendered insensitive to the needle by means of infiltration. After the appearance of Bier's paper, many surgeons, especially in France and America, adopted it.

The first surgical operation performed in America under spinal analgesia is credited to Tait and Caglierei. They did an ostectomy of the tibia on October 26, 1899.

Then many men proceeded helter-skelter to attempt surgical operations under spinal anesthesia. They did not stop to consider technique or contraindications. Many fatalities occurred, causing the method to be placed in a bad light. New methods should be devised Bier said "in an attempt to reduce toxicity of the drug and to prevent the unpleasant
by-effects so often noted”. This resulted in much experimentation and in a score of drugs being advocated.

Kreis is the first man credited with having employed subarachnoid analgesia in obstetrics. Tait and Caglierei in 1900 (7) reported three cases in which cocaine was injected into the sixth cervical interspace without unusual results. In 1900, Morton introduced the extension of spinal analgesia to surgical operations on all parts of the body. Jonnesco added strychnine to the analgesic solution, while others used it in conjunction with spinal analgesia.

Within recent times there has been some agreement as to indications and contraindications. The technique has been standardized. Blomfield (8) says “the majority of workers prefer to limit the use of spinal analgesia to operations below the level of the umbilicus”. In Europe this does not hold true. Additional study will have to be done in order to understand the effects on the bulb before it will be without danger.

The distinction of perfecting the technique belongs to Jonnesco and his report in 1908 to the Congress of the International Society of Surgeons in Brussels popularized the method and spinal anesthesia began to be used extensively. Unfortunately, there was a reaction due entirely to the recklessness with which the method was employed and the result was that when statistics were compiled they showed that ether anesthesia had a much greater range of safety. Until the time of the World War,
very little enthusiasm was shown toward spinal anesthesia.
Since then, with drugs that are within the limits of safety,
a fool-proof technique, with absolute indications and contra-
indications given due consideration, spinal analgesia has
passed the threshold of doubtful applicability and has re-
ceived wide recognition.
PHYSIOLOGY AND TECHNIQUE

Spinal anesthesia, lumbar anesthesia, medullary anesthesia, intradural anesthesia, or rachianesthesia, are nerve-root anesthesias produced by the injection of a local anesthetic into the cavity of the spinal arachnoid. In no other way can so extensive an analgesia be produced with as small a dose of a drug. Consequently, of all anesthetics it produces the least general protoplasmic disturbance or toxemia.

Many preparations under different trade names are on the market for use in producing spinal anesthesia. A few of these solutions are being most generally used with the best results.

Novocaine, a preparation known under a number of trade names, is most widely used to produce anesthesia at the present time. Although it has some drawbacks such as the short duration of analgesia in moderate doses, at the same time it is the least toxic of all and hence the safest to use routinely. The average dose, depending on the type of operation, physique of the patient, and length of time required, varies from 25 mg. to 300 mg. Some who are more venturesome use much larger doses.

Nupercaine is about twenty times as strong in its effect as novocaine, yet at the same time it is much more toxic. The toxicity is claimed to be dependent on the concentration, and due to the fact that it is used in great dilution, the danger from this is not considered any greater than with novocaine.
The chief advantage of Nupercaine is undoubtedly its power to produce anesthesia for much longer periods. The same is true of Pantocaine. The dosage again varies according to requirements. The solution is made up in 0.5 per cent. saline and the maximum amount injected is placed at 20 c.c., the maximum of nupercaine itself being 18 mg.

Spinocaine was devised by Pitkin (9) with the intention of producing a controllable anesthetic. He made up two mixtures of novocaine, one with a higher and one with a lower specific gravity than that of the spinal fluid. He then claimed that by placing the patient in different degrees of the horizontal and using these solutions, the height and area of anesthesia could be controlled to a great extent. For example, when using the heavy solution, which is made up with glucose, the patient is placed in the Fowler position, and when using the light solution, which is made up with alcohol, the Trendelenburg position is used. This method is not very widely employed. It is believed that the difference in the specific gravity of these solutions from that of spinal fluid is quickly offset by the rapid absorption which takes place in the canal, the end result being novocaine dissolved in spinal fluid and in doses sometimes more than double that required. It is felt by most men that the only safe position for a patient under spinal is the Trendelenburg.

Pre-operative sedation has been a topic of considerable
discussion among those using spinal anesthesia. Earlier workers believed that one great advantage of spinal anesthesia was that the patient remained conscious throughout the operation, whereas at present the weight of opinion indicates that he should be unconscious, or at least have his faculties dulled. For this reason, many men use pre-operative sedatives. These not only allay the fears and apprehensions of the patient, but also seem to aid the action of the spinal. Morphine is most commonly used for this purpose. It may be administered in combination with scopolamine, atropine, hyosine, and in conjunction with nembutal. Nembutal intravenously is receiving considerable mention by many of the recent writers. This is being given in doses sufficient to produce unconsciousness, three to three and one-half grains. It becomes very useful in those cases where the patient insists upon a spinal analgesic but wishes to be unconscious.

Ephedrine is used almost routinely in most clinics as a means of preventing or alleviating the drop in blood pressure. The average dose varies from one-half to one and one-half grains and is best given about ten minutes before the administration of the spinal anesthetic. Some who use nembutal advocate combining it with ephedrine.

Practically every authority on spinal anesthesia differs in some detail from the others. The reason seems quite apparent when one considers the many variable factors which may influence spinal anesthesia. The most common points of difference in
technique which I have found in those clinics where it is used routinely are as follows:

1. Position of the patient during puncture.
2. Interspace chosen.
4. Dose of the drug.
5. Resultant concentration of the drug.
6. Rate and force of injection.
7. Intradural pressure of the spinal fluid.
8. Specific gravity of the solution.

The prone position for spinal anesthesia is advocated and used in a great many clinics. Koster (10) of Brooklyn uses the prone position all the time, with the exception of those cases in which he finds a severe scoliosis or extreme obesity where the median line of the back cannot be determined in the lateral position. Complete flexion of the trunk is obtained by approximating the head and the knees. It is possible for an individual of average strength to maintain such flexion easily in an uncooperative patient by applying a well known wrestling principle. With the patient on his left side, the head approximating the knees and the arms extended over his head, if the assistant stands on the side facing the patient, places his right arm around the neck and his left arm around the knees, both from behind forward so that the hands can be clasped in front of
the patient, the latter is rendered helpless.

Orth (11) of Chicago states, "We have experimented with both the sitting and the lateral postures, and have preference for the latter." He finds by administering the anesthetic with the patient in the lateral posture, the immediate accidents such as headache, syncope, and others, are decreased or avoided. They are never dangerous, pass off rapidly when the patient is placed in the lateral posture, but should be avoided if possible as they may induce an unsuccessful anesthesia in a nervous patient.

Babock (12) of Philadelphia places the patient on the side of the operating table, well back from the edge, his legs dependent. An assistant, standing on a stool facing the patient, properly arches the exposed and carefully sterilized back by carrying his left arm back of the patient's neck to the front of the abdomen, where he grasps the crossed wrists of the patient. As he pushes backward on the abdomen, his left axilla presses the patient's neck downward and backward, arching but not inclining the back. (Fig. 1 and 2)

In either method, the exposed portion of the back between the sacroccocygeal junction and the lower dorsal spine is painted with picric acid and a sterile towel is placed over the side of the patient above the sterilized field so that the crest of the ilium can be located by the operator with the fingers of one hand. An imaginary line between the superior part
Fig. 1. Patient in correct position on side showing relative position of lower thoracic and lumbar interspaces. Line joining iliac crest crosses 4th lumbar interspace.

From Evans.
Fig. 2. Method of holding patient in sitting position for intradural injection. The assistant stands on a stool above the level of the patient, with the patient's neck under his left axilla. With his hands he grasps the patient's wrists and by bearing downward and backward upon the patient's neck, the back is properly arched. The back should be arched rather than inclined forward.

From Babcock.
of both iliac crests crosses the spinal column between the third and fourth lumbar vertebrae. The thumb of the same hand (after the fingers determine the crest) locates the depression above the imaginary line, that is, the interspace between the second and third lumbar vertebrae. At this point the puncture is made. (Fig. 3 and 4)

Certain anatomical facts should be mentioned at this time. Many failures to procure surgical anesthesia by spinal injection are fundamentally due to unsuccessful spinal taps.

The base of the spinous process of the second lumbar vertebrae is comparatively thicker than the others and this is regularly felt in locating the interspace between the second and third, namely, the injection site. The axis of the interspace between the lumbar spinous processes varies. That between the fifth and fourth lumbar is almost horizontal, whereas that between the vertebrae above is very slightly upward and forward. The distance between the bodies and spinous processes of the second and third lumbar vertebrae is great enough to allow a needle introduced horizontally in the median line between the bases of the two spinous processes to enter the subarachnoid space without impinging on any bony parts.

Attached to the base of each spinous process is the supraspinous ligament. Between each spinous process are the interspinous ligaments and along the posterior wall of the
Fig. 3. Marking the point for the introduction of the needle. With the end of the gloved thumb pressed against the lower edge of the spinous process the finger-nail is caused to make a line upon the skin, through which the needle is entered. From Babcock

Fig. 4. Showing the position of the needle after induction, or ready for induction of anesthetic. From Babcock
spinal canal extends the ligamentum subflavum. Each of these can be felt by the penetrating needle, and the last is a dependable guide to the depth of the needle point. Several trials enable one to identify the ligament easily by its characteristic resistance to the passage of the needle.

The spinal dura is continuous with that which invests the brain. It is a loose sheath unattached to the bony framework of the spinal canal and is separated from it by loose aricular tissue containing a plexus of veins. The latter are more numerous in front and on the sides. Very few are found posteriorly. The arachnoid, separated from the dura by a slight interval, the subdural space, is separated from the underlying pia by a relatively large space, the subarachnoid space. This latter space which attains its greatest dimensions at the lower part of the spinal canal contains cerebrospinal fluid.

The spinal cord terminates opposite the lower border of the first lumbar vertebrae. The lower spinal nerves between the first and second lumbar vertebrae, gathered into a bundle on either side of the filum terminale, pass down to form the cauda equina. The motor roots lie in front and the sensory roots lie behind. They are separated by an irregular cribiform membrane, the downward prolongation of the ligamentum denticulatum.\(^{(13)}\)
The needle is introduced horizontally in the median line through skin, subcutaneous tissue, supraspinous and interspinous ligaments, the ligamentum subflavum, the dura, arachnoid, and finally into the subarachnoid space. It may be necessary to tilt the needle slightly upward. The necessity arises only when incomplete body flexion is secured. If the needle is introduced horizontally in the median plane of the body, cerebrospinal fluid will be obtained at a depth of from 4.5 to 5 cm. If the needle is introduced through the skin at an angle, the distance from the median plane becomes greater as the penetration increases. Therefore, although the introduction through the skin may be in the median plane, the needle may be one or more centimeters lateral to the spinal canal at a depth of 5 cm., and a so called "dry tap" be obtained.

When the needle is known to have entered the subarachnoid space, the stylet is withdrawn and cerebrospinal fluid is allowed to flow into and fill the globular portion of the ampule containing the crystals of anesthetic preparation. If in crystalline form, between 3.5 and 4 c.c. of fluid are required. If the proposed operation is a short one and involves structures below the diaphragm, an ampule containing 0.1 gm. of the drug is sufficient. If the procedure is to extend over three quarters of an hour but less than two hours, and the site of operation is below the diaphragm, 0.2 gm. of neocaine dissolved in 4 c.c. of fluid is adequate. When, however, the operation involves the upper portion of the trunk or head, the same amount of
anesthetic may be used but should be dissolved in a larger amount of spinal fluid. The amount of anesthetic used depends upon the operator and the type of preparation being used, since they vary in strength greatly.

The filled ampules are placed on a sterile surface and the fluid drawn back and forth into a syringe to insure complete solution. The entire solution is drawn into a syringe. The needle used in emptying the ampule is discarded, the stylet of the spinal tap needle is removed, and the syringe is fitted to the latter. The fluid is then injected under force and at the rate of an ordinary hypodermic injection. The force and rate are the same, irrespective of the level or duration of anesthesia desired. After the injection, the needle is sharply withdrawn. The patient is immediately placed in whatever position is necessary for operation. At this time it is of paramount importance that the head be placed at a lower level than the trunk. This need not be a great distance, 2 or 3 inches being sufficient, unless during the course of the operation it becomes necessary to tilt the table at a greater angle in an attempt to relieve the cerebral anemia. Most operators find that the Trendelenburg inclination of 8 to 10 degrees is adequate. The field of operation is then prepared by proper sterilization and draping. As soon as this is accomplished, it will be found that the anesthesia is complete so that operation may be begun.
Many operators use a subcutaneous injection of cocaine at the point of puncture. This is merely to anesthetize the skin over this area, since the puncture needle is large and may be rather painful. The skin is the only structure passed through in making the puncture which is sensitive enough to cause a great deal of disturbance. In persons with a relatively nervous make-up, one finds that a subcutaneous injection may be quite helpful. It has been found that patients go into profound shock during the process of making the spinal puncture and the cutaneous anesthesia may prevent such a condition from occurring. On the other hand, some operators maintain that if a small needle is used, a subcutaneous anesthetic is not necessary.

Babock (14) of Philadelphia states, "The use of a fine sharp needle removes the necessity of using a local skin anesthesia about the area of puncture. If the puncture needle is given a quick thrust through the skin the pain need not exceed that of a small needle used in injecting the cutaneous anesthesia."

Spinal puncture and tapping of the spinal fluid is a necessary preliminary to spinal anesthesia. In this procedure the type of needle becomes an important factor. A needle of small gauge makes a small hole in the dura and thus lessens the possibility of leakage and subsequent headache.

Sise (15) of Boston recommends, "The point of the needle be such as to inflict the least possible trauma on the patient
and at the same time to deposit the anesthetic solution within the dura. The long sharp bevel is now generally discarded. A needle with a sharp cutting point produces a larger hole in the dura than a needle of the same size having a joint rounded like a cambric needle. This is because the sharp edge cuts the longitudinal fibers of the dura while the cambric needle tends simply to pry the fibers apart without cutting them, so that when the needle is withdrawn they may fall together again."

Sise uses a needle with what may be called a conical point, one which is bevelled equally all the way round, and of which the stylet forms the apex. This type of point seems possibly to obstruct more easily than the ordinary bevelled point, and when obstructed is less easy to free. Its advantages, however, appear to out-weigh these disadvantages.

Fine needles, on account of their flexibility, are less easy to use than are larger and stiffer needles. A stiff needle retains its direction even when traversing resistant tissues, and its direction may be altered while it is within the tissues. A fine needle, on the contrary, may bend on meeting resistance and its direction cannot be altered without practically complete withdrawal.

To meet these difficulties, Sise (15) devised an introducer. It is essentially a cannula 1½ inches long, with a sharp cutting point and a flange at the base, of a size to accommodate readily the needle to be used. This introducer is
employed by inserting it through the skin and posterior spinous ligaments much like a thumb tack. After the spinal needle has been inserted through this, it acts as a brace or splint to prevent bending of the needle. This introducer has not received much popularity and is not used by the majority of operators.

After the spinal puncture has been made and the anesthetic introduced, the patient should be carefully watched. The pulse, respiration, and color are to be observed as if ether were being given. The respiration may be observed by a wisp of cotton affixed to the tip of the nose. If the patient is awake, conversation to divert and encourage the patient should be carried on in a low tone. The patient is not to be informed as to the commencement of the operation, as many surgeons do, by inquiring as to his sensation of pain. If possible, the thought of pain, fear or danger should not be suggested by the conversation of bystanders. In not contra-indicated by the operation, the patient may be entertained by bits of cracked ice, little sips of water, or even the privilege of smoking.

The danger period of spinal anesthesia is from five to twenty-five minutes after injection. Ephedrine or adrenaline should always be available. The patient's shoulders should not be raised until one hour at least has elapsed from the time of injection. For asthenic patients, a funnel and rubber tubing connected with a transfusion needle should be conveniently at hand with a flask of sterile physiological salt.
solution. Care after giving spinal anesthesia is often neglected because operators think it insignificant, the end result many times being fatal.

A thorough understanding of the physiology of spinal anesthesia should be had by all those who use or intend to use this type of anesthesia. The following points are worth remembering:

First, spinal anesthesia produces analgesia of the tissues supplied by nerves, the roots of which are affected by the physiochemical action of the drug after it has been deposited in the subarachnoid space. In other words, it is an extensive nerve block and not a physiological section of the cord. Testing the degree of sensation after injection reveals a sudden and complete fall in conductivity. The property of conductivity is abolished very early, thus allowing operative trauma without sensation almost as quickly as the operative field can be sterilized and draped. The action of an anesthetic agent on nerve tissue depends upon an affinity between it and the lipoid substance in the nerve tissue, a physiochemical solubility reaction occurring at the point of application. The union between the anesthetics of the cocaine group and nerve elements is a comparatively unstable one, unlike that of the quinine group. It results in rapid and complete interruption of conductivity, particularly of sensory fibers. Increased diffusion, giving a higher level of anesthesia, may be produced by withdrawing a greater quantity
of fluid, using it all as a solvent for the drug, and reinjecting it in toto. By this means we secure a diffusion up to the brain.

Second, spinal anesthesia produces a sharp drop in blood pressure with a slow pulse, differing from the rapid pulse seen in low blood pressure during shock or following hemorrhage.

Third, there is a slow and shallow respiration.

Fourth, there is a dry wound, that is, less bleeding.

Fifth, the lumen of the intestines is contracted with a possible slight increase in peristalsis.

Sixth, there is an absence of abdominal movement and no bulging of the viscera through the operative wound.

All these phenomena, with the possible exception of one based upon the physiological action of the drug, are of no danger to the patient and are most desirable for the surgeon. One can operate with much more care, with greater rapidity, and with less trauma to the tissues. It is the sharp drop in blood pressure that carries the danger for the patient and it is this phenomenon in particular that causes many fatalities. (16)

Thirty-one pairs of spinal nerves spring from the cord, each nerve having an anterior motor and posterior sensory root, the latter always being distinguished by the presence of the spinal ganglion. From the second thoracic to the second or possibly the third lumbar, the anterior nerve roots
carry white rami which pass to the sympathetic chain by way of the rami communicantes. From ganglia of the sympathetic chain, gray fibers are sent to the blood vessels. These fibers are called postganglionic fibers. While the white fibers coming into these ganglia through the rami communicantes are called preganglionic fibers. These pre- and postganglionic fibers, the sympathetic chains, and the sympathetic fibers of the two vagi nerves constitute what is known as the sympathetic autonomic nervous system.

This system supplies nerves to the arteries, glands, muscles, and gastro-intestinal tract. Those supplying the arteries are vasomotor nerves. Their mechanism differs somewhat, depending on their anatomical distribution. Those nerves destined to supply the peripheral blood vessels receive postganglionic fibers from the ganglia of the sympathetic chain, in which the preganglionic white fibers from the rami communicantes have terminated. Each ramus communicans between a spinal nerve and a sympathetic ganglion consists, therefore, of two parts, one (white ramus) of preganglionic fibers passing from the spinal nerves to the ganglion, the other (gray ramus) of postganglionic fibers coming from the ganglion to the spinal nerve for distribution to the peripheral tissues. On the other hand, the vasomotor nerve fibers destined for the great vascular regions of the intestine and other abdominal viscera, after reaching the sympathetic chain by way of the white rami as preganglionic
Fig. 5. The physiology of the fall of blood-pressure under spinal anesthesia. From the second thoracic to the third lumbar the anterior nerve roots carry white rami which supply through the intervening ganglia the blood-vessels walls of the entire body. The fall in blood-pressure during spinal anesthesia depends on the number and position of the anterior nerve roots blocked by the drug. From Babcock
fibers, do not return to the spinal nerves by the gray rami. They have the sympathetic chain still as preganglionic fibers, in the branches of the splanchnic nerves and through them pass to the semilunar and mesenteric ganglionic or sympathetic fibers arising from these ganglia. (Fig. 5) (24)

The innervation of the heart differs quite decidedly from any other part of the vascular system. The cardiac plexus is formed by three cardiac branches from each vagus, a cranial nerve, and three or four cardiac branches from each sympathetic chain. The heart then, as you see, receives motor, sensory, and sympathetic nerve fibers. Afferent and efferent impulses are transmitted directly to and from the brain. The heart's action, therefore, is regulated in part by direct stimulation of the vasomotor center in the medulla.

The vasoconstrictor nerve fibers are constantly in action to a greater or lesser extent. If the sympathetic nerve in the neck is cut, the blood vessels of the ear become dilated. Blood vessels are kept in a condition of tone by the vasoconstrictor nerve fibers. Cut these fibers and the vessels lose their tone and dilate. The relatively enormous effect upon aortic pressure caused by the paralysis of the tone of the arteries in the splanchnic area shows that under normal conditions the peripheral resistance in this great area plays a predominant part in the maintenance of normal arterial pressure, and by the same reasoning variations in tone in the blood vessels of this region must play a very large part
in the regulation of blood pressure. (16)

Bower (17 & 25) and his co-workers have contradicted this theory on the fall in blood pressure. In their work, they severed both splanchnic nerves and a similar fall in pressure occurred. This fall in pressure must be mainly cardiac in origin. They explained the mechanism as "a paralysis of the intercostal and phrenic nerves interfering with normal chest expansion and diaphragmatic excursion, causing a damming back of venous blood in the right heart and its tributaries". They also observed in dogs a dilatation of the heart associated with anesthesia ascending to the fourth thoracic nerve root or higher. They also have shown that if artificial mechanical respiration is maintained so that the internal positive and negative thoracic pressure is regulated, the blood pressure and pulse do not vary greatly from the normal. Most men agree on the first theory as the most logical cause of the fall in blood pressure.

If we inject novocaine into the subarachnoid space, the drug will diffuse both toward the head and toward the sacrum for variable distances depending upon certain definite conditions. Novocaine so injected does not remain as a free fluid that flows freely up and down this space. There is a physicochemical action almost immediately and a semi-gelatinous mass is formed. The nerve tissues take up the greater portion of the drug and it is either destroyed locally or carried away in the blood stream in a comparatively short time. The position
of the patient has but little if any influence on the direction or distance of the diffusion of the drug itself.

There are three main factors which control diffusion of the anesthetic drug in the subarachnoid space: (1) the method of injection, (2) the site of injection, and (3) the degree of intraspinal pressure at the time of injection.

As the physiochemical action of novocaine, especially on nerve tissue, is greatest at its first point of contact, if it is injected very slowly and without pressure, the solution will tend to remain in the close vicinity of the site of puncture and allow the nerve tissues to take up the greater part of the drug leaving a dose too small to produce anesthesia by diffusion higher up. Specific gravity of the dissolving agent means nothing in so far as diffusion of the drug is concerned. Such lighter and heavier agents are usually made with distilled water to which alcohol is added to make an agent of higher specific gravity. When such agents are used, the incidence of headache, nausea, and vomiting is greatly increased. The patient's own spinal fluid renders one less liable to mistakes and it dissolves readily. This view is held by Koster (10) and numerous other operators. Pitkin (9) who has developed a heavy and a light solution for anesthesia at different levels suggests no particular space for injection since the extent of anesthesia is regulated entirely by the degree of Trendelenburg or Fowler's position used.
The average upward diffusion from the various sites of injection are about as follows: Injection between the twelfth dorsal and first lumbar vertebrae will diffuse to the fourth dorsal; injection between the first and second lumbar diffuses to the sixth dorsal; injection between the second and third lumbar diffuses to the ninth or tenth dorsal; injection between the third and fourth lumbar diffuses to the twelfth dorsal. Therefore, if the operation is to be performed on the lower extremities, anus, perineum, and external genitalia, the anesthetic drug is injected into the subarachnoid space between the third and fourth lumbar vertebrae; for operations on the bladder, prostate, rectum, sigmoid or lesser pelvic organs, injection is made between the second and third lumbar; for supravaginal hysterectomy and midabdominal operations, injection is made between the first and second lumbar; for operations on the kidney, gall bladder, stomach or spleen, and for other upper abdominal operations, injection is made between the twelfth dorsal and first lumbar. Higher anesthesia can be produced, spinal anesthesia, however, having its greatest usefulness for operations below the diaphragm.

Suppose the patient has received an injection of novocaine in the subarachnoid space, between the first and second lumbar vertebrae, and the anesthesia extended up to the sixth dorsal nerve. These nerve roots are blocked, consequently there is a motor and sensory paralysis of the tissues. The blood vessels,
especially the great splanchnic have lost their tone. They have dilated and drained the blood from the periphery and, most important of all, from the brain. The pulse rate is slow. Respiration is slow and shallow. Perhaps he does not respond to questioning as he should. If such a condition should exist, we know that all we have to do to relieve the patient's condition is to place him in the Trendelenburg position so that the blood can get back into the brain. Therefore, if the patient is put in a 15 or 20 degree Trendelenburg immediately after injection, the drop in pressure may be prevented. Blood pressure is the one and only true indicator in spinal anesthesia of the patient's condition. This condition is similar to that found in fainting. A stimulant in a fainting spell will arouse the patient. In spinal anesthesia, however, the vasoconstrictor nerve fibers to the blood vessels are paralyzed, the paths of action are blocked and stimulants cannot act. In spinal anesthesia (high) in which we have a sharp drop in blood pressure, the slow heart rate is due to interference of the sympathetic or accelerator nerve fibers of the vagus, not altogether unopposed but partly unopposed, with a consequently slower rate.

In the gastro-intestinal tract, the antagonism between the vagus and the sympathetic nerves still exists. However, their antagonism is directly opposite to that in the heart. Here the vagus is still a motor nerve but has no inhibitory fibers. Stimulation of this nerve, therefore, causes contractions of the intestinal wall. The sympathetics are the
inhibitory nerves for the intestine. If stimulated, they cause
dilation of the intestine. These two systems of nerves, with
their antagonistic action, influence the maintenance of the
normal size and motion of the intestine. In spinal anesthesia
the sympathetic or inhibitory nerves are paralyzed, leaving the
vagus unopposed, which accounts for the contracted lumen of the
intestine.
COMPLICATIONS

The complications and after effects of spinal anesthesia are less understood and more feared by the surgeon than many of the complications of general anesthesia or of major operations. By always employing the same drug, of known purity, an aseptic technique and atraumatic surgery, it is possible to limit the after symptoms to those which result from a fall in blood pressure. Respiratory failure was formerly the most serious complication. It is more seldom seen with the newer drugs and more modern methods of induction.

In reviewing the literature on complications of spinal anesthesia, most frequent mention is found of headache. Less frequently, reference is made to symptoms that are classified as meningeal in origin, being the result of either a meningism or, more rarely, a true meningitis. Occasional reference is made to the appearance of neurological disorders as paresthesia, myelitis, anal and vesicle incontinence, paralysis of the external rectus muscle of the eye. Mental alterations varying from mild psychosis to pronounced insanity have been recorded as sequelae.

The complications are not due to a general toxemia from absorption of the drug as the dose employed is altogether too small to produce such a condition. They are the result of the direct or selective action of the drug on those vital centers that are bathed in the spinal fluid, of a faulty technique, or
of mistakes in preoperative and postoperative care of the patient.

Evans (18) classifies the complications of spinal anesthesia into three groups, the immediate, the intermediate, and the late complications. The immediate symptoms are: (1) those of shock or syncope which occur at the time of the lumbar puncture or when the drug is injected; (2) the nausea or cold sweats occurring at the same time; (3) those resulting from depressed function following visceral sympathetic paralysis. The intermediate symptoms are those of headache, backache, stiff neck and the other symptoms of meningeal irritation. The late symptoms are palsies, persistent headache, and neuroses. The intermediate and late symptoms are the irritative results of the spinal injection or the results of spinal fluid leakage.

Vasomotor paralysis. The fall in blood pressure with its resulting acute bulbar anemia is the most important and the most dreaded of all the complications of spinal anesthesia. This sudden fall of blood pressure is often followed by nausea which, if not relieved, will lead to vomiting, pallor of the skin, a feeling of compression about the chest, thirst, air hunger, cold sweats, and a slowing of the pulse and respiration with a complete collapse in which the whole splanchnic nervous system is blocked and the blood has collected in the great splanchnic pool. The blood pressure may fall to zero. The function of the liver, kidneys and other organs may be
greatly diminished. The patient may become unconscious with cessation of the heart beat. In such cases, if respirations are maintained and the heart is not allowed to stop, a fall of blood pressure to zero at the wrist is well borne and the patient none the worse because of it. With the proper treatment, the blood pressure can be restored, the vital organs returned to normal function, and consciousness can be regained.

If vasomotor paralysis is to occur at all, it occurs during the first fifteen minutes after the injection or when the patient is suddenly moved. The degree of paralysis is governed by the depressed condition of the patient and the height and strength of the anesthesia is reached, after which there is a readjustment and the body functions gradually approach the normal. The reactions of the patient during the first few minutes of a normal spinal anesthesia are in many respects opposite to those of the patient during the first few minutes of a general anesthesia. In the latter there is excitement, muscular exertion, increased breathing, fast heart rate, and a bounding pulse, while the patient is becoming more depressed. In the former, there is normal breathing, a warm dry skin, and improvement of the general condition as the operation advances.

Adrenaline, a peripheral vasomotor constrictor, is the only drug that satisfactorily counteracts the central vasodilation produced by spinal anesthesia. When injected deep
into the gluteal muscles, it causes an increase in blood pressure which will usually last from twenty-five to thirty minutes. In the average case, this covers adequately the time during which a high anesthesia would cause a drop in blood pressure. The low blood pressure occurring in spinal anesthesia usually lasts from twenty-five to thirty minutes. After this time the action of the drug has worn off sufficiently to allow the blood pressure to return to about normal.

The whole syndrome is that of cerebral anemia, except for the slowing of the heart, which is due to the unrestricted action of the vagus nerve. That the slowing of respirations and the depressed feeling in the chest are not due to respiratory failure or paralysis is shown by the patient’s relief when the head is lowered, forced breathing started or a cardiac stimulant administered.

**Respiratory paralysis.** Roeder (19) states that spinal anesthesia produces respiratory failure in two ways; a paralysis of the motor nerves of respiration, and a paralysis of the vasomotor nerves of the splanchnic area which results in loss of blood pressure followed by a myocardial and medullary ischemia.

This is in accordance with other authors. Koster (20) finds that in spinal anesthesia a slight respiratory depression may occur without any degree of respiratory paralysis. This is
not true respiratory paralysis due to the drug but is the result of lessened bulbar function due to anemia, plus cessation of abdominal breathing. This shallow breathing with intervals of deep sighs readily clears up as the pallor, insomnia, and other symptoms of a lowered blood pressure are relieved. When the patient's respirations slow gradually, the cause is paralysis of the phrenic nerve and not of the respiratory center. With neocaine or similar novocaine products, fortunately, it is almost impossible to paralyze the upper cervical nerves when the drug is injected below the twelfth dorsal vertebrae.

True respiratory failure is due to a high anesthesia and it will vary with the height and concentration of the anesthetic, the vitality of the patient, and the operators. Cyanosis and unconsciousness may develop and the heart stop beating unless artificial respiration is begun. This is the important complication of high anesthesia and may prove fatal. In those surgical procedures below the umbilicus where the anesthesia is low, respiratory paralysis is of less consequence. Sudden respiratory failure may occur even with the lumbar puncture. Such individuals are predisposed to sudden complete collapse in any type of surgical procedure. This suggests a thorough study and examination of the patient before treatment is attempted. (26)

Shock and Syncope. The majority of the deaths which have been attributed to spinal anesthesia have been a result of
shock. No doubt many of these fatalities were the result of 
improper technique or disregard of definite contraindications. 
Evans (18) enumerates at least six ways in which shock or syn-
cope may be produced during spinal anesthesia.

(1) Lumbar puncture or meningeal reflex shock. This may 
occur in the nervous or over-stimulated patient, especially 
where insufficient preoperative morphine has been given. It 
may follow an injury to the meninges when a large needle is 
used or repeated attempts have been made to enter the dural 
canal or the patient has been kept too long in the sitting 
position. The onset in these cases is usually sudden com-
plete collapse with cessation of the function of the vital 
centers. The result is variable from a mild fainting spell 
to sudden death.

(2) Visceral reflex shock. This may occur when the in-
testines are too roughly handled, when the stomach or omentum 
is pulled upon, or when the upper abdominal organs are tightly 
packed off. According to Evans (18), "It is the result of 
disregarding the principles of atraumatic surgery and should 
not occur with those who are zealous of their technique."

(3) Hypersusceptibility. This very rarely occurs, since 
 few people are hypersusceptible to neocaine. Therefore, an 
acute drug poisoning may occur following its intra-spinal 
administration. The drug poisoning may be due to an unusually 
strong drug or to the accidental injection into one of the
meningeal veins. The symptoms are those of anaphylactic shock.

(4) Position shock. This occurs when the patient is suddenly changed from one position to another, especially from the Trendelenburg to the horizontal position. It occurs most frequently in weak or very old patients. These patients have had what, for them, is almost a lethal dose of the drug and have had low blood pressure and a decreased respiratory rate throughout the operation. The shock results from an added embarrassment to an already overladen heart. It is the most common complication occurring at the end of the operation. Patients who have been quiet and apparently asleep during the operation seem most apt to be affected this way.

(5) Intracranial pressure shock. This may lead to what is known as "lumbar puncture death". It may have been the cause of many deaths which have been cited to prove spinal anesthesia a radical and unsafe anesthesia. It is the commonest cause of death following the simple lumbar puncture, yet diagnostic lumbar puncture continues to be accepted as a valuable and standard procedure. Shonbeck thoroughly reviewed the literature and collected seventy-one cases. Over 50% had intracranial tumors, 13% had cerebral hemorrhage, and approximately 58% of the cases presented symptoms of some cerebrospinal pathology which was present at the time of the lumbar puncture.

This acute condition results from a loss of spinal fluid, either at the time of the puncture or by later leakage through
the dural opening. Due to the release of spinal fluid pressure below, the medulla is jammed into the surrounding foramen magnum. Death may be sudden, beginning with a terrific headache, or it may occur within a few hours. It is due to suppression of the medullary centers and the symptoms are those characteristic of severe intracranial pressure. This should invoke one to take a careful history and make a complete physical examination of the patient before instituting lumbar puncture.

Meningitis. The complication of meningitis occurs in a frequency which is proportional to the faults in technique. With those using correct technique, it is quite rare. Several types of meningitis may be found.

(1) Non-infective irritative meningitis is an irritative condition of the meninges which is often spoken of as "meningismus". It is essentially a congestion with resulting exudation following the exposure of the meninges to any toxic substance. It may follow a toxic dose of the drug, capillary hemorrhage when a dural blood vessel is punctured, trauma to the dura when several attempts are necessary to enter the dural cavity, or the introduction of foreign material, such as rust or dirt which may come from the syringe, needle or drug.

Beginning twelve to twenty-four hours after the injection, the patient shows mild meningeal symptoms such as pain along the spine, stiff neck, photophobia and nervousness. Rarely there may be a persistent headache, while the more severe cases may
show some involvement of the eye muscles. There is an increase in the spinal fluid pressure and an examination of this fluid shows an increased cell count but no marked increase in globulin. The symptoms in this form are mild and disappear after six to ten days with no after effects except possibly a neurosis which may be overcome by reassuring the patient.

(2) The meningitis may be of the purulent type and may be comparable to the infective peritonitis that follows a clean laparotomy. It is the same risk of sepsis encountered in every surgical case. The symptoms show themselves, usually, during the first twenty-four to forty-eight hours. Headache and restlessness are followed by the characteristic signs and symptoms of an infectious meningitis. The spinal fluid in this type will show a marked turbidity, the pressure will be high, and the cell count and globulin greatly increased. As a rule, the meningitis tends to clear up spontaneously in ten to fifteen days with no after effects. Very few cases have been reported and only two deaths have been reported in the last twenty years.

Neuritis or palsy. These rarely occur following spinal anesthesia and should cause little alarm since they clear up spontaneously with no after effects. One exception is often made, the motor or sensory paralysis due to extensive trauma of the nerve roots.

The palsies are of two types, those due to trauma at the site of puncture, and those due to damage at a distance. If
the spinal needle comes into contact with the spinal roots or the nerves of the cords equina, we find motor or sensory terminal disturbances. There may be sharp shooting pains, muscle spasm, anesthesia in the lower extremities, transient paralysis or irritation of the vesical or anal sphincters. These are due to a slight readjustment with no later complications.

When the nerve roots are more severely damaged, there will be a more lasting anesthesia or paralysis. When the continuity of the nerve roots is severed there will be a permanent damage. Unlike the puncture of a nerve root, the puncture of the cord causes neither pain or after effect. Fortunately, organic cord changes do not come on later in life following spinal anesthesia.

**Ocular complications.** These are practically limited to paralysis of the extraocular muscles, usually of the external rectus which is supplied by the abducens or sixth nerve. Although ocular disturbances have set in from several days after injection to as late as the second week after operation, cases have been reported wherein they occurred immediately following lumbar puncture. As a rule this complication tends to be transitory. After a maximum effect lasting from one week to ten days, the condition shows signs of beginning improvement.

Abducens paralysis is usually ushered in by a preliminary photophobia. Diplopia supervenes and is homonymous. Outward motion is limited and there is a convergent squint. All these
symptoms are exaggerated as the patient attempts to abduct the affected eye. A functional optic neuritis occasionally accompanies abducens palsy. There is a disturbance of vision, sometimes insignificant, at other times rather marked. There may be a complete temporary blindness. This usually lasts from two to five days. When it occurs, it is usually unilateral and is as frequent in the right eye as in the left eye. (27)

The explanation usually given of the mechanism by which the sixth nerve becomes involved, postulates an edema of the brain consequent to injection. The long course of the sixth nerve at the base of the brain allows for relatively more stretching. This, it is believed, interferes with its function. As the edema subsides, there is a recession of symptoms.

Another explanation advanced is that the sixth nerve is particularly susceptible to the effects of the anesthetic. While there is some evidence that different nerves are variously affected by anesthetics, why the delayed activity?

In treatment of this condition, the element of time is the most important factor, and the patient confidently assured of complete cure. Perhaps it is one of the symptoms of a low grade meningitis and can eventually be eliminated by better technique.

**Nausea and vomiting.** These usually occur in spinal anesthesia where there have been errors or omissions in the procedure. When it becomes necessary to put the patient in the
Trendelenburg position or to pack off the abdomen tightly, nausea and vomiting sometimes occur. There is no severe postoperative nausea or vomiting after spinal anesthesia alone. There may be several different causes, however, for these symptoms during a spinal anesthesia.

Cerebral anemia produces nausea and vomiting during the first fifteen minutes of the anesthesia or when the patient is suddenly moved. It may be merely the slight nausea which is concomitant of low blood pressure or it may go on to severe vomiting. It can be prevented or readily stopped by the methods used for treating a motor collapse. As in all other cases of cerebral anemia, the head and shoulders must be flat and the patient put in the Trendelenburg position.

Psychic nausea is the result of certain mental impressions. The patient may be reacting perfectly well to the operation and be showing no signs of either pain or excitement and then become suddenly extremely nauseated, vomit and extrude the viscera through the abdominal incision. Such upsets commonly follow lack of preoperative morphia and poor psychology on the surgeon's part. Such questions as, "Does it hurt?" and "You must be quiet now and help us" are rather suggestive. Such nausea is the result of the terrifying thoughts of an overactive mind which are often
intensified by the thoughtless questions of the operator. Such attacks are very similar to those which occur when one first sees human blood or mutilated bodies. Sufficient morphine and an entertaining and cooperative anesthetist should eliminate this complication. (45)

Reflex vomiting often occurs due to excessive action of the diaphragm in breathing, a sudden change in position of the patient, packing against the stomach, and manipulations of the stomach and duodenum. All these interfere with the normal function of the stomach and this dysfunction, added to an already existing slight cerebral anemia, is often sufficient to start a reflex vomiting.

Postoperative nausea and vomiting may develop as an accompaniment to the spinal puncture headache or may be one of the symptoms of a meningeal irritation or infection.

Headache. This is the most annoying complication of spinal anesthesia. Lumbar puncture headache is the most common headache following spinal anesthesia. It is not dependent upon the blood pressure of the patient and it may occur regardless of the fluid removed. A later lumbar puncture will show that the spinal fluid pressure is lower than it was at the time of anesthesia, and an examination of the fluid will show a decrease in the cell count and globulin content. The patients usually complain of an occipital or a parietal headache which appears during the first twenty-four hours after operation and which gradually
increases in severity. The headache is worse when the head and shoulders are raised but completely disappears when the head and shoulders are lowered. No drug gives sufficient relief in this type of headache.

Meningeal reflex headache occurs two or three hours after the spinal injection and is usually gone by the end of the third postoperative day. It results from meningeal irritation, especially when a large needle has been used or when there has been difficulty in entering the dural canal. It is not serious and will cease spontaneously within a few days, and may be relieved by mild sedatives and morphine.

Koster (20) states "Headache is not only the most troublesome complication of spinal anesthesia but it is also the most frequent." He also finds that they disappear within twenty to seventy-two hours. The severe agonizing persistent type that resists the ordinary analgesics is rare.

Much theorizing has been done in an effort to explain the cause of this type of headache. (1) Loss of cerebrospinal fluid through the puncture wound in the dura by seepage into the extradural soft tissues. (2) An increase in the volume of cerebrospinal fluid contained within the subarachnoid space. The mechanism of the first type is ascribed to the lack of elastic and contractile tissue in the fibrous dural membrane. The puncture hole caused in the dura by the needle point does not close until a fibrin clot forms or normal healing takes
place. Laminectomies have been reported eight to fifteen days after a lumbar puncture with the tracts of the puncture found still gaping, closed only by non-adherent, epidural fat.

Upon withdrawal of the needle, the dura and the underlying pia-arachnoid are left in one of two possible relations. Either the openings in the two membranes are superimposed, if the pia is drawn back through the dural opening by the needle, allowing leakage to take place, or else the movement of the soft membranes upon each other causes the openings in the respective membranes to be situated at different levels. The force of the cerebrospinal fluid is then thought to compress the pia-arachnoid against the dura for an interval long enough to permit the pial opening to close by virtue of its inherent elasticity. If the latter mechanism takes place, very little cerebrospinal fluid will escape.

As a result of the considerable seepage of spinal fluid during the first few hours after operation, there is a disturbance of the intracranial portion of the cerebrospinal fluid. It has been claimed that the latter factor, by removing the watery cushion, allows the brain to sag against the bony framework of the skull. This in turn supposedly irritates the dural fibers of the trifacial and two occipital nerves. Pressure on the basilar venous plexus diminishes the outflow of venous blood from the cranial cavity and brings about an increase of venous tension. Lowering the patient's head is
thought to remove the brain from contact with the aforementioned nerves and venous plexus, thus tending to lessen the severity of the headache.

The second variety mentioned above is thought to be due to an increase in the quantity of cerebrospinal fluid. Usually, other symptoms and signs are associated as, for instance, stiffness of the neck, photophobia, and, more rarely, paralysis of the external rectus muscle of the eye with or without a concomitant diplopia. This syndrome is described as the postanesthetic meningitis or meningismus. Whereas in the former variety of headache, the spinal fluid pressure may be very low, there is usually found an increase in the pressure associated with an increase in the cells and globulin constituents of the cerebrospinal fluid in those patients with meningismus. Thus, either a state of meningeal irritation is present, or else, rather infrequently, a true infectious meningitis. Such headaches do not respond to lowering of the head.

Anal or vesical incontinence. Some authors refer to these as complications of spinal anesthesia. A feeling of fullness is experienced in the rectum as if there was need for evacuation. This persists even after the bowel has been emptied. In some reports, cases of fecal incontinence due to the fact that sensibility of the anus had been lost have been mentioned. Urinary incontinence has been reported, followed by fecal incontinence. Fully a year may elapse before complete restoration of function.
appears. Salleras operated upon a boy of seventeen for acute appendicitis and the patient shortly afterward developed a marked vesical retention. Fecal incontinence was also present, as were exaggerated knee jerks, hyperactive tendon Achilles reflexes, ankle-clonus, and a positive Babinski reaction. Salleras advanced the theory that the medullary centers of defecation and urination had suffered damage as a result of a local irritation of the meninges. The latter gave rise to a meningitis which caused a compression of the area either by the increased quantity of fluid formed in response to the irritation or by the presence of hemorrhage into the subarachnoid space brought about by the trauma of the needle or else damage to the centers resulted from the onset of a sclerosis. (43)

It has been demonstrated that there exists groups of fibers in the tuber cinereum, one regulating the metabolism of carbohydrates, the other the retention of water in the organism. The nucleus proprius of the tuber cinereum (situated superficially) would be the center of nervous polyuria. It is easy to conceive of the causation of the infundibulo-tuberien syndrome (nervous polyuria) resulting from a meningeal lesion limited to the base of the brain near the posterior aspect of the tuber-cinereum. The lumbar puncture may have reactivated the latent meningitis either through the direct action of the injected anesthetic or more likely by simply disturbing the equilibrium of the dynamics of the cerebrospinal fluid. It has been shown that the intraspinal
injection of sterile water or even of normal saline solution is followed by after disturbances. (44)

The necessity of catheterizing patients occurs in about ten per cent. of cases, and of this number ninety per cent. need only one or two catheterizations and the remainder void spontaneously after the third day. Retention seldom lasts longer than the stay in the hospital necessary for wound healing.

Koster and Weintrob (20) found that following anesthesia induction in a patient just catheterized, upon opening the abdomen the bladder might be found full. It was assumed that the catheterization had been incomplete, but more recent observations on kidney secretion following splanchnic section have presented a satisfactory explanation. It is found that splanchnic section or block results in the simultaneous activity of all the kidney glomeruli. Normally, part of the glomeruli rest while others function. With all of them active during any given time, urinary secretion is tremendously increased. Apparently, glomerular activity is continuously controlled by impulses coming through the splanchnics. It was thus concluded that spinal anesthesia which is high enough to block all the splanchnic influences, abolishes the control and increased secretion results.

The complications of spinal anesthesia need not precipitate too great a fear of this anesthesia, but merely bring to one's attention that severe complications can arise if we are lax in our technique or are not always on the look out for complications.
APPLICABILITY

During my review of the literature on spinal anesthesia, I found considerable controversy as to the applicability of this form of anesthesia. It is quite generally admitted by both those advocating and those less enthusiastic about spinal anesthesia, that it is the anesthetic of choice for all operations below the umbilicus. In these operations the dose is small and danger of vasomotor collapse and respiratory paralysis is small.

A few authors, including Koster of Brooklyn (10), endorse its use for operation high up. With high injection, the danger of collapse and respiratory failure is markedly increased. The duration of anesthesia must be lengthened since these operations require more time. Thus a larger dose of the drug must be given and its toxic effects become greater. Its effect on the bulb and vital centers have not been fully worked out and nothing definite can be said about its use in operations higher up.

There are certain contra-indications to spinal anesthesia which must not be overlooked even though it has numerous advantages over other types of anesthesia.

As there is an almost constant drop in blood pressure of varying degree, spinal anesthesia should not be used in cases in which there is a marked hypotension from shock, hemorrhage or any other cause. Moderate hypotension need not be considered definitely contra-indicated in operations low down, and requiring small doses. Such hypotension can be alleviated by the use of
adrenalin or intravenous saline solution during the operative procedure.

Cases in which there is a marked interference with free cardiac action should not be chosen; pericarditis, advanced myocarditis, mediastinal tumors, and large pleuritic effusions displacing the heart are examples of this. These conditions may also play an important part in the movement of the diaphragm. This contra-indicates spinal anesthesia due to the respiratory paralysis induced by the anesthetic.

Cases in which there is existing cerebrospinal disease should not be chosen unless there are other conditions present which render spinal anesthesia the anesthesia of choice. It is also dangerous to use this form of anesthesia when there is any likelihood of a convulsion occurring at the time of or shortly after injection, such as eclampsia, tetanus or hysteria.

If there is a marked bony deformity, making puncture impossible, or if there is an active disease of the bone or overlying soft parts, this type of anesthesia should not be used. In using it one would be exposing the patient to some form of meningitis without question.

In spinal anesthesia a very small dose of a toxic drug is used and confined to a small area in its action, making it definitely indicative for use in many conditions. The action is temporary and there is no deleterious effect on structures remote from the area of injection. These points, in addition
to its particular physiological action, peculiarly adapt it to use in certain conditions in which inhalation anesthesia is contra-indicated. The latter is dangerous in these conditions because it places the organism in a state of general toxicity, because of its irritative action on the lungs and other less important physiological actions peculiar to it. In a broad way, when speaking in favor of spinal anesthesia, we may consider all operations below the nipples can be done with a sufficient degree of success and safety under spinal anesthesia to warrant its use, if in the hands of one with reasonable skill in the method.

Patients who have a very high blood pressure, or in whom a slight rise in blood pressure would be dangerous, or in whom it would be advantageous to lower the blood pressure during operation, should be operated under spinal anesthesia. The majority of cases falling in this class would probably be those suffering from advanced arteriosclerosis or cardiorenal disease and aneurisms. There is less impairment of renal function following operation under spinal anesthesia than under inhalation anesthesia. This fact has been definitely determined by a comparative study with phenolphthalein functional renal tests and by careful examination of catheterized specimens of urine before and after operation.

This fact renders spinal anesthesia doubly indicated in the presence of nephritis. Yount (21) reports two cases of severe nephritis developing after a small operation under
spinal anesthesia. He states, however, "We feel that sudden renal impairment is due more to trauma and toxic absorption than to any effect of the anesthetic on the kidneys in the case of spinal anesthesia." The higher percentage of impairment of excretion as shown by the phthalein test gives reason to this assumption.

Stabins and Morton (22) report in their cases that spinal anesthesia does not seem to upset the normal kidneys in any way that they could demonstrate clinically. There are no abnormal constituents in the urine and tests for kidney function show that there is no impairment after this form of anesthesia.

A very concise and yet complete summary of the advantages and disadvantages of spinal anesthesia is given by McGehee of Memphis. (23)

The advantages:

Before operation:

"(1) Assurance and calmness on the part of patients, especially those fearing a temporary loss of consciousness.

(2) Fluids and foods may be given until the time of operation."

During operation:

"(1) Consciousness of the patient during the performance of the operation. This permits closer observation of his general condition."
"(2) The analgesia is more perfect and the relaxation more complete than with general anesthesia.

(3) Packs and pads will not be necessary because of the complete relaxation of the intestinal tract and the intestinal coils drop away from the site of operation. This permits the surgeon to operate more quickly, more easily, and with less trauma."

After operation:

"(1) Postoperative shock is minimized, since the afferent nerves carrying painful impulses to the brain are blocked off.

(2) Since the minimal protoplasmic and metabolic disturbances are produced, there is less danger of disturbing the equilibrium of the patient or precipitating severe general reactions, which are always feared after deep ether anesthesia.

(3) The violent nausea and vomiting, the gastric and intestinal distention, and the various forms of muscular restlessness which usually follow a general anesthetic are absent.

(4) Although the intestines are stimulated, the anal sphincter is relaxed. This allows the patient to expel material which would later fill
the colon and rectum when intestinal movements
are frequently delayed thirty-six to forty-
eight hours after major operations. Therefore,
we have a patient who is able from the time of
operation to take and hold soft foods and fluids.

The disadvantages:

(1) Spinal anesthesia is not an anesthesia of
universal application. It has its limitations
and contra-indications which must always be
carefully considered.

(2) Consciousness in certain patients, especially
those in which sedatives are contra-indicated,
may give rise to psychical impressions which are
undesirable.

(3) There is a definite limit to the duration of
spinal anesthesia and operations requiring time
greater than this limit must be finished under
general anesthesia.

(4) The severe, persistent headache which some-
times follows the use of spinal anesthesia, al-
though not dangerous is very annoying to both
the patient and the surgeon.

(5) The ocular palsies, though rare, are con-
sidered serious sequelae. They seldom occur
in well conducted cases, and in all cases clear
up spontaneously.
(6) The danger of meningeal infection or cord injury is omnipresent, but this is rare and unimportant when the pneumonias, emboli, pulmonary edema, acute gastric dilatation, and the many other untoward effects of inhalation anesthesia are considered."

The danger of pulmonary complications postoperative is considered by many to be as great in a local type of anesthesia as in the general anesthetic. Stabins and Morton (23) state "It is a matter of common knowledge to operators that postoperative pulmonary complications are noted as frequently after local anesthesia as after general." This is one of the main arguments for the embolic theory of pulmonary postoperative involvement. A great many investigators doubt the existence of true pathological processes in the lung due solely to irritation of inhalants. There is one possible exception, according to Morton (23), where inhalation anesthesia may be responsible for a spread of pre-existing lung pathology, that is, quiescent tuberculosis. Even here, there is no general agreement among authors. Pulmonary complications are due to pre-existing foci which have lodged in the lung fields, or to deficient ventilation and consequent congestion of patches of lung tissue. More and more it is being believed this last type of condition is most often responsible for acute postoperative pulmonary complications. Spinal anesthesia is less irritative to the lung tissue and may
prevent the flaring up of a pre-existing foci, but can hardly prevent the spread of small emboli.

No anesthetic is suitable in all cases requiring surgical therapy. The induction of anesthesia, or better analgesia, should be based upon a number of factors. The anesthetic should be made to conform to the patient's condition and the condition demanding surgery. As may be seen from the advantages and disadvantages just enumerated, spinal anesthesia is the only type to employ in some cases, while it might be most dangerous in other cases.
Spinal anesthesia has found a definite place in modern surgery. It is yet young and in its experimental stages, with possibilities of an even greater future. It, as other forms of anesthesia, had its accidental beginning. It progressed through all the experimental stages with much criticism. Many operators thinking spinal anesthesia a very simple procedure had many fatalities due to neglect in technique. Thus, spinal anesthesia received much undue criticism which has left its imprint throughout the entire development.

The fact has been stressed that success in spinal anesthesia depends upon the anesthetist rather than the drug or technique of injection alone. Danger is increased from practically nil to a very real quantity by neglect of the available safeguards and antidotes. Failures should be attributed to incorrect technique alone. Postoperative complications are dependent upon either the "sins of commission" or the "sins of omission".

Mastery of spinal anesthesia will place in the surgeon's hands the safest, the quickest and the most satisfactory anesthesia known today for use in a great number of operative procedures. On the other hand, one must know when other agents are best employed.
SELECTED BIBLIOGRAPHY