CONTINUOUS SPINAL ANESTHESIA *†

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In the opinion of many, continuous spinal anesthesia is the most significant advancement in anesthesia of the past decade. The name "continuous spinal anesthesia" has been subject to criticism, and substitutes for it have been suggested, among which are "fractional" (1), "serial" (2), "intermittent" (3), and "controllable" (3) spinal anesthesia. We should like to interpose here a word in defense of the original name, "continuous spinal anesthesia." All that is implicit in this expression is that the anesthesia is spinal and that it is continuous. It is true that the injection of the anesthetic drug is not continuous, but the needle remains continuously in place with its tip within the dural sac, and the anesthesia is continuous if the procedure is a success. Most anesthesiists would concede that drop ether provides continuous anesthesia, yet it is given not in a continuous stream, but drop by drop; even the gases are inhaled intermittently, and during one component of respiration, there is no movement of gas from the mixture in the lungs into the blood.

Spinal anesthesia, as we are familiar with it, is based on the work of the pioneers, Niemann, Von Anrep, Köller, Hall, Halsted, Corning, Einhorn (4), and Quincke (5).

Niemann, a pupil of Wöhler, isolated cocaine in 1860. Von Anrep, in 1879, reported that skin under which cocaine had been injected was insensitive to the prick of a pin. Köller (1884), to whom Sigmund Freud had spoken of the anesthetic properties of cocaine, performed conclusive animal experiments to demonstrate the effect of the drug in rendering the cornea insensitive to pain. Hall, in 1884, introduced the use of cocaine in dentistry. In 1885, Halsted showed that cocaine could block the transmission of impulses in nerve trunks. In the same year Corning gave the first spinal anesthesia, employing a dog as the subject. He attempted an extradural nerve block, but the needle penetrated the dura, and spinal anesthesia resulted. Einhorn synthesized procaine in 1905, and today it is still the most widely used drug for spinal anesthesia. In 1891, Heinrich Quincke demonstrated lumbar puncture (5). Spinal anesthesia was first used in man by Bier in 1899 (4).

* Read before the Staff Conference of the U. S. Naval Hospital, Philadelphia, on January 6, 1943. Since the reading of this paper, additional cases have been added.
† The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.
Ephedrine is the sympathomimetic drug that is most widely used to sustain blood pressure during spinal anesthesia. The active principle was isolated from the Chinese herb ma huang in 1885 by Yamanashi (4). Nagai (4) produced the pure alkaloid in 1887 and gave it its name.

The first continuous spinal anesthesia was given by Lemmon (6) on April 10, 1939. He developed the method in order to overcome two of the most obvious disadvantages of the single injection procedure, namely, the occasional failure of the anesthesia to take, and the frequent waning or disappearance of anesthesia before the operation has been completed. The first of these objections is overcome by permitting the giving of repeated injections until anesthesia is established in patients requiring larger than average doses of procaine. The second is corrected by allowing supplemental injections of the drug to maintain a well-established anesthesia for as long a time as necessary. Furthermore, in those cases in which an untoward effect results from the spinal injection, the continuous apparatus permits removal of the drug from the spinal canal by aspiration. The allegedly toxic effects of spinal anesthesia are said to be greater after the initial injection than after subsequent injections (6), and the first thirty minutes of subarachnoid block is generally accepted as being the most dangerous period, according to Sise (quoted by Lemmon and Paschal, 7). Obviously, then, if this first half hour occurs after the injection of a small dose of anesthetic drug to be followed later by additional small doses, the safety of the procedure is enhanced.

One who uses continuous spinal anesthesia cannot escape the fact that a small initial dose occasionally proves adequate for an operation for which a much larger dose would have been necessary if given as a single injection. An initial injection of 50 mg. of procaine may afford adequate anesthesia in one patient for exploration of the stomach, whereas in another, four times this quantity may be required to give sufficient anesthesia to make the skin incision, and the latter patient may exhibit no more of the side effects, such as fall in blood pressure, than does the former. It is of interest and of considerable importance that, if a given dose of procaine fails to give anesthesia, it fails likewise to give signs of the toxic effects of the drug, and additional quantities may be administered safely. In this respect there is a similarity to morphine, which, if a routine dose fails to relieve pain, can be given again without danger. In the opinion of Lemmon (quoted by Ansbro and Pico, 8), only a small amount of procaine in the spinal fluid is used at a time, the rest remaining idle and available for causing "shock." The conclusion to be drawn from this is that the single injection dose for a given operation, and for a patient of given age, weight, blood pressure and so forth, is adequate for the majority of such patients, is inadequate for a few, and, in all probability, is larger than necessary for many. In other words, there is a marked variation in the effect of the drug on different individuals. This is a well-known phenomenon among drugs, and in the field of anesthesia anesthetists are perhaps most familiar with it in the use of ether, for a quarter pound may suffice for one case while several times this amount may be needed for another.
The apparatus necessary for continuous spinal anesthesia consists of a special mattress, a Sise introducer, special needles, a Luer-lok syringe, and a 3-foot length of rubber tubing. The mattress measures 5 inches by 18 inches by 6 feet, and contains a 7 inch gap on one side beneath the lumbar spine. The mattress is made in sections so that the lower portion may be removed to allow operations requiring the lithotomy position, and also to break at the knees for the use of the Trendelenburg position. The Sise introducer is a short, large needle of sufficient diameter to admit a spinal needle. The spinal needles are 17, 18 or 19 gage, and 2½, 3 and 3½ inches in length. They are made of German silver and are quite malleable. The Luer-lok syringe generally employed is of 10 cc. capacity. The rubber tubing is thick-walled, noncompressible, and of a caliber such that its 3 feet contain 2 cc. of fluid. The tubing is fitted with Luer-lok connections, one to attach to the hub of the spinal needle, the other (which is provided with a stopcock) to the syringe. The procedure consists essentially of connecting the syringe, by means of the tubing, to the spinal needle which is allowed to remain in position between the vertebral spines with its tip inside the dural sac. The details of the technic, as given here, are those used in the U. S. Naval Hospital, Philadelphia, and are subject to considerable variation among different anesthetists.

The patient, before being turned on his side, is placed flat on his back so that the site of the proposed tap rests directly over the gap in the spinal mattress. This permits resumption of the proper supine position with a minimum of shifting. He is then carefully rolled onto his side, care being taken to anticipate and thwart a universal urge on the part of the patient to shift the hips toward the opposite side of the table. The hips and knees are flexed and the latter are approximated to the chin. The use of a stretcher beside the table to support the lower extremities helps to stabilize the patient.

After painting the skin with an appropriate antiseptic and placing a sterile drape, a wheal is raised over the spinous interspace selected. The second lumbar interspace is used for upper abdominal procedures and the third for operations on the lower abdomen. We do not use an interspace higher than the second because of the danger of injury to the cord, which, although it is drawn away from the needle point in flexion of the spine, is brought closer to the posterior border of the canal in extension, and is there liable to puncture or laceration by the indwelling needle.

A quantity of ephedrine is mixed with the 1.5 cc. of 0.5 per cent procaine which is used to infiltrate the skin and interspinous ligament. The amount is usually either 25 or 50 mg., the smaller amount being used in younger, more robust individuals. If the systolic blood pressure of the individual is less than 150 mm. of mercury, the ephedrine is given as suggested. If the pressure is higher than 150 mm., the drug is injected after the spinal anesthetic has been given, to avoid raising an already elevated tension in the event that the pressure-lowering effect of the intrathecal procaine does not follow, owing to some unforeseen technical difficulty.
The Sise introducer (an ordinary spinal needle of the same caliber may be substituted) is used to penetrate the skin and interspinous ligament, and is then removed. This provides a perforation through skin and interspinous ligament for the introduction of the spinal needle. It is important that this perforation be made accurately, for its path largely determines the direction taken by the spinal needle. The spinal needle is next introduced until its point enters the dura. In the event that calcification of the interspinous ligament renders a midline tap impossible, an adjacent interspace may be tried or the paramedian tap may be employed. For this tap the wheal is raised 1 to 2 cm. to one side of the midline, and the needle is inserted at an angle of about 10 to 15 degrees from the sagittal plane so that its point penetrates the dura at approximately the point where it would in the midline tap. It has been found expedient to employ a paramedian tap with a continuous spinal needle three times in our series. In four other cases, in which a satisfactory tap could not be made with the malleable needle, we have used the usual steel spinal needle. A paramedian tap with the spine in normal extension was done and the patient could then be placed on his back without any change in the relationships of the vertebrae and adjacent structures, thus obviating strains which might break the needle.

At times the anesthetist may feel that the needle has penetrated the dura, but no fluid flows from the needle. If the pressure of the spinal fluid is low (it may even have a negative value), it may be raised by moderate pressure over the internal jugular vein on either side. Occasionally the tip of the needle may be plugged with a fragment of fibrocartilage; aspiration with a syringe will remove it. Again, the needle may fail to perforate the dura owing to dullness of the former, or unusual toughness or laxness of the latter.

The anesthetic solution is made by mixing a 10 per cent solution of procaine with a quantity of spinal fluid. Three cubic centimeters of 10 per cent procaine and 9 cc. of spinal fluid are mixed to make 12 cc. of a 2.5 per cent solution, each cubic centimeter of which contains 25 mg. of anesthetic drug. This solution is used for extraperitoneal operations, such as repair of inguinal hernia, and for operations upon the inferior extremity. A 5 per cent solution is made by mixing 6 cc. each of 10 per cent procaine and spinal fluid. This preparation contains 50 mg. per cubic centimeter, and is used for intra-abdominal operations, such as those on the biliary tract, the stomach, the colon, and so forth. In certain patients having a low systolic blood pressure and therefore a low spinal fluid pressure, it may be difficult to withdraw 6 or 9 cc. of spinal fluid. Furthermore, it may be impossible to aspirate small amounts during the operation to make certain that the needle point is still within the dural sac before making supplemental injections of the anesthetic solution. The reason for this is not clear, but it may be that the undistended, or at least poorly filled, dura or the arachnoid collapses about the needle, obstructing its opening. In these cases we have substituted physiologic saline solution for spinal fluid as a diluent for the procaine. Thus we do not further reduce an
already low pressure, the dural sac remains filled, and free aspiration persists.

The syringe containing 12 cc. of well-mixed anesthetic solution is attached to the rubber tubing, which in turn is filled by injecting 2 cc. from the syringe (the 10 cc. syringe readily accommodates 12 cc.). The stopcock is then turned off and the other end of the tubing is fixed securely to the hub of the spinal needle. The term “fixed securely” is used advisedly, for we have had the mortifying experience of having the tubing and needle part company, and as a result we were injecting carefully measured amounts of procaine which collected in a puddle on the operating table beneath the subject's back, while no amount of assurance could persuade the patient and surgeon that the anesthesia was satisfactory. The error is not readily detected by the unalert, for, unless more than 2 cc. is aspirated into the syringe, no air appears to indicate what has occurred.

The next step is to roll the patient onto his back so that the spinal needle and attached tubing find protection in the gap in the mattress. This is accomplished by first extending the hips and knees, so that the feet may be placed at the foot of the table, and then turning the patient, hips and shoulders together to avoid twisting of the spine, until he is once more flat on his back. Care is then taken to place him in the center of the table.

At this point it is essential to test the apparatus in order to make certain that spinal fluid can readily be aspirated. This is the only means of knowing that the needle communicates with the intradural space and that therefore the anesthetic solution can be brought into contact with the spinal nerve roots. If free aspiration is not present, certain maneuvers may succeed in restoring it. The needle should be rotated slowly on its long axis, constant but gentle traction being made meanwhile on the plunger of the syringe. If this fails, the needle may be slightly advanced or retracted, with rotation again as before. Pressure on the jugular veins, by distending the dural sac and perhaps lifting the dura, arachnoid or other membrane, may restore the desired continuity. It may be useful to disconnect the tubing from the needle and then to perform these manipulations, as the dripping of fluid from the needle at once indicates that it is again in a satisfactory position. If these devices fail, the needle should be withdrawn, the patient turned again on his side, and a fresh start made. It is unwise to make an injection in the absence of free aspiration, for successful anesthesia under these circumstances is exceptional. It is not recommended that the initial injection be made while the patient is still on his side. If the needle is displaced while turning him onto his back, he must be turned again, with danger of disseminating farther cephalad the drug already injected and with the further danger of shock from change of position while under spinal anesthesia.

When aspiration is found to be free, the initial injection may be made. For the average upper abdominal operation, the amount is usually 100 mg. of procaine or 2 cc. of the solution. This serves to establish a satisfactory and safe anesthesia in about ten minutes in most cases. If by
This time the anesthesia has not risen to a sufficiently high level, another
25 or 50 mg. is injected. It may be necessary to tilt the head of the table
5 or 10 degrees below the horizontal in order to allow the mildly hyperbaric
anesthetic fluid to migrate slightly cephalad. Once the anesthesia has
been established, it can be maintained by the injection of 25 mg. at in-
tervals varying from 15 to 30 minutes. If the supplemental injections
can be made just as the anesthesia begins to lessen, overdosage can be
avoided, and an anesthetic level more satisfactory to both patient and
surgeon can be maintained. The signs of waning anesthesia include rest-
lessness, flushing of the face, warm perspiration, rise in blood pressure,
quickening of the pulse, increase in the tone of the abdominal muscles,
and relaxation of the intestines. If the 2.5 per cent solution is being used,
as in operations for inguinal hernia, an initial injection of 50 to 75 mg.
may suffice, and supplemental injections of 12.5 mg. may be given every
fifteen to thirty minutes.

It should be understood that these standard doses must be varied con-
siderably to meet the needs of different patients. Much larger doses may
be required. On the other hand, in debilitated or aged individuals,
smaller doses may be used. Rhoads (9, quoted by Lee et al.) has sug-
gested the use of as little as 5.0 mg. as a supplement to local anesthesia
in poor risk subjects. It is in just such patients that continuous spinal
anesthesia is especially valuable, for its benefits may be obtained without
the danger of a large dose of anesthetic drug. Small injections establish
the threshold, indicating the quantities which are safe and yet effective.

An intravenous infusion of glucose solution is a valuable adjunct to
continuous spinal anesthesia. It compensates for fluid loss during a pro-
longed operation, can be run rapidly to stay temporarily a fall in blood
pressure, and maintains ready access to a vein in the event that prompt-
acting medication is needed. Morphine sulfate, in ½ grain doses, may be
given intravenously (slowly, over a period of 5 minutes) if needed to allay
apprehension and restlessness in the absence of pain. Pentothal sodium
in minimal doses, given intravenously, may be combined advantageously
with continuous spinal anesthesia.

If the systolic blood pressure falls below 80 mm. it is of some concern
to the anesthetist. If this occurs at an interval of fifteen to twenty-five
minutes after the first injection, lowering the head of the table a few de-
grees, the administration of an oxygen-carbon dioxide mixture, and the
speeding up of the infusion may suffice to tide the patient over. This is
the time when maximum fall in blood pressure is to be expected, and a
spontaneous return to a safe level can be expected within a period of five
to fifteen minutes. If these measures fail, 2 or 3 minims (6 to 9 mg.) of
ephedrine may be given intravenously and repeated as needed, or pitresin,
5 units, may be combined with ephedrine, 25 mg., and given subcutane-
ously (5).

Blood plasma or citrated whole blood are indicated by refractory hy-
potension or in long or shock-producing operations, or in those accom-
panied by considerable blood loss.
When the special mattress is not available, folded sheets may be laid under the patient's back to afford a 1½ inch clearance of the spinal needle, in accordance with the suggestion of Leigh and Burford (2).

The first continuous spinal anesthetic to be given in this hospital was administered on July 30, 1940. From that date until September 1, 1943, it has been employed 703 times. The average duration of the anesthesia was one hour and fifty-two minutes, and the average dose of procaine per anesthesia was 230.18 mg.; thus the average dose per hour of anesthesia was 122.46 mg. The smallest dose was 50 mg. (inguinal hernia) and the largest 625 mg. (abdominoperineal resection of the colon). The average fall in systolic blood pressure was 22.72 mm. of mercury, and this included many individuals with hypertensive heart disease in whom a fall of 50 to 70 mm. is not uncommon. The complications were as follows:

<table>
<thead>
<tr>
<th>Per cent</th>
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<tbody>
<tr>
<td>Headache .................................. 11.0</td>
</tr>
<tr>
<td>Urinary difficulty .................. 10.3</td>
</tr>
<tr>
<td>Bronchopneumonia ..................... 4</td>
</tr>
<tr>
<td>Mild cough ................................ 4</td>
</tr>
<tr>
<td>Catarrhal fever ....................... 1</td>
</tr>
<tr>
<td>Paresthesia of lower extremity ...... 1</td>
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These figures compare favorably with those to be found in a series of single injection spinal anesthetics. The incidence of headache seems high, but this figure includes mild headaches of short duration.

That the cooperation of the patient is of considerable importance to the success of the procedure may be taken for granted. The surgeon must more than cooperate; he must participate in the administration of the anesthetic. He must not be impatient and make the incision before the skin has become insensitive, as this may cause the patient to lose his morale. If the surgeon is restless and turbulent, the anesthetist must abandon this advanced form of anesthesia and revert to ether and the gases.

**Summary and Conclusions**

1. A brief history of the events leading up to the first use of continuous spinal anesthesia is given.
2. The technic as used at the U. S. Naval Hospital, Philadelphia, is given in detail.
3. The paramedian tap, the use of the steel needle without flexion of the spine, and the substitution of folded sheets for the special mattress (2) are mentioned as adjuncts which occasionally serve to extend the usefulness of the method.
4. The results of the use of the procedure on 703 patients at the U. S. Naval Hospital, Philadelphia, are reported.
5. Continuous spinal anesthesia has proved, in our hands to be a most valuable addition to the anesthetist's armamentarium.
REFERENCES


Announcement is made that the Directory of Medical Specialists is now to be published by the A. N. Marquis Company of Chicago, publishers of "Who's Who in America." Previous editions have been published for the Advisory Board for Medical Specialties by the Columbia University Press of New York City.

It is planned not to issue the next edition before 1945, on account of the war, but the A. N. Marquis Company will publish a supplemental list of all those who have been certified by the American Boards since the last (1942) edition of the Directory, totaling about 3600. This is to be distributed at cost, and monthly or bi-monthly bulletins listing successful candidates for certification at examinations during the additional interim before the next edition, are to be issued as a subscribers' service.

Dr. Paul Titus (Pittsburgh) of the American Board of Obstetrics and Gynecology will continue as the Directing Editor, and Dr. J. Stewart Rodman (Philadelphia) of the American Board of Surgery continues as Associate Editor. The Editorial Board will be composed, as before, of the Secretaries of the fifteen American Boards.

Communications should be addressed to the Directing Editor, Directory of Medical Specialists, 919 No. Michigan Avenue, Chicago (11), Illinois.