A Report

ON

CLINICAL EXPERIENCES WITH SPINAL ANALGESIA IN 100 CASES,

AND SOME REFLECTIONS ON THE PROCEDURE.

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I. CLINICAL.

At the outset of this communication I wish to disclaim all intention of advocating the immediate or general introduction of spinal analgesia. This essay is only intended to be a report on a series of 100 cases in which the procedure was employed tentatively during the last year in the ordinary course of hospital study, with some reflections on its many aspects. I have approached the subject without any prepossessions and with a due sense of its seriousness, not feeling justified, with the abundant evidence before us as to its *possibilities*, in putting it aside as either necessarily dangerous or unpractical. For it must not be forgotten that more than eight years have elapsed since August 16th, 1898, when spinal analgesia was first produced by Bier with *cocaine*, and that a week later he requested his assistant to inject his own lumbar sac to observe its effects. On the same day he injected his assistant, and their careful observations¹ on themselves did much to put the use of cocaine in this way in its true position. But only during the last three years, since the discovery of *stovaine* by Fournneau, has the procedure come into anything like general use. This was due to the frank avowal by Bier, after a most cautious trial of the method, that so long as *cocaine* was the only drug available the disagreeable sequelae seen in some cases, notably his own, would prevent the general adoption of spinal analgesia. But with *stovaine* a new point was reached, and the results since obtained in thousands of cases in France and Germany, including 2,000 by Tuffier and 1,000 in Bier's clinic, alone suggest that an addition to our surgical resources of considerable value, *if properly employed*, may have been made.

In the history of the procedure we note the same slow painful evolution which is seen in all important surgical procedures. Antiseptics, asepsis, renal, brain, spinal and stomach surgery, all had vigorous opponents at the outset. And v. Esmarch² has left on record an account of the enthusiastic reception of ether and chloroform (1846-7), and the change of feeling towards them as their drawbacks and dangers were demonstrated. This may or may not be the history, too, of spinal analgesia, but to me it seems well to subject it to a cautious theoretical and practical study, and so help either to its rejection or perhaps limited acceptance. In its present stage of development it cannot simply be ignored. There seems but little doubt that it has rendered possible life-saving operations which would have been almost certainly fatal under general anaesthesia, and one of our cases seems to prove this. To inject a small quantity of a toxic agent into the lumbar sac is not necessarily more dangerous than to charge the whole circulation with a poison such as chloroform. There are, of course, the dangers of sepsis. But here, perhaps, more than in many now well-recognized procedures on the brain and spine, these can be controlled. The few drops of solution required as well as the simple needle and syringe can be easily sterilized by boiling. Some very few cases have, perhaps, been lost from an overdose of the drug, but the same may be said of morphine and other poisons in daily use now, which we do not hesitate to employ. The question for the future to decide will be whether these risks are not outweighed by certain advantages in the procedure.

That there are a large number of conscientious workers in this field no one keeping an eye on the current literature of Europe can fail to see, and references to a few of the most important papers on the subject out of a very large number which have appeared are given below. Bier and his pupils have led the way in a spirit of conscientious

inquiry embracing the anatomical, physiological and clinical aspects of spinal analgesia, and to him belongs the idea of producing analgesia by injection into the lumbar sac. Corning's discovery of the effects of cocaine on the peripheral nerves, since utilized in *regional analgesia*, of which this is only an extension, and the experiences in tapping the spinal dura in meningitis, doubtless prepared the way, but the idea of applying an analgesic compound to the spinal nerve roots and cord is due to Bier and to him alone whatever view may be held as to its merits.

The 100 cases in the following analysis have been chosen partly for their variety and partly because of some condition present which would have admittedly made a general anaesthetic particularly undesirable. In some, chloroform or ether, in the opinion of those who saw them, would have been perilous in view of heart or lung troubles. Others expressed a great dread of chloroform, and, on the suggestion of an alternative, eagerly grasped at it. So far spinal analgesia has been shown to be only generally applicable to the lower half of the body, although some have used it as an exception for the thorax or even higher. Nevertheless, if it only be found safe and of value below the episternal notch and *local* or *regional analgesia* be employed for the upper part of the body, a good deal will be gained. In all cases where the patients have expressed a wish not to know anything about the operation and to go to sleep, a general anaesthetic has been had recourse to, as also in the case of obviously nervous and excitable people and children. The youngest person in the following list was aged 15, the oldest 71. In both the procedure was eminently successful, and followed by no particular trouble except pain at the seat of puncture, which in the old man lasted until the next day. The method has, however, been used on children by Deetz,³ and with success. As to the limits in the other direction, it is hard to speak positively. In old people, with damaged lungs, liver, kidneys, or heart, all operations with any anaesthetic are, I believe, more or less dangerous. And in such cases it is difficult to apportion the risk between the anaesthetic and the shock of apprehension or of the operation itself, even though the last be slight. Syncope is very likely to follow even slight violence without operation in old, decrepit people. Perhaps it is well, at all events for the present, to avoid spinal analgesia in *very* old individuals; at least, this appears to be the opinion of many of those who have had the largest experience of the method, although some operations have been done with it on patients over 80. But it is just in such cases that *local* or *regional analgesia* has great advantages, and can be employed much more often than is generally supposed, and without risk in the writer's experience, which is now large.

In all our 100 cases, *stovaine* only has been employed in order to gain some adequate idea of its behaviour from a fair number of observations. But a hundred or even a thousand cases will not settle our convictions *finally*. They serve, however, at least as material for the preliminary study of the technique of the procedure, and enable us to estimate the percentage of difficulties and failures in the hands of a beginner. For there can hardly be any doubt that at the outset most surgeons will have less perfect success than when they have had a larger experience. The reason for this will appear in the contrast of the first 50 cases in our list with the second. In the first I failed to produce adequate analgesia in 11 cases, in the second group in *none*.

The *stovaine* employed came direct from the laboratory of M. Billon in Paris, whose courtesy to the writer in many ways, and especially in compounding the drug in different ways to suit some particular objects which I had in view, is cordially appreciated. A beginning was made with Chaput's solution (*vide infra*), which was used in 38 cases of the first 50. The remainder of this first group is made up of 2 cases in which the canal could not be reached, 1 in which Bier's solution was used, and 9 in which a glucose-*stovaine* solution made for me (*vide infra*) took the place of Chaput's, the supply of which had failed for the moment. All the second 50 were treated with my own glucose-*stovaine* solution, except one in which the canal could not be reached. It would be hardly safe to base any conclusions as to the value of the two solutions from the results in the two series just given, inasmuch as the first series was done without the same experience as the latter. It was hoped that some accurate deductions might be

possible from a comparison of the two series in regard to the frequency of "by-effects" in each. But, as the notes of the first series were not as fully kept on this point as in the second by one observer, such a comparison in figures would be misleading. The impression left, however, is that on the whole the "by-effects" were less marked and less frequent in the last 50 cases with the glucose-stovaine than in the first with the sodium chloride-stovaine (Chaput) solution. If this is correct, experience may have played a part again to some extent. These sequelae consisted in occasional headache and nausea or actual vomiting, usually slight, but in 2 cases in the first series and in 1 in the second sharp for a day or two. It seems clear that these sequelae are more common among highly-strung, sensitive people, and in a good many are independent of the drug. They usually yielded at once to a dose of phenacetin and caffeine or to a dose of castor oil, as recommended by our French colleagues. In one way or other they were present in 20 cases in our second series, but mostly very slight.

The amount of stovaine first injected in either of the solutions was from 3 to 6 cg. (= centigrams), and was in most cases about 5 cg. In only 3 cases in the 100 was a supplementary injection to procure more adequate analgesia required, and in each an extra 2 cg. was injected about fifteen minutes after the first, with the desired effect (vide Mr. Morriston Davies's notes). It will be seen that they all belonged to the second 50 cases. Of the 11 cases in the first 50 in which analgesia was imperfect, 9 were abdominal operations out of 25 such, 1 was a fissure in ano, and 1 a knee case. None of the 20 abdominal in the second series failed.

The time elapsing from the moment of injection to analgesia varied from five to fifteen minutes, and was usually about eight minutes. The course of events was that recorded by other observers—first, formication in the feet; then abolition of the cremasteric and knee reflexes, followed by loss of sensation, usually first in the perineum, then in the legs, groins, and abdomen. Motion remained in a few cases throughout. The height on the abdomen to which the loss of sensation rose varied according to the measures adopted, and to some extent to the amount of drug injected. As a rule, with a full 5 cg. and a moderate elevation of the pelvis, the analgesia rose to the episternal notch before the end of the operation. In a very few cases it reached the transverse mammary line (for reasons vide Part II).

The duration of the analgesia has varied between twenty-three minutes and a couple of hours. The average appeared to be about fifty to seventy minutes; but the testing of a number of cases demanded much time which I could not give while operating on other cases, and was sometimes only noted on the patient's statement. The addition of adrenal derivatives in the form of adrenal chloride (1) or epiprenin borate (2) was only made in 3 cases. Of these the first was a complete success, the analgesia lasting a full two hours; the two last were inadequate. But there appears to be little doubt that these additions do prolong the analgesia. So far I have not found them necessary, although they are employed almost as a routine by others. Having used adrenalin largely myself in local analgesia and with the greatest advantage, its effects on the skin and subcutaneous tissues are well known to me, and I have often been struck with the fact that some hours after injection these tissues look ecchymosed or coloured with blood pigments as though the effects of the adrenalin on the vessels had caused small haemorrhages, and there has been a sense of dull ache and fullness all over the area injected (for example, my own arm). Such punctiform haemorrhages have never to my knowledge led to any trouble in the skin, but one can imagine their giving trouble in the nerve roots or cord. And one cannot help speculating whether some of the undesirable sequelae recorded in a few cases of spinal analgesia may not have been due to the adrenal compounds. Even the suspension of the functions of the nerves for five hours, as in Goldmann's case,⁴ seems of doubtful expediency, and may be the explanation of what he records of this case. For these reasons no adrenal principles have been used in this series except in the 3 cases mentioned. And the duration of the analgesia has been ample in all cases but one, which was a very long and complicated operation in which a little general anaesthesia had to be superadded at the end. In the case of vari-

cose veins in which the sensation was abolished only for twenty-three minutes, less than 4 cg. had been injected, and the time was ample for the operation. In another case of arthrectomy of the knee, perfect analgesia lasted all through the extensive operation, but began to return after it was over in fifty minutes. The object has been steadily kept in view of always employing as little of the drug as possible to produce the effect desired, and here we learn from experience. But neither the height nor the duration of the analgesia has in all cases appeared to depend on the amount of the injection apparently reaching the dural sac, though as a general rule it seems to do so. This is in accord with the experience of others in longer series of cases. As a rule, with the patient lying on his right or left side, the analgesia rose higher and lasted longer on that side which was lowest in this series (for reason vide infra). All have been eventually turned on the back for operation. Several other points of interest are given in Mr. Morriston Davies's notes appended.

LIST OF CASES.

	First Fifty.	Second Fifty.
Strangulated hernia, inguinal and femoral	4	0
Radical cure of hernia, inguinal, femoral, and ventral	10	7
Resection of gut for faecal fistula	1	0
Epiploxy for cirrhosis of liver	0	1
General peritonitis (uraemia 1, perforation 1)	1	1
Acute appendicitis	2	5
Appendectomy <i>à froid</i>	5	3
Colotomy	2	2
Exploration of abdomen for cancer	0	1
Fistula and fissure in ano	6	3
Piles (Whitehead's operation)	1	7
Varicose veins of legs	2	6
Varicocele, hydrocele, elephantiasis scroti, ruptured perineum	4	6
Caries of pubis (1), of hip (1), knee (1)	3	0
Suppuration in knee (Flushing)	0	1
Breaking down adhesions in knee	0	1
Internal derangement of knee	2	0
Fracture of patella (wiring)	0	3
Necrosis of femur (1), sup. bursa patellae (2)	1	2
Amputation of thigh for gangrene; heart disease	1	0
Sarcoma of thigh (1), tuber ischii (1)	2	0
Resection of tarsus	1	0
Failed to reach dural sac with needle	2	1
	50	50

It will be seen from this list that the variety of cases has been considerable. In abdominal surgery, of which there were 45 cases out of 100, and about which there was at first some doubt as to the suitability of spinal analgesia, it has in the 20 falling to the last 50 cases proved most satisfactory as far as the lower half of the abdomen is concerned. Operations above the umbilicus I have not done as yet, and still feel some doubts as to the expediency of doing so, though abroad this is not an absolute rule. But as all this was the work of a comparative beginner I thought it better to advance slowly from step to step, noting everything that might help to a sound appreciation of the value or the reverse of the procedure. So far I have the impression that it will prove of value in proper cases and if carried out with every care.

Among the 100 cases there were 3 deaths, wholly unconnected with the method of anaesthesia employed.

The first, a man, aged 49, entered hospital in a desperate condition with suppression of urine and intense bronchitis. Respirations 40, pulse 132, temperature 104.6° F., and general peritonitis supposed to be from appendicitis. An incision was made over the appendix, which was healthy; but the abdomen was full from end to end with inflammatory fluid. No cause was found, and a gauze drain was inserted. The analgesia was good, with 4 cg., and passed off rapidly, but the peritonitis ran its course to death next day.

The second, a hugely obese patient, seen with Dr. Barnett of Hampstead, was also a case of general peritonitis from carcinoma of the sigmoid flexure of colon. The lady, aged 61, was very feeble. She had put off any operation for some weeks after the tumour was found. High fever then set in, with increased distension. Colotomy was done, and on opening the abdomen the usual turbid fluid of peritonitis escaped in large quantities. The analgesia was most satisfactory, and she was much relieved by the operation; but the peritonitis ran its course to death.

The third was a case of very advanced cirrhosis of the liver and ascites in a man aged 50. Epiploxy was done with 5 cg. The analgesia passed off quickly, and he was well in the evening and passed 3 vj of urine. He then began to have much pain in the wound, and was given by the house-surgeon, at 9 p.m., ½ gr. of morphine per rectum. He at once became profoundly sleepy, with contracted pupils and snoring.

When I arrived at the hospital next morning I was told this, and found the man snoring, with pin-point pupils and suppression of urine. When roused he smiled and said he was very comfortable, but immediately began to snore again. This condition lasted to the morning of the fourth day, when he had some uraemic twitching and died comatose, not having passed any urine since the evening of operation day. The necropsy (Dr. Thiele) showed *extreme* cirrhosis of the liver and engorged lungs; bladder empty.

All these operations, with the exception of seven or eight in private, were done at University College Hospital, and the procedure was studied by many strangers as well as our own class, and usually followed up by them in the wards later. I think these gentlemen realized how desirable it is to see the thing done before undertaking it themselves. There are many details as well as essentials to be attended to and errors to be corrected from time to time.

The private cases included 3 colotomies, 2 removals of varicose veins, 1 radical cure of inguinal hernia, and 1 an excision of a large prolapse of the rectum. All were more than pleased with the mode of analgesia employed.

From the patient's point of view this procedure has been quite satisfactory as far as they have expressed themselves. They have been prevented from seeing the operators or operation by a special sloping screen made for me for the purpose which fits on the operating table. It does not prevent those present from observing their expression, which is usually perfectly tranquil. The puncture of the back has not appeared to cause much distress, except in two or three cases, and in these they have made light of it later. But the best evidence on this point exists in the fact that where it has been necessary to operate twice on the same patient, as was the case in several instances, they have been given the choice of the same spinal analgesia or general anaesthesia, and all have unhesitatingly chosen the first, except one nervous woman, who preferred this second time to know nothing about the operation at all. On this question I confess my mind has been much relieved, as I had at first some misgivings as to how the patients would regard the procedure. When they have had the opportunity of contrasting their condition under chloroform anaesthesia in one operation with their experiences under spinal analgesia in another soon after, they have unhesitatingly said they preferred the latter.

The conditions produced by spinal analgesia from the operator's point of view were, as far as this series shows, remarkably good. In from five to ten minutes, during which the final preparation of the field of operation, of the hands, etc., were made; the patient, without any struggling, excitement, or coughing, was not only absolutely anaesthetized but also relaxed in all the parts supplied from below the segment reached to. In rectal operations—piles, for instance—the sphincter relaxes completely, and the piles present themselves without any dilatation with the fingers and without that straining and movement which is sometimes seen under general anaesthesia. The same was the case with abdominal operations.

The impression left upon my mind by the experience of this series is that there is undoubtedly a place for spinal analgesia in surgery, but only when those who would employ it have studied its theory and practice fully as far as they are known. It is not for casual use by the inexperienced.

NOTES BY MR. MORRISTON DAVIES.

[In these notes Mr. Davies refers to my own stovaine-glucose compound when he writes "Glucose A.E.B. (No. 1)" for shortness. The amount in centigrams refers to the stovaine alone.]

Cases in which a Second Injection was Necessary.

LVII (Ruptured Perineum).

1st Injection, 2nd Space.—Flow of cerebro-spinal fluid slow; 9 c.cm. withdrawn. Glucose A.E.B. (No. 1), 5 cg. injected. No result in 12 minutes.

2nd Injection, 2nd Space.—Flow of cerebro-spinal fluid faster; 2 c.cm. withdrawn. Glucose A.E.B. (No. 1), 2 cg. injected. Analgesia present in 5 minutes and extended up to iliac crests.

LXXV (Appendectomy à froid).

1st Injection.—1st puncture, 2nd space: Easy. Some cerebro-spinal fluid withdrawn but needle blocked. 2nd puncture, 2nd space: Failed to enter canal. 3rd puncture, 2nd space: Cerebro-spinal fluid escaped very slowly; 8 c.cm. withdrawn. Glucose A.E.B. (No. 1), 5 cg. injected. Loss of

knee-jerks and motor power in legs. Analgesia up to 1 in. below anterior superior spines, after 11 minutes. No extension 7 minutes later.

2nd Injection, 3rd Space.—Cerebro-spinal fluid escaped rapidly; 4 c.cm. withdrawn. Glucose A.E.B. (No. 1), 2 cg. injected. Analgesia to within $\frac{1}{2}$ in. of iliac crests.

CXVI (Subcutaneous Wiring of Patella).

1st Injection, 2nd Space.—Flow of cerebro-spinal fluid rapid; 10 c.cm. withdrawn. Glucose A.E.B. (No. 1), 5 cg. injected. No result in 12 minutes.

2nd Injection, 2nd Space.—1 c.cm. cerebro-spinal fluid withdrawn; 2 cg. glucose A.E.B. (No. 1) injected. Sense to pain markedly blunted; felt some pain all through operation but could stand it easily. 15 minutes: Apparent analgesia to iliac crests and anaesthesia to crutch. No paresis.

Cases in which Analgesia was Uniform, but of Unequal Heights on the Two Sides.

LXXIX.—Patient lying right side. 37 minutes after injection: Analgesia extending to umbilicus on right side, and iliac crest on left.

LXXXI.—Patient lying right side. 40 minutes after injection: Analgesia extending to tip of tenth rib on right side, and umbilicus on left. Anaesthesia to iliac crests on both sides.

Cases in which Analgesia was not Uniform.

LXXXIV.—Patient lying right side. 5 minutes after injection: Analgesia to anterior superior spines on both sides, but on the right side the margin of iliac bone, external to it, and for 2 in. on the abdomen internal to it, sensation was unaffected. 50 minutes: Analgesia to umbilicus both sides, except for area along inner side of right iliac crest, over crest itself, and on adjacent part of buttock.

XC.—Patient lying left. 6 minutes: Analgesia 1 in. above umbilicus on left side, and as high as anterior superior spine right: but four minutes later incision into scrotum (? squeezing right testicle) produced pain, nausea, and faintness. 20 minutes: Analgesia both sides up to xiphisternal notch, but pinching right testicle caused pain.

Cases in which Analgesia extended above Line of Incision, but some Pain felt during Operation.

LXIII. (Piles).—Slight colicky pains from introduction of spirit mop high up into the rectum. (5 cg. glucose A.E.B. (No. 1). Analgesia of perineum only.)

LXXVI. (Piles).—Slight colicky pains on and off throughout operation, increasing towards end. (4 cg. glucose A.E.B. (No. 1). Analgesia of perineum only.)

LXXII. (Appendectomy, acute).—Slight gripping during manipulation of peritoneum. (6 cg. glucose A.E.B. (No. 1). Analgesia to umbilicus.)

LXXXI. (Appendectomy, acute).—Momentary gripping on mopping peritoneal cavity above upper end of incision and scraping caecal abscess. (5 cg. glucose A.E.B. (No. 1). Analgesia tenth rib, right; umbilicus left.)

LXXXIV. (Femoral hernia through inguinal incision).—Slight smarting pain on retracting inner side of wound, and some gripping on manipulating sac. (5 cg. glucose A.E.B. (No. 1). Analgesia to umbilicus, with exception of area on side along right inner side of iliac crest, over crest and spine, and adjacent part of buttock.)

Cases in which some Faintness occurred during Operation.

LVIII.—5 cg. glucose A.E.B. (No. 1).

LXII.—5.75 cg. glucose A.E.B. (No. 1).

LXV.—5+ cg. glucose A.E.B. (No. 1).

LXXXIII.—5— cg. glucose A.E.B. (No. 1).

Maximum Duration of Analgesia.

LXXVII.—3 hours with 5 cg. glucose A.E.B. (No. 1).

Minimum Duration of Analgesia.

LXXI.—23 minutes with 4 cg. glucose A.E.B. (No. 1).

Maximum Dose.

LVII.—7 cg. glucose A.E.B. (No. 1). Duration 1½ hours. Analgesia to iliac crests. (Patient's pelvis raised.)

LXXV.—7 cg. glucose A.E.B. (No. 1). Duration 1½ hours. Analgesia to iliac crests. (Patient's pelvis raised.)

Minimum Dose.

LXX.—4 cg. glucose A.E.B. (No. 1). Duration 55 minutes. Analgesia 1 in. above umbilicus. (Patient's pelvis raised.)

LXXXVI.—4 cg. glucose A.E.B. (No. 1). Duration 1½ hours. Analgesia round anus. (Patient's pelvis not raised.)

Maximum Height of Analgesia.

LXV.—Third intercostal space (nipple line). 5 cg. glucose A.E.B. (No. 1). (Patient's pelvis raised.)

LXXVII.—Iliac crests. 5 cg. glucose A.E.B. (No. 1). (Patient's pelvis not raised.)

Minimum Analgesia.

LXXXVI.—Round anus. 4 cg. glucose A.E.B. (No. 1). (Patient's pelvis not raised.)

LXXXV.—Iliac crests. 7 cg. glucose A.E.B. (No. 1). (Patient's pelvis raised.)

I have to acknowledge with pleasure the great help received from Messrs. P. Heath and H. Morriston Davies in observing the phenomena of sensation, etc., during the operations and afterwards, and in filling in the tables which I had prepared beforehand to include these and to secure uniformity of observation. Mr. Davies especially has spared no pains to make these tables complete in the last 50 cases, and from them to extract the data given in the text and compile the summaries subjoined. It would be impossible for an operator to observe the various phenomena of sensation and motion during the operation and after, while engaged on other cases, and one cannot entrust this duty to any but skilled observers. Some of the points to which he paid particular attention are here given in his own words.

REFERENCES.

- ¹ Bier: *Deutsch. Zeitsch. f. Chir.*, Bd. 51, p. 361, 1898; *Verhandl. d. deutsch. Gesellsch. f. Chir.*, 1901, p. 171; *Münch. med. Wochenschr.*, 1906, No. 29, p. 1059.
- ² Becker: *Ibid.*, July 10th, 1906.
- ³ Deetz: *Ibid.*, July 10th, 1906.
- ⁴ Goldmann: *Centraltbl. f. Chir.*, 1907, No. 2.
- ⁵ Bosse: *Deutsch. med. Wochenschr.*, 1907, No. 5.
- ⁶ Chaput: *Soc. de Biologie*, Paris, May 12th, 1904; *Soc. de Chir.*, Paris, October 12th, 1904.
- ⁷ Tuffier: *Wiener klin.-Therap. Wochenschr.*, 1905, No. 15.
- ⁸ Baisch: *Deut. med. Wochenschr.*, September 20th, 1906.
- ⁹ Russe: *Münch. med. Wochenschr.*, September 18th, 1906.
- ¹⁰ Freund: *Deutsch. med. Wochenschr.*, July 12th, 1906.
- ¹¹ Sonnenburg: *Ibid.*, 1905, No. 9.
- ¹² Kendirdji: *La Presse Méd.*, Paris, May 31st, 1905.
- ¹³ Dönitz: *Münch. med. Wochenschr.*, July 10th, 1906 (1,000 cases in Bier's Klinik).
- ¹⁴ König: *Ibid.*, July 5th, 1906.

II. PHYSICAL.

In speculating about the propriety and possibilities of producing analgesia by the introduction of special drugs into the lumbar dural sac and thus suspending the functions of the lower nerve roots and part of the cord we are at once confronted by several problems. The ease or difficulty of solving these is only fully realized when we come to have some practical experience of the procedure. We then learn that the results are sometimes "wayward," or "launenhaft" as Bier says, and that no drug yet employed for the purpose in question has so far given absolutely uniform results as to the height and the side affected by the analgesia and with a complete absence of those "by-effects" which led to the disuse of cocaine in this field. The waywardness which has been occasionally seen by all operators has manifested itself in various ways. First, it has been noted as a rare exception that even where lumbar injection has been accomplished to all appearance correctly no effect whatever has followed. Secondly, where analgesia has been more or less produced it has been found in a few of the earlier cases to affect a region other than that required for operation. For instance, the right leg was to be dealt with, and only the left was influenced by the drug, or perhaps a hernia had to be relieved and analgesia was only produced in the perineum. These results, though quite exceptions, have been disconcerting, and up to the present have not been fully explained, and as long as this is so they remain as a weak point in the procedure. Thirdly, we now know that in a large series of cases injected with the same amount of the same drug no by-effects may be seen, and then two or three may be troubled with considerable sickness or headache, though the conditions have been apparently the same.

With these experiences before us, we have to set ourselves to solve the following problems:

1. How to explain and meet the difficulty that in a few cases no analgesia at all follows an apparently orthodox injection (vide Part III).

2. How to explain those occasional variations as to height, the side, and the duration of the analgesia which are met with by all.

3. How to avoid the by-effects noticed as not infrequent, though rarely of much intensity.

Meeting with a few of these difficulties among the earlier cases in our list last year, I soon became convinced that when no effect at all followed on the injection it was due to the fact that the needle had only partially entered the dura, and that though the spinal fluid flowed out of the needle on puncture, the injection did not enter the sac at all, or only partially; and I devised a contrivance to meet the difficulty. This will be referred to below under "Technique." That the drug used in these cases had been overheated, or heated too long in sterilization, and so been rendered inert, appeared improbable, as the results with

other samples from the same consignment were good. And that some patients are inherently "refractory" to stovaine seemed also improbable, though possible. It seemed to me purely due to fault in technique.

Again, a little experience at the outset as regards lack of uniformity of analgesia in some of the cases suggested imperfect penetration of the canal and consequent delivery of some of the injection external to the dura.* It also led to speculation as to whether the physical properties of all the fluid injections were the same, and, if not, whether the want of uniformity in results might not depend upon the difference in their behaviour within the canal.

Finally, it suggested itself that perhaps the by-effects might be as much due to the physical conditions produced within the canal by injection as to the specific action of the drugs themselves, for they have followed the injection of many different drugs.

It is clear that the compound used ought to fulfil several requirements besides the suspension of the sensory and motor functions of the nervous structures with which it comes in contact for a time long enough for operations of considerable duration to be performed. It ought to leave no local or general permanent ill-effect on the tissues of the body and little or no transient disturbances in them apart from its analgesic properties. The first of these requirements has been met by stovaine and a number of other drugs, but here we are only concerned with stovaine. This has been found both in local, regional, and spinal analgesia to suspend the functions of nerves for a variable time. With the addition of adrenal principles the duration of its specific effects has been much prolonged, but, for several reasons this addition appears undesirable to me personally. With regard to the second requirement, stovaine alone has been, so far, found to produce no local or general ill-effects on the tissues when properly used, and thousands of patients who have undergone local and spinal analgesia with it are going about now years after showing no injurious effects of any kind (Tuffier). As to transient "by-effects," we have seen that these occur in a number of cases though of slight consequence. These after-effects have been variously explained. Headache and faintness have been put down in many cases to psychical disturbances, and from what we have seen probably with reason, where they occurred during or just after operation. But where they have been more persistent they have been explained as probably due to increased pressure within the intradural space caused by mild irritation, the result of perhaps the puncture itself or the stimulus of the injection. In some earlier cases in France, where the headache has resisted other treatment it has been relieved by subsequent lumbar puncture and removal of a few cubic centimetres of fluid. Such cases have all apparently done well ultimately. But in spite of the attention bestowed upon their causation these by-effects remain very obscure, the more so as they are not uniformly present, the great majority of cases showing no signs of them. This emphasizes the urgent need of scrutinizing the composition of the injected fluid in all its aspects.

That the specific influence of stovaine is limited almost exclusively to the locality into which it is injected in moderate doses seems highly probable from experience with it as a local and spinal anaesthetic. Its effects, if any, on the pulse is to reduce its frequency and increase its volume, and a patient after injection usually looks and feels warmer than before. A good deal has been written upon this point, but it is only necessary to say that other general effects of any great importance have not been observed where moderate doses have been given.

To prevent any local or general irritation the fluid injected must be aseptic, and this is easily secured, as stovaine solutions may be boiled at 115° C. for fifteen minutes without loss of potency. Too much or too prolonged heat renders it inert, which might explain an occasional failure unless it has been prepared by experts. But in addition to this, all fluids injected into the tissues of the body ought to possess the same osmotic tension as the blood serum. In other words, they should produce neither shrinking nor swelling of the blood or tissue cells by osmosis. This point is justly considered of prime importance, and especially where nerve structures are concerned. To secure isotonicity might appear an easy matter at first

* This is also suggested independently by Bosse in a paper since published (*vide Deut. med. Wochenschrift*, January 31st, 1907).

sight, but from my own observations is not so. Without going into the question more fully at present, it may be stated that a 5 per cent. solution of stovaine in distilled water freezes at about -0.58°C ., almost the same point as that of blood serum (-0.56°C). If this were the only test applied it ought to be isosmotic with the blood. But if a drop of blood be added to a little 5 per cent. or 4 per cent. solution of stovaine under the microscope, in five minutes the red corpuscles swell and become pale, in ten minutes are almost invisible, and in twenty minutes are all gone. The same is seen if a drop of blood be added to 5 c.cm. of these solutions in a test tube. But here the changes are apparently slower. At the end of an hour a few swollen pale cells can still be seen, but in an hour and a half they are all invisible. In a really isotonic fluid such as normal saline (0.91 per cent. NaCl) or normal glucose solution (5 per cent. of glucose) the cells are seen in twenty-four or forty-eight hours unchanged. This haemolytic action of stovaine, which I have tested in every way I could think of, appears hitherto to have escaped notice. It has been supposed too readily that if its 5 per cent. solution had the same freezing point as the blood it would be isotonic with it. But as we have seen, the blood cells are destroyed by it. Even the solution prepared for Bier in the belief that it was isotonic (stovaine 4 per cent., NaCl 0.11 per cent., epirenin borate 0.01 per cent.) I find to be markedly haemolytic tested as above on the microscope slide and in a test tube. Successive samples taken from the latter show rapid blood-cell destruction until in one and a half hours none are to be seen. But further than this I have found that if to an isotonic solution of NaCl or glucose, in which blood cells are seen to be unaltered at the end of twenty-four hours, 5 per cent. of stovaine be now added the cells rapidly swell, grow pale and disappear, no trace of them being found in one and a half hours. No combination of NaCl or glucose with stovaine which I have made hitherto has prevented this haemolytic action of the drug. Furthermore, it may be added that I have added a 5 per cent. solution of stovaine with a freezing point of -0.58°C . to an equal part of cerebro-spinal fluid and found in this compound destruction of all blood cells in about one hour. Nothing is seen then under the microscope but debris and oily globules. This is as much as to say that a 5 per cent. solution of stovaine injected into the spinal canal would be haemolytic too.

Leaving this point of osmotic tension for the present, and admitting that we have no evidence to show that the small amount of the drug injected has produced any injurious effect as the result of its haemolytic action, there are other physical qualities which an injection compound may possess which also appear to have attracted little or no attention.

It appears beyond all question that there are only three ways in which an analgesic fluid injected in the second lumbar interspace can make its direct effects felt in the mid-dorsal region, or even higher, as is sometimes the case in this procedure. These are either (1) by slow diffusion; (2) by shifting of the whole column of the cerebro-spinal fluid in which it is suspended upwards; or (3) by gravitation, if the injected compound be distinctly heavier than the liquor spinalis. Lumbar analgesia, it must be remembered, is only an extension of the principle of *local* or *regional* analgesia, in which we bring the drug directly in contact with certain nerve tracts which we wish to rob temporarily of their functions. Within the spinal dura, where, as we shall see, we are precluded from injecting above the second lumbar interspace, while desiring to affect the roots or cord in many cases at least as high as the middle of the dorsal spine, we can only do so in one of the ways indicated above, modified, of course, more or less by their combination.

1. Diffusion *alone* of one fluid in another is a slow process, and, as we shall see, is unlikely to be the mode of spread of the injected fluid in this procedure.

2. Bier and his followers have aimed at shifting the injected compound upwards or downwards with the whole mass of the liquor spinalis by raising or depressing the pelvis. That the cerebro-spinal fluid does recede somewhat towards the head on elevation of the pelvis is undoubted, but it is hard to imagine its doing so to such an extent as to carry with it a cloud of fluid lighter than itself from the second lumbar to the fifth dorsal vertebra, some 8 or 10 in.

I venture to think that with such a fluid as he has used, whose specific gravity is 1.0058 suspended in the liquor spinalis, whose specific gravity is 1.0070, what he has achieved by elevation of the pelvis has rather been a more rapid diffusion of the injected drug, due to the consequent oscillation of the spinal fluid, aided, perhaps, by vascular pulsation. But this rapid diffusion would, of course, dilute the injection, and perhaps carry it further than desirable.

3. There remains, then, the third possibility—namely, that an injected compound heavier than the liquor spinalis may be affected by gravity, and sink through the latter in a way quite different to the behaviour of a fluid of less specific gravity, such as that just referred to.

It is easy to observe the behaviour of one fluid injected slowly into another through a needle if the first be coloured with aniline blue. Provided that each be of the same temperature and specific gravity, the injected liquid forms at first a distinct blue cloud, which slowly diffuses itself through the whole mass into which it enters if the latter be in a state of rest. On the other hand, if the injected fluid be of the same temperature, but of much greater specific gravity, it sinks rapidly from the point of the needle in a definite stream to the bottom of the second fluid, and remains there as a distinct stratum without diffusion for a time proportionate to its density and viscosity.

Taking these points into consideration, it has for a long time past appeared to me that if we are to aim at localizing our spinal analgesia to any particular region of the cord we ought to employ the force of *gravity* acting upon an injected compound of greater density than that of the liquor spinalis. This would sink to the most dependent part of the canal open to it independent of any displacement of the cerebro-spinal fluid. Here it would remain more or less undiluted in contact with the structures around.

The densities of the only three compounds used in our series compared with that of the cerebro-spinal fluid are as follows at 15° to 17°C .:

Liquor spinalis (from 3 patients mixed fresh)	=	1.0070
Chaput's Compound:		
1. Stovaine 10%, NaCl 10%, distilled water 80%	=	1.0831
Writer's Compound:		
2. Stovaine 10%, glucose 5%, distilled water 85%	=	1.0300
Bier's Compound:		
3. Stovaine 4%, NaCl 0.11%, epirenin bor. 0.01%	=	1.0058

All these are, as we have seen, more or less haemolytic, tested by immersion in them of blood cells, the first much the most so (3 minutes), the two last about the same in this respect (1 to $1\frac{1}{2}$ hours). The first, a very heavy fluid, in which the common salt is present at the point of saturation at ordinary temperatures, has long been used by Chaput⁶ and Tuffier⁷ with good results, but apparently for other reasons than its density. Their grounds for employing such a high percentage of common salt, as stated by the former, were that M. Billon, who prepared the compound for them, hoped thereby to prevent the splitting up of the stovaine by the alkalinity of the spinal fluid. That it does not do so is evident to any one who adds some of their compound to the cerebro-spinal fluid drawn off. It will then be seen that the latter becomes almost at once milky. If a little of the fluid in this state be examined under the microscope, it will be seen that this turbidity is due to the presence of small globules of an oily nature, which in the course of time run together into larger and larger globules.

I venture to suggest that the undoubted success which our French confrères and we and others have had with their compound probably lies in its high specific gravity (1.0831). Owing to this it sinks rapidly and almost undiluted through the lighter spinal fluid (1.0070) and comes to rest in an almost unbroken stratum at the lowest point it can reach (Figs. 1 and 3). It has, however, the defect that its high percentage of NaCl alone renders it much more hypertonic than the two other fluids, which, taken with the intrinsically haemolytic action of the added stovaine, ought to lead, at least theoretically, to some irritation of the structures with which it comes in contact. This is to some extent diminished no doubt by the French method of injection, in which the few drops of compound in the syringe are mixed before injection with the spinal fluid escaping from the needle by first drawing back the piston

before the syringe is emptied into the canal. This hypertonicity is strongly objected to by many, and has, in fact, been supposed, rightly or wrongly, by some to be the cause of the headache which sometimes followed the use of the compound and possibly also of the occasional sickness.

Taking these points into consideration, I asked M. Billon to prepare for me a compound in which the 10 per cent. sodium chloride was replaced by 5 per cent. of glucose, and this I have been using for about a year now. [In Mr. Davies's "Notes" it is indicated, for convenience and brevity, as

drug by employing, not only a heavier, but also a slightly viscid solution, and so making a smaller dose operative, does not appear to have been noticed so far as published matter goes.

Whether our stovaine glucose solution will in its further use satisfy all the requirements we have supposed to be desirable remains to be seen in a larger number of cases. Glucose is said to be more stimulating to the tissues than sodium chloride, but on what grounds is not stated; I have not found it so in a large experience of subcutaneous

injection with it. But theoretically our compound ought to be safe, and in our second 50 cases, in which it alone was employed, the results were remarkably uniform as to the height and side of the analgesia, and no general anaesthetic had to be employed in a single case, although 20 were abdominal operations. But if experience should show that glucose is undesirable, 5

Fig. 1.—A photograph of a tracing from Braune's well-known plate of a frozen mesial section of the female cadaver lying level. Details omitted for the sake of clearness. Over the spinal canal, and following its curves accurately, is a glass tube filled with saline solution of the same specific gravity as that of the cerebro-spinal fluid = 1.0070. Through the middle vertical arm over the second lumbar interspace the hollow needle has been introduced into the curved tube, and 1 c.cm. of Chaput's solution (specific gravity 1.0831) coloured with methyl violet has been slowly injected. This has run down rapidly into the dorsal curve, and at the end of two minutes is seen as a dark stratum opposite the fifth and sixth dorsal vertebrae. The dark area in the cervical portion of the tube is a shadow on the glass.

glucose, A.E.B., (No. 1)] A solution of 5 per cent. pure glucose in distilled water freezes at about -0.56°C ., and is *really* isotonic, producing no effect on the blood or tissue cells in twenty-four hours. Its specific gravity is 1.0178. It is rendered still heavier by the addition of the 10 per cent. of stovaine, and comes out then at 1.0300 at 19°C . But this addition renders it haemolytic, as we have seen, and lowers its freezing point. This, apparently, cannot be helped wherever stovaine is used. It is, however, no worse in this respect than Bier's solution (vide supra). But it is much heavier than the latter, which has only a specific gravity of 1.0058 at 17°C . The latter is, therefore, actually lighter than the spinal fluid, and can only be moved by the oscillation of the latter from elevation of the pelvis and by diffusion. In consequence of its greater weight the stovaine-glucose solution, on the contrary, may, like Chaput's, be made to flow in any direction within the canal, in obedience to the laws of gravity, and, being slightly viscid, remains for a considerable time undiffused, the drug exerting its full power at a given point. These points relating to the use which may be made of fluids heavier than the spinal liquor, acting through gravitation upon the various curves of the spine without those *extreme* measures of inversion of the body and oscillation of the cerebro-spinal fluid resorted to by many authorities abroad, seem to have been almost or altogether overlooked. Further, the possibility of more or less limiting diffusion, and consequent dilution, of the

per cent. stovaine in normal saline would still be heavy enough with a specific gravity of 1.0126. In every case it has been my aim to keep the amount of the drug as small as possible, and to carry the effect on the cord by position or slight elevation of the pelvis only as high as was considered absolutely necessary for the operation in hand. In one or two cases the margin was cut just a little too fine both as to the amount of the compound used and the extent and duration of the elevation of the pelvis. One regretted in these cases, not having elevated a little more or a little longer so as to bring one

Fig. 2.—Same as Fig. 1, but with the pelvis raised 3 in. from the level. In this case 1 c.cm. of Bier's solution has been similarly injected coloured. This, having a specific gravity of only 1.0058, has not altered its position, except that, being lighter than cerebro-spinal fluid (1.0070), it has risen in the vertical arm. In this position it remains for a long time undiffused.

more segment of the cord within the area of the analgesia. Instances of other forms of waywardness were not seen in this 50, and no blank was drawn. Fairly bad headaches were seen once or twice and some cases of nausea and vomiting; but neither seem to have reached the degree described by others. From what we have seen I am inclined to think that the frequency and extent of these sequelae are largely determined by individual susceptibility to the amino-alcohol employed (stovaine), just as there is a difference in the way two individuals may react to a glass of the same wine. One will soon have a

headache while the other is quite comfortable. But before we can settle definitely these questions as to by-effects and uniformity of the distribution of the analgesia, we must know more about the physical properties of the compounds we inject, and how they behave in the canal. After this the specific action of the various drugs will be easier to study. That there are wide differences in this respect in those compounds hitherto in use is quite clear from what has been shown above, and uniformity of result with them could hardly have been expected. And it is the same with some other drugs which have been praised, but which I have not yet had occasion to use. Their 5 per cent. solutions contrast very remarkably with one another in weight and with the specific gravity of the cerebro-spinal fluid, and consequently they would behave quite differently if injected into the latter. One is lighter than the spinal fluid, the other two are considerably heavier, and their distribution within the canal ought to be widely different both as to time and locality.

Alypin 5 %	distilled water 95 %	sp. gr. 1.0036	freezing point 0.53°
Novocain 5 %	distilled water 95 %	sp. gr. 1.0090	" 0.555°
Tropacocaine 5 %	dist. water 95 %	sp. gr. 1.0106	" 0.545°
Stovaine 5 %	distilled water 95 %	sp. gr. 1.0064	" 0.585°
Cerebro-spinal fluid		sp. gr. 1.0070	

The freezing points I have taken three times for each.

It is quite plain that a 5 per cent. solution of alypin, with its low specific gravity (1.0036), ought to float in the highest layers of the spinal fluid, while a 5 per cent. of tropacocaine, with a specific gravity of 1.0106, would rapidly sink to the lowest layers. The greater uniformity of results which are claimed by some for tropacocaine may possibly be due in part to this physical property, perhaps more so than to any difference in specific action on nervous structures. But what I wish to insist upon is that we cannot expect exactly uniform results as long as we employ injection compounds of widely different specific gravities, unless we calculate on their weight in relation to the fluid into which they are injected and act accordingly in regard to the posture of the patient during puncture and after.

To observe the general behaviour of various fluid compounds when injected into the spinal canal, I had made many months ago a number of $\frac{1}{2}$ -in. glass tubes bent as accurately as possible to the curves of the spinal canal, as seen in Braune's frozen section of an adult lying on the back (Fig. 1). These tubes are turned up at each end for 3 in., and have another vertical tube rising to the same height as the ends fused on to them at a point corresponding to the second lumbar interspace (Figs. 1, 2, and 3). When filled with a solution of sodium chloride of a specific gravity of 1.0070, they may be held to represent roughly the spinal dura from the foramen magnum to its sacral end filled with its fluid, but minus the cord, which is not material for our present purpose.

These tubes, accurately adjusted over a tracing of the canal in Braune's plate and filled with the saline solution (specific gravity 1.0070) have been used at various inclinations of the body to observe what occurs, at all events *in vitro*, when the different compounds now in vogue for spinal analgesia are injected into the lumbar sac. Of course, it is conceded that certain vital phenomena would modify the conditions somewhat. But, in the main, what occurs here furnishes us with fairly correct evidence on most of the simple physical points connected with these injections in the living patient.

Each of the compounds to be injected has been coloured with the same quantity of methyl violet and used at the ordinary temperature of the air and of the saline solution filling the tube. It has been gently passed into the latter as on the living patient with the usual needle through the vertical arm over the second lumbar interspace. The figures are from photographs of the conditions actually present in the tubes *in situ* over Braune's plate two minutes after injection. But as the photographer had difficulties with the shadows on the glass thrown by the plate behind, I have had photographs taken of the tubes alone without Braune's plate, the level of the tubes relative to one another being the same.

From Braune's frozen section of the cadaver lying on its back (Fig. 1) it may be seen that the highest point of the canal from the level is in the cervical region, and next to this a point between the third and fourth lumbar vertebrae, that is, the point at which the puncture for spinal analgesia is made. From this last point the dural tube slopes downwards in both directions. The caudal incline ends for the dura opposite the third sacral vertebra. The cephalic incline slopes from the point of puncture downwards as far as the fifth or sixth dorsal vertebra, when it begins

Fig. 3.—Three tubes as in Figs. 1 and 2, but without the tracing behind. Into the top one Bier's light solution has been injected, into the middle tube glucose stovaine (author's solution, specific gravity 1.0300), and into the lower tube Chaput's. The pelvis had been raised 3 in. as before. In the top tube Bier's compound, being lighter than the fluid in the canal, has remained stationary; the glucose-stovaine, 1.0300, is still running down. Chaput's, the heaviest compound, has already reached the dorsal curve and is at rest. Photographed two minutes after injection.

to run upwards again to reach its highest point at the third cervical vertebra. With the head thrown forwards on a pillow, as the writer believes it should always be during intradural injection with heavy fluids, the foramen magnum would be the highest point in the spinal canal. These curves vary considerably in individuals and at different ages,* but the above may be taken as generally correct. Now, if it were possible to puncture the lumbar sac from behind at the classical spot, with the patient lying on the back perfectly horizontal, a liquid heavier than the spinal fluid would always flow for the greater part from the injection needle towards the dorsal curve and settle in a layer about the fifth dorsal spine, while some of it would gravitate to the caudal end. This is actually what happens when the experiment is made with the glass tube bent accurately to the curves of the spinal canal (Fig. 1). But in the living body there are practical

* Vide Professor D. J. Cunningham.

difficulties in puncturing from behind with the patient supine. However, if the injection be made while the patient lies on the side, or face, as I have occasionally done, and he then turns over on the back with the head thrown forward, a heavy fluid should take the same course. That it does so is almost proved by the regularity with which the analgesia produced by the Chaput's heavy saline stovaine-sodium chloride compound or the writer's stovaine-glucose one, though not quite so heavy (see above), rises to about the episternal notch or a little higher—that is, the region supplied by the sixth and seventh dorsal nerves. This varies a little, according as the head and neck are raised, and so the dorsal curve increased. This was so frequently observed in the second fifty cases, where the glucose-stovaine compound was alone used, as to be remarkable. Of course, this may be modified somewhat by raising the pelvis a little, as has usually been done, to hasten the flow of the injected fluid towards the dorsal curve before it becomes diluted by diffusion. It must not be forgotten, however, that in raising the pelvis, while the head and neck are supported forwards on a pillow, the lumbar curve is diminished, while that of the dorsum is increased. And the pelvis would have to be raised very high indeed to bring the level of the dorsal curve at the fifth or sixth spine above that of the foramen magnum, with the head and neck bent forward as described. There is, therefore, but little likelihood of the heavy compound reaching the medulla, or even into the cervical region at all. In some cases in Germany inversion has been carried to a very extreme degree, the head being unsupported, with the idea of displacing the whole mass of the cerebro-spinal towards the cranial cavity. But we must remember that in these cases the compounds have usually been of low specific gravity, and in the case of Bier's (see above) actually lighter than the spinal fluid, so that it would not be likely to move as far as the neck by any oscillation of the column of the spinal fluid. There have been a few cases, however, both in France and Germany, in which the analgesia has extended over the whole head as well as the rest of the body without injury, but the details as to injection and pelvic elevation are not given. They were probably instances of diffusion helped by oscillation. Personally I have never aimed at getting a higher analgesia than to the transverse nipple line. At the caudal curves the effects of a heavy compound can be limited in the same way by position. If the patient be seated on the edge of the operating table with his feet on a low chair and his back rounded the heavy fluid injected at the second lumbar interspace at once tends to run into the sacral dura, as we see also in our tube experiment. Here it accumulates at the end of the dural sac, where it quickly affects the roots of the nerves supplying the parts about the anus and the perineum. This is seen so constantly, even where analgesia is less satisfactory in other parts, that it suggests that when the injection is made in the sitting position most of it makes its way caudally, and it requires much and immediate elevation of the pelvis and oscillation of the cerebro-spinal fluid to dislodge it from the sacral sac. That is why I have thought it well in some cases to puncture with the patient lying face downwards, with a hard pillow crosswise under the umbilicus, so as to decrease the lumbar curve. In this position a heavy fluid runs towards the head, and if after half a minute the patient roll over on the back, and have a pillow placed under the head and neck pretty high, the injected fluid collects in the lower dorsal curve. This prone position, otherwise desirable, has the defect that the flow of cerebro-spinal fluid is not so good unless the patient is told to raise his head and to bear down. But I think this can be overcome. But so great is the tendency for the injection fluid to be in part locked up in the sacral sac when the injection is done in the sitting position that if I want the analgesia to reach to the border of the ribs for an abdominal operation the patient is placed on the side with the knees drawn up as high as possible for puncture, and thus all the compound flows at once upwards and all of it collects in the dorsal curve as the patient rolls over on the back. In such cases where the patient remains for any time on the side after the puncture, we have noticed that the analgesia reaches higher up at the end of the operation on the side on which he has been lying. This seems to indicate clearly that the bulk of the compound has run along the roots on that

side, but that it ultimately becomes segmental, affecting both sides, though still unequally.

For the careful preparation of the fluids employed in the above experiments and for the estimate of their specific gravities, which have been accurately made with a Westphal's balance, I am much indebted to Mr. R. Bennett, our pharmacologist at University College Hospital.

III. TECHNICAL.

To enter the lumbar dural sac effectually with the point of the needle, and to discharge through this all the contemplated dose of the drug directly and freely into the cerebro-spinal fluid below the termination of the cord, is the first technical problem which confronts us.

The human spinal cord terminates at the lowest opposite the second lumbar vertebra, and is below this out of reach of harm. The lumbar dural sac extends about as far as the third sacral vertebra. But from the configuration of the bones any ordinary needle puncture would present great difficulties, or be practically impossible below the fourth lumbar spine. We have, then, a choice between the second and third interspace of the lumbar vertebrae. Here we could reach the sac either laterally between the laminae, or by thrusting the hollow needle exactly in the middle line between the second and third or third and fourth lumbar spines. On theoretical and practical grounds, however, it is now almost universally acknowledged that puncture in the middle line is the easiest, safest, and best course. Here the puncture is least painful, and there is less risk of wounding any nerve structure or vessel if the needle is kept true to the middle line, and only just penetrates the dural sac completely. At either side there is a possibility of touching the strands of the *cauda equina* (Fig. 4). Besides this, any small quantity of fluid injected in the middle line can spread in all directions through the spinal fluid, whereas if delivered among the nerves of the *cauda equina* on either side it has a decided tendency to be entangled there, and to pass upwards and downwards in the interstices between them on that side alone, and not to reach the general cavity of the sac at all, or very partially, as was shown experimentally on the cadaver by Dönitz. The consequence of this in such cases is either an effect too low for the contemplated operation, or a one-sided analgesia. And though the latter might be desirable for some operations, there is no guarantee that, if the needle were designedly entered between the laminae on one side, its point would not be engaged among the nerves of the cauda on the other side. This appears to have been actually the cause of some of the few one-sided analgesias which are recorded elsewhere in earlier publications. The exact middle line, therefore, is decidedly preferable for injection. Here the analgesia compound passes freely into the spinal fluid, and reaches both sides equally, and can move freely upwards or downwards from the point of entry. Afterwards it can be influenced in various ways and for various objects according to its weight relatively to that of the spinal fluid, as already suggested. The fourth lumbar spine is recognized by being on a line uniting the highest points of the two iliac crests across the back. The hollow needle is thrust in just above this or the third spine, and aimed straight forwards and a little upwards (Fig. 4). If this is accurately done, there is no difficulty in the average patient as a rule in reaching the middle of the sac. But in some very stout people it is often difficult to feel the spines with the finger, and the point of the needle may strike bone. Its upward slant is then varied, and this will usually be sufficient for success without a fresh puncture if the back has been well rounded so as to obtain the greatest amount of separation between the spines. But in a few very powerfully-built middle-aged men it may happen that the spines are clubbed or twisted at their ends, or even overlap. In such we may fail altogether to reach the sac, but such failures are not common. Only three of these cases were found in our series of 100 cases. Whether the patient during the puncture should sit on the edge of the table, with the back rounded to its maximum, or lie on the side with the knees well drawn up, or, finally, on his face with a hard roller pillow under the umbilicus, is still open to debate, but the puncture is certainly easier in the first position. How the various compounds behave when they

have reached the spinal fluid in these several positions, has been already dealt with.

The needle employed in this series was that used by Bier, and has a close-fitting stylet about 1 mm. in cross section (Figs. 4, b, 5, a). The point is hollowed out so as to secure sharpness without lengthening the terminal opening too much. The object of this is that when the puncture is made the whole of the open end of the needle shall lie within the dura without the point being pushed so far as to wound any structures within the sac. It is obvious that if the open end of the needle were only partially through the dura (Fig. 4) the spinal fluid might run out freely enough through the needle, but that when the analgesic compound was injected part of it might enter the sac, while part of it escaped through that portion of the terminal oblong opening which had not entered the sac and be lost in the extradural space. As the operator is dealing with very small amounts of injection fluid, such a loss, if it were only of three or four drops out of eight or ten, would make all the difference between partial and complete analgesia. My own three failures in this respect

at the beginning of the first series soon convinced me that this was what had happened. Acting on this conviction, I have since employed the following device for delivering all the injection compound beyond the actual point of the needle, whether the whole of its terminal opening be actually within the sac or not. I had a second slender cannula made to fit the first hollow needle loosely and to project beyond its point about 1 mm. when the cone at its base is pushed home (Fig. 4, d). This cannula is attached to the syringe, which is filled with the drug compound through it. When the puncture with the first hollow needle is made and the spinal fluid has run out through it to the amount of 10 c.cm., the cannula, still attached to the charged syringe, is passed through the first needle until its cone closes it. The point of the cannula, which is quite blunt, now projects beyond the point of the first needle by about 1 mm., and must be within the dural sac (Fig. 4). When the syringe is now emptied, all its contents must be delivered within the canal, even though only half of the oblique terminal opening may have penetrated it (Fig. 4). This cannula being of less diameter than the first needle, enters it easily, and, having a transverse, blunt end, can do no harm itself besides guarding the sharp point of the first needle. This device has been used for about a year now, and in the second series of 50 cases there were no failures.

The syringe employed (Fig. 5) was that known as the "Record," and is well adapted to the purpose of graduation of dose. It varies in capacity, that here used holding 2 c.cm. A larger syringe of the same make is now used by many who employ tablets which are dissolved in cerebrospinal fluid, but the author recommends beginners to work with Billon's solutions and the syringe here de-

scribed. In filling it the end of one of Billon's "ampoules" containing the sterilized solution was broken off, and the cannula attached to the syringe was introduced into the fluid and the piston withdrawn. The point of the syringe was then turned upwards with the cannula still attached,

and bubbles were dislodged by tapping. In this position all the fluid was expelled except the required dose, and the syringe was laid aside for a moment. The lumbar puncture was then made. The hollow needle armed with its stylet was thrust through the skin sharply at the classical point and pushed on steadily for about an inch in the direction given when the stylet was withdrawn. The needle was then pushed on steadily, and as a rule easily. After it had passed the supraspinous and interspinous ligaments very little resistance was felt; it was rather as though it were crossing an empty space. Finally there was a sensation of having punctured a tense membrane, and the spinal fluid flowed out in rapid drops or, more rarely, a continuous stream. This is most important, as otherwise there is no guarantee that the sac has been reached by the needle. If the drops come very slowly the needle

may be turned round a little on its axis, when they will usually come more rapidly. But in no case should the analgesic compound be injected unless the fluid runs satisfactorily. When about 10 c.cm. of liquor spinalis had run off into a measure glass the slender cannula

attached to the syringe was inserted and pushed home, and the previously-measured compound was delivered into the sac by a slow thrust of the piston. Then both needle, cannula, and syringe were withdrawn, still attached as before, and the puncture was covered by collodion or a square of rubber plaster at once. The patient was then quietly rolled over on the back without hurry, and the pelvis was raised a little as described, about 3 or 4 inches, a pillow being also placed under the head and neck.

The puncture made as above was not as a rule painful once the skin was passed, but if the needle scratched the periosteum it was considerably so. But few complained of it, and mostly made light of it afterwards. Of course, the area to be punctured could have been previously rendered insensitive with a local anaesthetic such as ether or ethyl chloride spray; but this has seemed unnecessary if the patient be warned a moment before the prick in the skin, and so far I have never regretted not having used a local anaesthetic. Having undertaken all the punctures myself I can see that a little practice is necessary here, as elsewhere, before proficiency is achieved and that confidence which communicates itself to the patient.

In only a very few cases has any trace of blood appeared in the needle

either before, during, or after the escape of the spinal fluid. This was probably due to the fact that almost in every case the puncture was made as carefully as possible in the middle line; had it been made laterally between the laminae this would most likely have been

Fig. 4.—Diagram, adapted after Quain's Anatomy, shows third lumbar vertebra from above in part; a, part of body; b, hollow needle with open point half-way through the dura; c, dural tube in section with nerves of cauda equina on either side in section; d, cannula entering the canal completely through hollow needle.

Fig. 5.—a, Hollow needle, with cannula inserted; b, cannula alone; c, "Record" syringe, each c.cm. divided into five.

otherwise, as the veins are much more developed at the side of the dura than directly in the middle line behind.

To secure perfect asepsis in the whole procedure is beyond everything absolutely necessary, but in the nature of things ought to be comparatively easy to any one realizing its importance. And among the many large series of cases operated on by skilled surgeons, in the aggregate including thousands of cases, errors in this respect are practically unknown. But it must be insisted on that the whole procedure demands on the part of those who would practise it both skill in and mastery of the details of asepsis. Moreover, in the use of the usual germicides for the sterilizing of the skin we have to take care that no trace of them be left on the surface which could be conveyed by the needle in any way into the spinal canal, where they are particularly undesirable from their irritating qualities. For the cleansing of instruments, etc., they are not required, and it is easy to sterilize the simple outfit by heat. The first point to be insisted on is that all needles, syringes, etc., to be employed for this procedure shall be kept apart in their own special metal box for this procedure, and for it alone. It will not do, for instance, to use a needle and syringe one day to aspirate an abscess, and the next for spinal anaesthesia, even though they be boiled; nor will it do to use them for morphine injections even, and then for our purpose. They must be set apart for the spinal puncture, and for that only. The same holds good of the little sterilizer in which they are boiled. This should never be used with any alkali whatever, as is done for general purposes. Any trace of an alkaline fluid remaining in needle or syringe would destroy the stovaine; moreover, soda solutions are particularly irritating if injected into the tissues. Distilled water or steam should be used for sterilizing purposes, and any water with a sediment should be rejected as injurious to the syringes with accurately-fitting pistons. It is also desirable to boil the outfits after each case, and finally to put them away aseptic in their own special box dried. The piston should not be put away in the syringe, but separately, and the same holds good of the stylets, otherwise they may be found to have jammed in drying.

The stovaine in solution, which is apparently antiseptic in itself, was in these cases taken from Billon's sealed glass "ampoules," which had been sterilized before fusing their ends at a temperature of 110° C. (=230° F.) for ten to fifteen minutes. These capsules were only opened a moment before use by breaking off one end, through which the needle was introduced. Such solutions and capsules should always be prepared by one with a large experience and skill in these matters. Overheating the drug or prolonging its sterilization too much renders it inert. As a matter of fact, all the ampoules were prepared for me by M. Billon, one of the coadjutors of M. Fourneau, the discoverer of stovaine, and his experience and knowledge of what is demanded is probably unequalled. Tablets are prepared containing all the ingredients of several compounds, but how they are sterilized is not mentioned. These are placed in the syringe, where they dissolve in the fluid which runs from the puncture needle, and this is reinjected. The results we shall be able to judge of in time, and if found safe and satisfactory this method of preparing the solution will have some advantages.

The skin of the lumbar area is carefully cleansed beforehand by repeated washings with very hot water, soap, and brush. After this come compresses of the usual antiseptics for some hours if possible. A moment before the puncture the skin is washed with normal saline to remove any traces of bichloride, carbolic solution, or spirit which may remain on it, and which might possibly be carried by the needle into the sac. All these precautions, carried out rigorously, are necessary in every case, and with them the chances of infection of the canal are remote indeed. They would be considered sufficient for many much larger operations done every day upon the brain and spine.

This report originated in a desire on the part of the writer to fairly test the value of a procedure which has been now for more than eight years attracting much attention. This has naturally led to an examination of the theories and conclusions of those who originated and elaborated the method and practised it with the most praiseworthy caution in large series of cases. Reflection on these and on the work of others who followed has

aroused a doubt here and there as to the correctness of some of the conclusions arrived at so far, and suggested explanations of some of the phenomena connected with the procedure which are not in accord with views held hitherto. It is hoped that these suggestions may be tested, and if found unsound rejected. They will at all events have called attention to some points not yet clear, and perhaps paved the way for further and more fruitful inquiry.

Since this paper was drafted some months ago, some 28 cases have been added to our list, and have only fortified the conclusions here stated.

INFILTRATION ANAESTHESIA IN MAJOR AND MINOR SURGERY.*

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For some years I have been interested in local infiltration anaesthesia, or rather analgesia, and my experience of the method leads me to believe that in this country surgical operations are too infrequently performed with its help.

We owe our knowledge of infiltration anaesthesia as a substitute for general anaesthesia almost entirely to Continental and American surgeons, but the few recent papers by British writers, although not marked by much originality, have served to call attention to the good results attained by the method.

The term "infiltration anaesthesia" is far from signifying the haphazard subcutaneous injection of a solution of cocaine or eucaine with a view to rendering painless some trivial proceeding of minor surgery. Local anaesthesia of this kind is inefficient and dangerous, sometimes even fatal, owing to the toxicity of cocaine.

Connell¹ states that out of 250 reported cases of cocaine poisoning 13 terminated fatally. The subcutaneous injection of a solution of indifferent strength is painful in itself, and may be followed by sloughing of the tissues, a point to which I shall again refer.

In 1899, Schleich of Vienna introduced infiltration anaesthesia. Next to the pioneer work of Schleich and to the discovery of other agents less toxic than cocaine, the advancement of local anaesthesia is probably most indebted to Dr. Takamine, the discoverer of adrenalin. Braun of Leipzig first suggested the addition of this substance to solutions used for infiltration anaesthesia. The essential desiderata of such solutions may be summarized under three headings:

1. The percentage of the active agent contained in the solution must be sufficiently high to render the fluid efficient as an anaesthetic, but the total quantity of fluid infiltrated from beginning to end of an operation must contain an amount of the active agent insufficient to give rise to toxic results. As a corollary, it follows that solutions of cocaine are inadmissible unless only a small quantity of fluid be required, since it is not safe to inject more than about $\frac{1}{4}$ gr. of this substance.

2. The solution must be sterile, which is nearly equivalent to saying that its active agent should be capable of being boiled without impairment of its anaesthetic properties.

3. The third essential of the solution on which stress must be laid concerns its physical and physiological features. It must be as nearly as possible isotonic with the tissues.

In specific gravity, freezing point and osmotic pressure, it must correspond with the tissues. Solutions either too concentrated or too weak will be painful when injected, and are liable to cause destructive changes in the tissue cells, which may be followed by necrosis and sloughing. Such untoward results have not infrequently followed the injection of an-isotonic solutions. Sodium chloride is common to every infiltration solution, which should be no more destructive by its local effects on the tissues than normal saline. The salt is added in correct proportion to render the solution isotonic.

The addition of adrenalin chloride or its equivalent under another name, such as suprarenin, reneglandin, hemisine, etc., in the proportion of one part in 100,000 is a manifest gain. It acts as a powerful capillary haemo-

* Amplified from a paper read before the South-Western Branch of the British Medical Association.