CONCERNING SPINAL ANALGESIA*

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Two problems confront the spinal anaesthetist when he makes his injection :—

1. Which are the spinal nerve roots carrying the pain impulses from the operation area. This problem will not be further considered. It involves basic anatomical knowledge with which the anaesthetist must make himself familiar.

2. How is the local anaesthetic, deposited in the lumbar region, to be brought into contact with these nerve roots. In the case of an abdominal operation the nerve roots to be anaesthetized may be some 9 in. or 10 in. away from the spinal puncture.

An understanding of how the injected analgesic is brought into contact with the desired spinal roots is the very basis of spinal analgesia, and no apologies are needed for the manner in which it will be dealt. Consider a few simple, almost childish experiments which each of us can perform for himself in his own kitchen. For the first experiment a beaker of water is needed, a mark being made on the glass a little way up from the bottom. A long needle is inserted to the bottom of the glass and some coloured sugar solution injected into the water until the solution reaches half-way to the mark (Fig. 1A). To bring the coloured sugar solution into contact with the

mark, the obvious thing to do is to tilt the glass. The sugar solution responds to the pull of gravity and moves inside the water until it reaches the mark. This experiment demonstrates the ability of gravity to move one fluid inside another. If the contents of the glass are not stirred, the sugar solution will remain separate for many months.¹ In this instance, diffusion in the scientific sense of the word, that is, intermingling by molecular movement, is so slow that it can be ignored, for it must be reckoned in months, instead of minutes as in the case of gases. The term 'diffusion' therefore should not be used in speaking of the spread of spinal solutions.

Now for another simple experiment. The same beaker is completely filled with water (Fig. 2A). Some coloured sugar solution is again injected. As the injection is made, some of the water spills out of the beaker (Fig. 2B). If sufficient solution is injected, its level will ultimately reach the mark on the beaker. This experiment teaches that any injected solution occupies space, and the extent of the glass wall with which it comes in contact depends on the volume of the solution.

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FIG. 1

FIG. 2

These two experiments illustrate the two main methods of controlling the movement of the injected anaesthetic inside the sub-arachnoid space, namely, gravity, and volumetric displacement. Volumetric displacement operates whatever the specific gravity of the anaesthetic may be, since the latter must occupy space. Gravity comes into play after the solution has been injected and has therefore already come into contact with a number of nerve roots depending on its volume.

'Volume'

In order to utilize volumetric displacement in the most accurate manner, the specific gravity of the injected solution should be as near that of the C.S.F. as possible, so that once injected no further shift of the anaesthetic takes place. Many techniques have been described utilizing this principle, notably those using isobaric nupercaine,² those which employ barbotage³ and those which employ light nupercaine. In connection with light nupercaine, it is doubtful how much virtue lies in the difference in specific gravity.

The difference in specific gravity between C.S.F. and light nupercaine at body temperature, is extremely small—perhaps less than three parts in a thousand.

The volume of light nupercaine used is relatively large and usually ample by itself to ensure the desired height. The concentration of nupercaine in this solution is nearly at the limit of potency and the solution is probably rendered inactive very quickly after contact with the nerve roots. After all, 12 cc. of 1 in 1,500 nupercaine contains nearly the same weight of nupercaine as 1.5 cc. of the familiar 'heavy nupercaine.' Practical experience has demonstrated to me that the height to which an injection of light nupercaine will reach is determined mainly by the volume injected (Fig. 3). Many different methods of using light nupercaine have been described. All give excellent results. In only one of them—that of Howard Jones⁴—is there any implied connection between the volume injected and the height to which the spinal is desired. He advised measuring the length of the spine to arrive at the volume necessary to give a certain height of analgesia.

'Gravity'

In utilizing gravity the volumetric factor is minimized by injecting the smallest volume possible, and by having a sufficient difference in specific gravity between solution and C.S.F. to ensure a fairly rapid rate of movement. A volume of 1-2 cc.s is practical, in that its measurement is easy, while the volumetric effect does not account for analgesia of more than one or two spinal segments. An example of a small volume light

spinal solution is spinocaine, while heavy nupercaine⁵ is an example of a small volume heavy solution.

The behaviour of heavy solutions will be dealt with in a little more detail because their inherent safety in terms of life has made them deservedly popular. When a patient is lying on his back on a horizontal surface, two curves of the spine project posteriorly, separated by the lumbosacral projection (Fig. 3). One of these is the thoracic curve with its greatest convexity opposite the fifth to the seventh thoracic vertebrae, and the other is

FIG. 3.—Curves of spine and estimated volume of C.S.F. at various levels.

that formed by the sacrum and coccyx. Two curves project forward, the cervical, not well marked and of little importance in spinal analgesia, and the lumbo-sacral. The highest point of the latter curve is opposite the fourth or fifth lumbar vertebra, so that the third interspace, the common site for the injection of spinal anaesthetic drugs lies at, or slightly on the cephalic side of the highest point of this curve. Thus, with the patient lying horizontally on his back, a 'heavy' solution when injected in the usual place tends to split up; most of it gravitates towards the mid thoracic region, while some flows towards the sacral region. On the thoracic side of the lumbo-sacral projection the solution cannot travel beyond the most dependent part of the thoracic curve, which therefore acts as an automatic stop to its headward spread.

When abdominal analgesia is desired, the drug is required to come into contact with the lower thoracic roots, and that part of it which passes into the sacrum is wasted. In order to prevent this, lumbar puncture should be performed with the patient in the lateral position with his spine tilted slightly head down. Fig. 4 shows the importance of watching the spine and not the table, for in a man, the spine may be head up while the table is head down. With the spine slightly inclined in a head down position the solution will flow from the needle away from the sacral region, and when the patient is then placed on his back the solution will all be on the thoracic side of the lumbo-sacral curve. It will now travel on, and in its course anaesthetize the thoracic roots up to, but no further than, the sixth or seventh thoracic segment. By this means, analgesia is produced to

FIG. 4.—(a) Female. (b) Male. Showing discrepancies which may exist between tilt of spine and tilt of table. In both cases the spine has been made horizontal.

about midway between the umbilicus and the ensiform cartilage—a very convenient clinical level for most operations on the abdomen, especially if supplementary general anaesthesia is used. Since each pair of nerve roots requires a certain amount of drug to anaesthetize it, analgesia will in any case stop before the most dependent point is reached, if the quantity of drug injected is insufficient. In no case, however, will the anaesthesia rise above the most dependent part of the thoracic curve, unless the patient is tilted in a head down position, and there is still unabsorbed drug at that point. Ideally, therefore, the dose should be so adjusted that most of the drug is removed from the C.S.F. by the time the highest desired segment is reached.

In the production of perineal analgesia with heavy solutions, the patient sits up during and after the lumbar puncture, and gravity causes the injected fluid to sink to the lowest part of the thecal sac. The volume of the solution largely determines the number of segments here affected. Injection of 1 cc. usually anaesthetizes up to at least the first sacral nerve segment, although partial analgesia will probably exist up to the level of injection, i.e. the 3-4 lumbar. The longer the patient is kept sitting up the more sharply limited and demarcated is the area of analgesia. When the patient is then placed on his back the solution in the sacral region cannot travel against gravity past the lumbo-sacral curve.

The thoracic curve is thus a safety factor inherent in the use of heavy solutions of small

volume. It limits cephalic spread when the patient lies on his back on a horizontal table. In addition two levels of analgesia adjust themselves automatically, one, to the costal margin midway between umbilicus and ensiform cartilage suitable for most abdominal surgery, and the other to the perineal region.

A phenomenon which has been frequently described by authors, including myself, in connection with spinal analgesia and the existence of which I now doubt, is unilateral analgesia. I have made serial observations on patients throughout the whole period of their spinal analgesia, and have found that analgesia which is limited to one side during the early part of the operation usually becomes bilateral later, and although there may eventually remain a slight difference in level between the two sides, this is never more than a few segments in extent and hardly justifies the use of the term 'unilateral analgesia.' To satisfy themselves on this point anaesthetists should test both sides of the body throughout the duration of the operation, in cases where 'unilateral' spinal analgesia has been aimed at.

Duration of Spinal Analgesia

We commonly use the terms 'short-acting' and 'long-acting' drugs, and the impression is general that once an injection of, say, nupercaine or amethocaine has been made, then analgesia of two to three hours is certain, whereas if procaine is injected, only one hour of analgesia can be expected. These statements must be qualified. If the limits of the analgesia are determined carefully every five or ten minutes throughout the whole course of the analgesia, and the result plotted in the form of a graph, something like Fig. 5 would be obtained. This was an abdominal operation,

FIG. 5.

'heavy nupercaine' being the spinal, and it can be seen that after injection the analgesia extends quickly to a maximal distribution, and then within a short time begins to recede but more slowly than it developed. The duration of analgesia at any one particular spot on the patient, depends on the relationship of that particular segment to the upper limit of analgesia. Thus, in the case of the cephalic end of an abdominal incision (say the fifth thoracic segment), the analgesia might last about one hour only. But in the pubic region, the analgesia might be of nearly three hours duration. In planning the extent of the analgesia to be produced, therefore, the general shape of this graph should be borne in mind and the anaesthetist should see that the upper level of the analgesia is well above the highest operative level so that the duration of analgesia at the latter is sufficient.

Indications and Contraindications

Spinal analgesia has two outstanding attributes. One is its power. It anaesthetizes the nerve roots of weak and strong alike, with little difference in effort or skill required of the anaesthetist. Its second attribute is that the paralysis of the muscle in the part of the body anaesthetized is complete, being matched only by the effect of curare or the most profound general anaesthesia. Its indications may therefore be summed up under two heads :—

1. It is given to produce analgesia when any other method would be less safe or less efficient from the patient's point of view. Examples here are readily found among the more robust sections of the population. The burly seaman who decides to have his varicocoele operated on while his ship is in port, will tax the resources of the anaesthetist, should the latter decide on a simple inhalation anaesthesia. Anaesthetists at hospitals like the Seamen's Hospital, where such patients tend to congregate, have learnt this from experience, and almost invariably employ spinal analgesia.

2. Spinal analgesia is also indicated when profound muscular relaxation is demanded for the operation, and when this state cannot be produced more safely for the patient by other means. This indication includes the whole field of extensive abdominal and pelvic surgery in fit patients, although at the moment, the former supremacy of spinal is being challenged by curare.

So far as contraindications are concerned, I might introduce the list by making two general prohibitions. Firstly, spinal analgesia is contraindicated unless the most perfect asepsis both in regard to the skin of the patient, and the instruments, is possible. The second prohibition is this: 'Don't give a spinal to anyone you don't like the look of.' Spinal analgesia finds its best use in the robust, and any patient whose general

state of health gives rise to anxiety should be given spinal analgesia with great caution. If a spinal is used as a routine for all patients irrespective of their condition, that anaesthetist's practice will be characterized by frequent anxiety for his patients, and an unnecessary number of fatalities. Now for some specific contraindications.

1. Beware of those who have an abdominal tumour of such a size that the diaphragm is pushed up and is unable to move efficiently. The danger of spinal analgesia in such patients lies in the fact that when most of the intercostals are paralysed, as they are with a spinal for abdominal operations, the diaphragm cannot maintain the function of respiration. The patient must suffer from increasing respiratory difficulty, and may, if unrelieved, die. Included under this heading are patients who have a large ovarian or other cyst, a distended abdomen, or, and most important, those who are pregnant and at full term. The hitherto unexplained, and unpredicted deaths when spinal was used for Caesarian Section or for the removal of large ovarian cysts were probably due to this cause.

If the patient is attended by an anaesthetist with the ability and the equipment to maintain oxygenation until the tumour is removed, then spinal analgesia becomes permissible in these circumstances. Those who use spinal analgesia frequently for Caesarian Section bear out that with a large baby or a hydramnios, there are not infrequently moments of anxiety when the patient becomes slightly cyanosed. As soon as the baby is delivered, a dramatic turn for the better is observed, since now the woman can breathe well with her diaphragm.

2. Beware of those who have lung disease of such extent that they depend on every bit of their respiration for life. The inevitable lowering of respiratory efficiency with spinal analgesia precludes its use in these subjects. Examples of such people are those with very extensive pulmonary tuberculosis or bronchiectasis, those who have had a pneumonectomy performed or have a pneumothorax. These patients do far better with general anaesthesia where temporary respiratory difficulty can be countered by the anaesthetist without having to cope with the added complication of extensive intercostal paralysis.

3. Beware of those who have an impaired activity of the heart muscle, and particularly those who are known to have had a coronary thrombosis, or who suffer from angina pectoris. These patients are bad subjects for high spinal analgesia. The nourishment of the cardiac muscle is via the coronary arteries, and the blood flow through these vessels is dependent almost entirely on the systolic blood pressure. It is not difficult to

imagine the effect of a low blood pressure, with consequently poor coronary blood supply and so ischaemia, on a damaged myocardium. One might almost suggest that ideally, every patient who is to have a high spinal analgesia should have an electrocardiogram. A positive indication of cardiac infarction should exclude this form of anaesthesia.

4. Think twice about those who have a lesion of the kidneys with poor excretory function. Examples are patients with long-standing back pressure due to, say, prostatic enlargement or hydronephrosis. The danger of spinal analgesia to such patients lies in the low blood pressure during the spinal. Efficient functioning of the kidney depends, to a very large extent, on the systolic blood pressure. A pressure of about 30 to 40 mm. Hg. is needed to overcome the osmotic pressure of the blood proteins, while a further 30 to 40 mm. Hg. is required to overcome the resistance to the urinary tract and so drive the urine down the ureter into the bladder. A total, therefore, of about 70 to 80 mm. Hg. blood pressure is required to ensure that the kidney does excrete liquid and that the liquid reaches the bladder. The patient who is suffering from latent uraemia may ill afford to exist for one or more hours without kidney function.

Blood Pressure

A characteristic feature of spinal analgesia is the low blood pressure which occurs shortly after its administration. This fall in blood pressure, while not producing any obvious harm in the majority of patients, cannot be regarded as in any way beneficial. In certain patients, notably those with poor kidney function and with cardiac infarction, it may be harmful or even fatal. Numerous factors have been put forward to account for this phenomenon, and it is probable that each of them is partly responsible rather than any one of them the sole cause.

1. The oldest theory is that the fall is due to the paralysis of the sympathetic fibres which leave the spinal cord with the anterior roots and which convey constrictor impulses to the blood vessels. The peripheral resistance is undoubtedly lowered during spinal analgesia, but the dilatation of skin vessels and the accumulation of blood in the splanchnic area have not been clearly demonstrated.

2. On inspiration, air is drawn into the thorax via the trachea, but blood is also drawn in via the venae cavae. Intercostal paralysis means a decreased action of the 'thoracic pump,' and therefore a diminished return of blood to the heart. This in turn means a poor cardiac output which, with the inevitably lowered oxygenation of the

blood in the lungs, must play a big part in causing a fall in blood pressure. The blood pressure will often rise dramatically with the administration of oxygen and the adoption of the Trendelenberg position—a position which helps blood to return to the heart by gravity.

3. Paralysis of the secretory nerves of the suprarenal glands occurs when the spinal analgesia reaches the fifth thoracic segment, and this must be a factor in causing the marked fall in blood pressure when analgesia extends to this level. Acting on this hypothesis, many workers set up a dilute adrenalin drip infusion and administer this intravenously to keep the patient's blood pressure at any desired level. This was first tried in this country by Rowbotham⁶ many years ago but was given up after 100 cases because of the need for continuing the injection for some time if post-operative hypotension was to be avoided. The method was later popularized by Frankis Evans⁷ and is entirely successful if performed properly.

4. It has more than once been stated that the fall of blood pressure is due to the toxic effect of the anaesthetic on the heart and brain after it has been absorbed from the C.F.S. into the blood stream. In fact, we have been cautioned in many papers and books to limit the dose of our spinal analgesic in accordance with the weight of the patient. Considering the small amount of drug which is injected for spinal analgesia compared with the amounts of the same substance injected as a local anaesthetic, and considering that the dose of a spinal must more reasonably be related to the number of nerves to be anaesthetized, most anaesthetists in this country hold that this theory is unlikely to be correct.

It is a common practice to inject vasopressor drugs to prevent the fall in blood pressure. Certain points however should be kept in mind in this connection.

1. It must be rare that a healthy person suffers serious harm by a temporary fall in blood pressure alone. Some surgeons have conducted large and highly successful practices in which they operated on every part of the body under spinal analgesia. The notable example in recent years is Koster of New York who rarely operated under any other anaesthetic, even for operations on the head and neck. Like colleagues holding similar beliefs, he was not partial to the use of vasopressor drugs. In most instances the blood pressure was unreadable but the high esteem in which Koster's work was held by a discriminating public indicated that recovery with little morbidity was the rule.⁴

2. One of the advantages of spinal analgesia, particularly appreciated in these days of curare, is the bloodless field in which the surgeon works. Thus, it is not the relaxation alone which makes

a spinal so valuable, for, say, abdomino-perineal excision of rectum, or for the removal of vascular growths in the abdomen. In such cases, vaso-pressors may almost destroy this virtue of spinal analgesia. In connection with this point, it is interesting to note that at a recent meeting of the Section of Anaesthetics of the Royal Society of Medicine, many speakers emphasized that curare was contraindicated for abdomino-perineal excision of the rectum because of the very marked bleeding that occurred during the perineal dissection. For long, spinal analgesia has been a method of choice for this operation, largely because of the avascularity of tissues which it produced.

Of complications specifically due to spinal analgesia the neurological ones are the most important. There seems little doubt that the majority of these complications are due to infection of varying grades of severity of the meninges at the time of lumbar puncture. One cannot emphasize too strongly the need for scrupulous asepsis when administering spinal analgesia. It is probable that the majority of spinal headaches are infective in origin.⁸ It has long been believed that headaches may also be caused by leakage of C.S.F. through the puncture hole in the dura into the epidural space. A recent paper from Scandinavia⁹ indicates that there is little doubt that leakage is also an important factor. To those who have difficulty in imagining the escape of much liquid through such a small hole, I would remind them of the fact that negative pressure exists in the

epidural space.¹⁰ All grades of headaches are met with after spinal analgesia from the very mild affair about which the patient may not complain spontaneously, to the severe headache where the patient resembles one with mild meningitis. From long observation, I now believe that even under the best conditions, the incidence of headache is much higher than published reports indicate. The figure usually given is between 5 and 10 per cent. The true figure is probably much higher. The frequency with which this complication is recorded depends on the diligence with which it is sought. Many may go unrecorded because of the large meshes of the net which gathers them. I do not know of any reliable way of differentiating clinically between the headaches due to infection and those due to leakage. In any case, the treatment is symptomatic for three or so days. By this is meant darkened room, head down position, quietness and sedatives. If at the end of this time no improvement is noted, or the headache gets worse, it is time to call in one's medical colleague to consider the possibility of meningitis and its treatment by chemotherapy.

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INHALATIONAL ANAESTHESIA

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Inhalational anaesthesia is just over one hundred years old. It is difficult to believe that this indispensable auxiliary of surgery was unknown in past civilizations but evidence from historical writings is too meagre in descriptive detail to permit any deduction whatsoever that alleviation of pain was ever practised with the same assurance for patient and surgeon as has been possible since the introduction of ether in 1846. In early times, surgical intervention was determined mainly by urgency and great necessity, factors which outweighed the many difficulties involved—not the least of those being the suffering of the patient. The extremely slow development of operative surgery

over a period of centuries might justifiably be considered an indication that dependable anaesthesia had not yet arrived and that methods of preventing pain were unsatisfactory and of insufficient help to surgeons in extending the scope of their work.

Primitive anaesthesia was probably inhalational in type, this mode of entry of medicinal drugs being preferred to swallowing because of the association of the latter with poisoning. Herodotus (c. 500 B.C.) wrote the earliest known account of inhalational anaesthesia when he described the intoxication resulting from smelling and inhaling vapours obtained by burning cannabis