with the syringe attached is pushed along under the skin for almost its full extent. Injection is made as the needle is withdrawn, the point being directed upwards so that it can be seen running along beneath the skin. *In this way injection into vessels is avoided.

Summary

The various types of anaesthesia for abdominal surgery are discussed. It is suggested that the most satisfactory methods are continuous pentothal nitrous oxide-oxygen or field block nitrous oxide-oxygen. The value of the latter method in all poor risk cases and in cases where pentothal is contra-indicated is stressed. The techniques for the two methods are described.

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GRAVITY CONTROL IN SPINAL ANAESTHESIA

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Lumbar puncture for spinal anaesthesia is performed in the third, or fourth lumbar interspace because at these levels there is no danger of injury to the spinal cord, and the disposition of the spinous processes facilitate the passage of the needle. The problem confronting the anaesthetist after introducing his drug is to make it come into contact with the anterior and posterior roots supplying the area in which anaesthesia is desired. "Volumetric displacement" and "gravity control" are the means used to bring about this movement of the anaesthetic drug.

The volume factor

By the first is meant the displacement of cerebrospinal fluid by another fluid, containing the anaesthetic drug. By virtue of its volume alone, a solution injected intrathecally will affect a certain number of segments, since "diffusion" of one liquid into another of different composition takes place slowly in the absence of turbulence. Some idea of the levels that

FIG. 1.—Curves of spine and estimated volume of C.S.F. at various levels.

may be reached by injected solutions can be gathered by the figures given of the estimated capacity of the subarachnoid space from the sacral region upwards (Fig. 1). This displacement of the C.S.F. by injected fluid takes place irrespective of differences in specific gravity, with the proviso that if the patient is sitting up, a fluid lighter than C.S.F. may not displace the latter below the site of puncture. Thus in every method of producing spinal anaesthesia the volume of the injected fluid affects the level of anaesthesia, and the larger the volume the more spinal segments are affected. The effect of gravity is always an addition to the effect of volume, and it becomes an important factor, as far as height is concerned, only when the volume of injected fluid is small. The quantity of drug to be injected depends largely on the number of nerve segments to be anaesthetised, since each nerve root "fixes" a certain amount.

In order to produce a hypobaric solution (lighter than C.S.F.) without the addition of a "lightening" substance like alcohol, it is necessary to use a drug, potent in such dilution, that its weight will not increase the specific gravity of the solvent ($\frac{1}{2}$ per cent saline) above that of C.S.F. Such a solution is 1 in 1,500 nupercaine, whose specific gravity when warmed to body temperature is less than C.S.F. However, this solution is used in volumes of 10–20 cc., and the volumetric displacement factor is the most important in controlling the level. In using this solution, gravity may be called in to assist in producing extra height as with the Etherington Wilson method, or a predominantly anterior or posterior root effect as in the Howard Jones method. For true gravity control, however, it is necessary to keep the volume of the injected drug as small as possible. With the best known drugs at our disposal, that is procaine, nupercaine, and pontocaine, the volume of solution used for an average abdominal case is not easily reduced below 1 or 2 cc., since other factors must be considered, such as the greater local toxicity of these drugs in high concentration, and the bigger margin of error in estimating and measuring dosage. With doses of 1 to 2 cc. the effect of volumetric displacement is small, since by itself this will not make a difference of more than 1.2 thoracic segments. With the exception of Pitkin's Spinocaine (a solution of procaine made hypobaric by the addition of alcohol) all the modern small volume solutions designed for gravity control are heavier than C.S.F. In some, as when procaine is dissolved in C.S.F., the drug itself makes the solution heavier than C.S.F. In the case of nupercaine and pontocaine (Amethocaine), these solutions have isotonic glucose solution added to make them hyperbaric.

In this short paper spinocaine will not be discussed, since for several technical reasons it is not to be generally recommended, and is not in common usage in this country.

Heavy Solutions

There are certain fundamental facts of anatomy and physics which must be known in order to understand what happens when solutions heavier than C.S.F. are introduced into the subarachnoid space, and it is vitally important that this behaviour should be visualised at the time of administration by the anaesthetist. When a patient is lying on his back on a horizontal surface, two curves of the spine project posteriorly (Fig. 1), separated by the lumbo-sacral projection. One of these is formed by the thoracic vertebrae, and has its greatest convexity opposite the fifth to the seventh thoracic vertebrae, and the other is formed by the sacrum and coccyx. Two curves project anteriorly, the cervical, not well marked and of little importance in spinal anaesthesia, and the lumbo-sacral projection. 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 a "heavy" solution when injected at the third lumbar interspace splits up, when the patient is lying on his back on a horizontal table. 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 dependant part of the thoracic curve, which therefore, automatically stops its cephalic spread. When abdominal anaesthesia is required, the drug must be made to come into contact with the lower thoracic roots, and that part of it which passes into the sacral hollow is wasted. In order to prevent this, lumbar puncture should be performed with the patient in the lateral position with his spine (see Fig. 2, showing possible discrepancies between table and spine) tilted slightly head-down. The solution will now 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 projection; and it will travel on, and in its course anaesthetise the thoracic roots up to, and no further than, the sixth or seventh thoracic segment. By this means, anaesthesia is produced

FIG. 2.—(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.

up to about midway between the umbilicus and the ensiform cartilage. Motor loss is usually one or two segments below the sensory, since being heavy, the solution stays in the dependent part of the theca, and anaesthetises more posterior roots than anterior. Of course, since each pair of nerve roots requires a definite amount of drug to anaesthetise it, anaesthesia will stop when all the drug has been used up, even if this happens before the bottom of the thoracic curve is reached. 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 unused drug at this point. The dose should therefore be so adjusted that all the drug is absorbed by the time it reaches the mid thoracic segments.

When the patient is placed on his side, the curves of the spine are no longer of importance from the point of view of gravity, since viewed from this aspect the spine is a straight line (Fig. 3). Drugs heavier than C.S.F. when injected in this position will tend to stay in, and travel along, the dependent part of the thecal sac and anaesthetise the nerve roots of the side on which the patient is lying. Predominantly unilateral anaesthesia is thus very often produced, particularly so with those solutions containing glucose, and which mix little with the C.S.F. The spine itself must be tilted if gravity is to control the level of anaesthesia. In doing this it is important to regard the inclination of the spine itself, rather than the tilt of the operation table, for a muscular man with broad shoulders and narrow hips may need a slight head-down tilt of the table to produce a horizontal spine, while in women the reverse may be necessary (Fig. 2). It must also be remembered that when unilateral anaesthesia is being produced by this means there is no automatic safety factor to stop the anaesthetic action at a certain level, and if there is enough drug and a head-down tilt of the spine, the cervical roots will eventually be reached. In these cases, therefore, limitation of the dose of drug is necessary to provide a safety "brake" effect. In practice, however, once the anaesthesia has reached the desired level, the patient

can be placed on his back and the thoracic curve will limit the anaesthesia to the sixth dorsal segment.

In the production of perineal anaesthesia with heavy solutions, the patient sits up during and after the lumbar puncture, and gravity makes the injected fluid sink to the lowest part of the thecal sac, but the volume of the solution largely determines the number of segments here affected. Injection of 1 cc. usually anaesthetises up to at least the second sacral nerve segment. The longer the patient is kept sitting up the more sharply limited and demarcated is the area of anaesthesia. When the patient is then placed on his back the solution in the sacral region cannot travel against gravity past the lumbo-sacral curve.

There are thus two safety factors which are inherent in the use of heavy solutions of small volume. The thoracic curve, limiting cephalic spread when the patient lies on his back on a horizontal table, and gravity, limiting anterior root involvement with consequent less intercostal and sympathetic paralysis. There are also two levels of anaesthesia which adjust themselves automatically, one, to the costal margin, midway between umbilicus and ensiform cartilage suitable for lower abdominal surgery, and the other to the perineal region. Anaesthesia to levels intermediate between these two is obtained by visualising the behaviour of the solution at the time of injection, and adjusting the patient's position accordingly. Thus, to obtain anaesthesia of one leg the heavy solution is injected at the third lumbar space and the spine is kept horizontal while the patient lies on the affected side. In this position the injected fluid will spread equally on each side of the site of injection, and the volume injected will determine how many segments on each side of the site of injection will be affected. Two or three segments on each side of the site of puncture are reached with about 1-1.5 cc. anaesthetising from the first lumbar to the second or third sacral segments, giving anaesthesia of the whole of the lower limb. To obtain bilateral anaesthesia of the legs the patient must be turned on to his back

FIG. 3.—Showing effective method of obliterating the lumbar lordosis.

directly after the injection, both thighs flexed to straighten the lumbo-sacral curve (Fig. 3), and the table made horizontal so that the solution spreads on each side of the site of injection.

The possibility of obtaining inadvertently too high a level of anaesthesia when these fundamentals are understood and applied is remote, and in practice it is found that the production of high abdominal anaesthesia to the fourth thoracic segment difficult, when using gravity control of small volume hyperbaric solutions. Personally, I do not feel that spinal anaesthesia finds its best field of usefulness for surgery of the upper abdomen, but those who do use heavy solutions for the production of upper abdominal anaesthesia use other factors in addition, such as expansion of the dose into a larger volume with C.S.F. (barbotage), and tilting the patient to neutralise the safety factor of the thoracic curve.