SITES OF SENSORY BLOCKADE DURING SEGMENTAL SPINAL AND SEGMENTAL PERIDURAL ANESTHESIA IN MAN * † ‡

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The purpose of this report is to evaluate and summarize experimental and clinical data dealing with the site of anesthetic action during spinal and peridural block.

It has generally been believed that spinal anesthesia develops because conduction is blocked in the nerve roots (1) although this assumption has never been proved. For example, the theoretical basis for the production of differential spinal block (2) was the correlation between the diameters or conduction velocities of various fiber groups in the peripheral nerves of the frog and their sensitivity to cocaine block (3). The conditions in these latter experiments conducted by Gasser and Erlanger were quite dissimilar to those encountered during clinical spinal anesthesia. It was decided, therefore, to test the validity of these interpretations for spinal anesthesia in man under controlled circumstances.

The problem was approached by producing a segmental spinal sensory block of the lower thoracic and upper lumbar dermatomes by the method first described by Saklad *et al.* (4). A radiopaque catheter was inserted intrathecally in 8 adult human subjects so that the catheter tip was at approximately the body of the twelfth thoracic vertebra. The location of the tip of this catheter as well as others to be described later was verified radiographically. A half milliliter of 5 per cent procaine hydrochloride (25 mg.) in 0.7 per cent saline solution was then injected through this catheter. In all cases but one, the zone of anesthesia extended equally above and below the twelfth thoracic dermatome. The cephalic border of this zone was approximately the eighth

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thoracic and the caudal border was the fourth lumbar or higher. Figure 1A was constructed from a typical experiment which demonstrates this relationship. The significance of this finding can be assessed by correlating this pattern of anesthesia with the anatomy of the spinal cord and the other intradural structures.

In adult man the spinal cord ends as the conus medullaris at the first lumbar vertebra and the roots of all segments caudal to the first lumbar, therefore, are present in this region and comprise the cauda equina (fig. 2). The three possible sites of blockade, the spinal cord, the dorsal roots and the dorsal root ganglions will be considered in turn. If cord blockade is the chief means of anesthetization, then the sacral segments should have been denervated when procaine was deposited in the region described and the lumbar and thoracic dermatomes should have been spared. Precisely the opposite was observed,

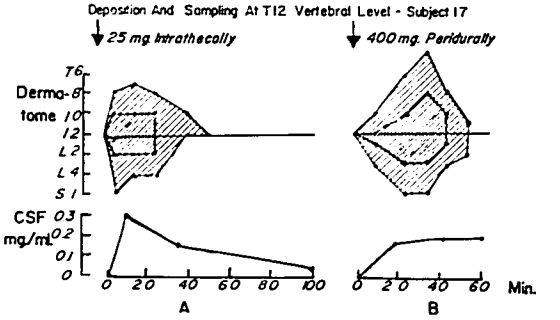

FIG. 1. The dermatome distribution and spinal fluid concentrations of procaine during segmental spinal and segmental peridural block in subject 17. Heavily shaded areas —zones of anesthesia. Lightly shaded areas—zones of hypesthesia.

however; namely, the sacral segments were spared whereas the more cephalic segments were blocked. Therefore, intramedullary block under these conditions appears to be excluded. If root blockade had occurred, conduction should have been impaired in all of the roots of the cauda equina and the entire lower part of the body should have been anesthetized. The absence of such a chemical transection, that is, the failure to anesthetize the sacral and the lower lumbar dermatomes, appears to exclude this possibility of root blockade with low concentrations of procaine.

The third possible site of blockade is the dorsal root ganglions. The ganglion cell bodies in contrast to the axons within the roots are devoid of myelin and are covered only by the delicate pia and a relatively small amount of connective tissue (figs. 3 and 4). Furthermore,

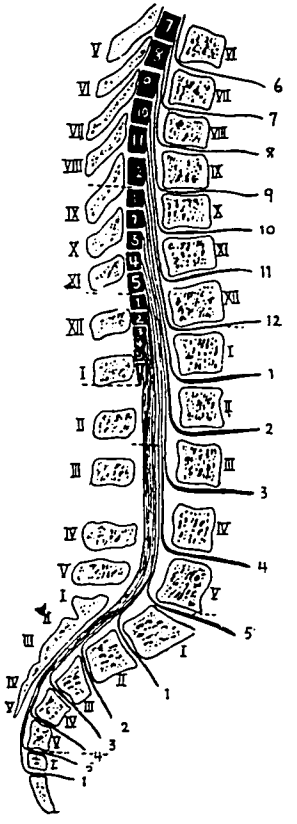

FIG. 2. The relationship in sagittal section between spinal cord, roots and vertebrae in adult man. This figure and figures 4 and 5 are reproduced with permission of the publisher from "*Human Neuroanatomy*" by O. S. Strong and A. Elwyn, Second Edition, The Williams and Wilkins Co., Baltimore, 1948.

the spinal fluid bathes these structures as they lie free in the lateral dural projections (fig. 5). The ganglions are exposed, therefore, to the action of spinal anesthetic agents and are probably more susceptible to block than are the other intrathecal neural elements.

The concept of the ganglionic site of sensory block was supported by some preliminary data dealing with the pattern of procaine concen-

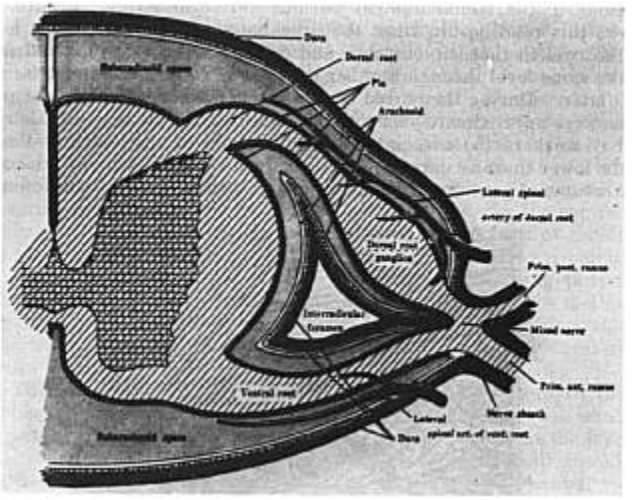

FIG. 3. The relationship in cross section between the spinal cord, roots and meninges. This figure is reproduced with permission of the publisher from "*Neuroanatomy*" by F. A. Mettler, Second Edition, The C. V. Mosby Co., St. Louis, 1947.

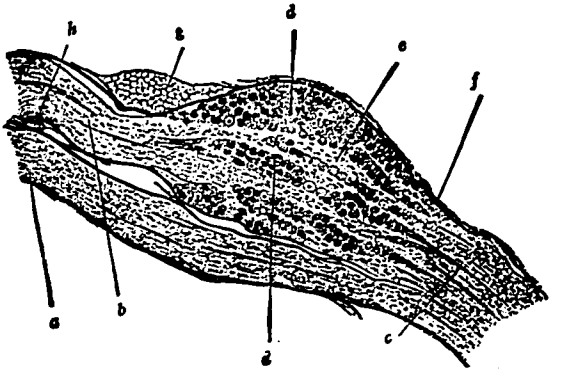

FIG. 4. The human dorsal root ganglion.

trations in the spinal fluid at various vertebral levels. Figure 1A shows this relationship when the procaine was deposited at the level of the twelfth thoracic vertebra and 0.5 ml. samples were withdrawn at the same level through another catheter at ten, thirty and 100 minutes later. During the period of anesthesia the concentrations of procaine were approximately 0.2 mg. per milliliter, the value which Helrich and co-workers (5) associated with threshold or minimal anesthesia of the lower thoracic dermatomes. As the anesthesia wore off, the concentrations of procaine were usually subthreshold. These preliminary

FIG. 5. The human dorsal root ganglion.

data suggests that the ganglions are the site because only the ganglions of the denervated dermatomes are located in the region where the procaine concentrations were found. Such a correspondence cannot be established for the roots of the cord in this unique region around the first lumbar vertebra.

There are also questions of interest on the site of block in peridural anesthesia. Comparatively little is known about transdural passage of local anesthetic drugs, the mode of production of conduction block and the distribution of the solution within the peridural space around the site of injection.

Clinical impressions (6) and early experiments with colloidal suspensions (7, 8) and dyes have led to the general impression that local anesthetic agents do not penetrate the dura and that the site of blockade is the mixed spinal nerve at the intervertebral foramen distal to the point where the dura fuses around the nerve. This is equivalent to multiple paravertebral block. More recently, anesthetic concentrations of procaine have been found in the spinal fluid of calves by Numans and Havinga (9) and of dogs by Rudin *et al.* (10) following peridural injection. The conditions of these studies, however, differed from those of clinical peridural anesthesia in man. In the canine experiments the complex procedure of continuous perfusion of the dural sac was used in order to circumvent the difficulties posed by the minimal amounts of spinal fluid ordinarily available for sampling purposes. Numerous objections could be directed to other aspects of the methodology in both instances and consequently it was considered desirable to note whether procaine did permeate the dura during peridural anesthesia in man.

The experimental approach was similar to that employed in the earlier spinal study. A radiopaque catheter was inserted into the peridural space in 10 subjects so that its tip was usually at the level of the twelfth thoracic vertebra. A second catheter was introduced intrathecally at the interspace between the fourth and fifth lumbar vertebrae and was advanced cephalad so that the tips of the two catheters were usually just opposite each other, being separated by dura, arachnoid and spinal fluid. Twenty milliliters of 2 per cent procaine hydrochloride was then injected peridurally and spinal fluid samples were drawn at twenty, forty and sixty minutes thereafter. In figure 1B are shown the results in a typical experiment. The segmental anesthesia of a few dermatome segments above and below the twelfth thoracic was quite similar to that described previously following intrathecal injection. This pattern of distribution was also noted in a series of 43 subjects reported elsewhere (11). The concentrations of procaine in the spinal fluid at twenty and forty minutes following injection were approximately threshold for sensory anesthesia with average values of 0.18 and 0.21 mg. per milliliter, respectively. As anesthesia wore off at sixty minutes the concentrations also declined in a parallel fashion. Thus it appears reasonable to attribute at least part of the anesthesia to block of some neural structure within the subarachnoid space. In only one subject were all values less than 0.15 mg. per milliliter. In one subject the intrathecal catheter tip was directed caudally deliberately and 0.04 mg. per milliliter was the maximal concentration found in the sacral area. In still another subject 20 ml. of 1 per cent procaine was injected at the level of the eighth thoracic vertebra and the anesthesia was spotty and quite limited in extent while the concentrations of drug were low.

There are obvious similarities in the anesthetic pattern between

these results and those in the earlier study with spinal anesthesia in which the injection was carried out at approximately the same vertebral level (cf. figures 1A and 1B). Concentrations of procaine in the spinal fluid are also similar. It appears probable, therefore, that at least part of the block of peridural anesthesia must occur within the subarachnoid space. No information is as yet available on the disposition of all the drug injected into the peridural space.

An important limitation to the transference of these interpretations to clinical spinal and peridural anesthesia must be stressed. In both studies only threshold concentrations of the drug and minimal sensory blocks were produced. The occurrence of motor paralysis during conventional clinical spinal anesthesia when greater drug concentrations are created must mean that either the ventral roots or the cord are blocked with these higher concentrations. However, at the upper border of the zone of anesthesia where the procaine concentration is threshold, as demonstrated by Helrich *et al.* (5), anesthesia probably does occur by virtue of a ganglionic block.

The exact mechanism whereby procaine penetrates the dural barrier is still unknown. Mettler and Allen (12) have described the passage of particulate matter from the subarachnoid space at the region where the arteries and veins traverse the dura and have confirmed by direct observation the existence of small stomata in the dura in this area.

However, neither these anatomical observations nor the spinal fluid procaine concentrations just noted exclude the possibility that blockade could also occur at an extradural site. The observed patterns of segmental anesthesia could be produced by equal volumes of fluid moving cephalad and caudad within the peridural space from the point of deposition, with some of the solution emerging at the intervertebral foramina to produce bilateral multiple paravertebral block. It was desirable, therefore, to examine this hypothesis to determine just how fluid does actually spread within the peridural space.

Virtually all attempts to determine the dimensions of the peridural space or to understand the fate of the injected fluids have been based upon cadaver dissection following the injection of colored suspensions or the visualization of oily radiopaque materials like lipiodol. These studies are subject to the obvious criticism that the state of this fascial plane is quite different in the embalmed cadaver from that in the living subject; furthermore the differences in viscosity between watery procaine solutions and thick, oily contrast media may cause variations in the manner of spread.

A supply of abrodil®, a water soluble radiopaque material, which has been used extensively in the Scandinavian countries for myelography both intrathecally and peridurally, was obtained for this purpose. Twenty milliliters of a 20 per cent solution of this compound was injected peridurally at the level of the twelfth thoracic vertebra with

the patient supine and horizontal. The fluid was noted to extend to more vertebral segments in a cephalad than a caudad direction. However, the difference in size between the thoracic and the lumbar vertebra may account for most of this apparent inequality of spread.

SUMMARY

Threshold intrathecal concentrations of procaine produce anesthesia through a selective blockade of the dorsal root ganglions.

The occurrence of procaine in threshold concentrations in the spinal fluid of man during peridural anesthesia can account, in part, for the production of sensory block with this technique.

The spread of watery radiopaque solution within the peridural space was studied.

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