FUNCTIONAL LOCALIZATION OF INTRASPINAL CATHETERS *

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SINCE the advent of intraspinal catheterization (1, 2) the necessity for precise localization of the tip of the catheter has been met in a variety of ways. Markings indicating the distance to the tip of the catheter have been used. This technic is subject to errors resulting from the considerable variations in spinal proportions that exist in different patients. Occasionally the catheter will loop or double back on itself in the subarachnoid space so that the tip is far from the level that is anticipated (2, 2a). More precise anatomic localization has been accomplished by roentgenographic determination of the site of the tip. By roentgenographic technics, however, the tip of the catheter is located in relation to the bony structure of the spine rather than in relation to the segmental neuronal outflow. This latter type of localization, functional localization, is the real concern of the anesthetist since is is a precisely localized effect on the nerve fibers for which he is striving. The anatomic discrepancy between the emergence of the nerve fiber from the spinal cord and its emergence from the spinal canal is, of course, appreciable, and increases gradually in degree as the more caudal areas are reached. The quantitative element in this discrepancy varies from site to site, and it is also conceivable that some patients do not conform to the generally accepted pattern in this regard, thus superimposing an additional error in the segmental localization of the catheter tip. Of importance also is the fact that obtaining a roentgenogram adds an appreciable amount of time to the sequence of preparing the patient for surgery if the location of the catheter tip is to be known *prior* to injection.

The stimulation of motor fibers is readily accomplished by electrical potentials appreciably below the threshold required for the stimulation of pain fibers. Thus, by working up from zero voltage, one can readily and quickly reach that voltage which is capable of exciting motor fibers while leaving pain fibers unexcited (3).

Previous experience with electrophrenic respiration in man revealed that the phrenic nerve could be repeatedly stimulated in such a way as to cause adequate diaphragmatic respiration without causing pain (4,

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5). It seemed, therefore, that by producing an electrical potential at the tip of the catheter and gradually increasing the voltage until a minimal, localized motor response is obtained, one should be able to tell from the muscles which respond, the segmental motor level which is closest to the opening of the catheter. It follows that that segmental level would be first exposed to the highest concentration of the subsequently injected anesthetic agent. This communication deals with the development of this technic in the dog.

METHOD

Mongrel dogs, anesthetized with 30 mg. per kilogram of sodium pentobarbital intravenously, were used. A number 3½ intraspinal catheter was fitted with a slender, flexible stilet, to the end of which was fixed the retaining knob of an ordinary spinal needle stilet. The length of the stilet was carefully determined so that, when fully inserted, its end lay 1.0 mm. proximal to the open end of the catheter. The catheter was not provided with any other opening at its distal end. This arrangement provided for electrical contact between stilet and cerebrospinal fluid at precisely the point from which the subsequently injected anesthetic agent was to emerge. The stilet retaining knob was provided with a small rod at its back for convenience in attaching it to the alligator clip lead from the stimulator.

The stimulator was especially constructed for the purpose in anticipation of its clinical application. Simplicity of operation, limitation of maximum current, patient fuse, compactness and lightness were thought to be desirable in this type of clinical instrument. The controls include (1) an on-off switch and pilot light, (2) voltage control for varying the voltage between zero and sixty volts, and (3) toggle switch arranged so that when it is placed in the "up" position it remains there. When placed in the "down" position it automatically springs back to the "middle" or off position as soon as it is released. The "up" and "down" positions permit the stimulator to deliver sixty impulses per second. The "up" position produces tetany, and this control may be left on while adjustment of the voltage control is made. The "down" position permits the operator to deliver discrete twitches by quickly pressing and releasing the control rod. This latter type of stimulus may be of value in more critically localizing the threshold response, since discrete twitches may be more apparent than a continuously contracted or tetanized segment of muscle.

Both the voltage control and toggle switch control are fitted with an octagonal recess in the handle. A 4 inch bar fits into each of these recesses. These bars are sterilized along with the spinal set and are placed on the stimulator controls by the anesthetist at the time of lumbar puncture. This permits the stimulator to be manipulated by the anesthetist without contaminating his gloves.

Potentially harmful voltages may be delivered to the subarachnoid space if the stimulator is turned on and connected to the stilet while the voltage control is at high settings (as, for example, if left at a high setting by the previous user). Thus, it was thought advisable that the voltage control should automatically return to zero by means of a spring mechanism unless it is held in place at any given setting by the anesthetist.

Of the two leads from the stimulator, one is connected to a 3 inch × 4 inch × ½ inch felt pad moistened with saline solution which acts as the indifferent or ground electrode. The other lead is connected to the catheter stilet by means of an alligator clip as described above.

The impulse used is biphasic and has a rapid fall off from the peak, figure 1. The impulse duration is 4 milliseconds.

FIG. 1. Single electrical impulse used by catheter localizer.

For the purposes of clarity in portraying the segmental response photographically (fig. 2) the voltage was turned up to the point where a vigorous motor response involving several segments was obtained. Continuous stimulation was used in order to obtain a tetanic contraction during the photographic exposure.

In the experiments to be described, the spinal catheter was introduced through the atlanto-occipital membrane of the dog according to the method of Co Tui (6), and threaded down the subarachnoid space until its tip lodged in the sacral region. The stilet was then inserted and electrical stimulation begun. With the stilet in place, the catheter was carefully withdrawn an inch at a time and stimulation repeated until the tip was finally withdrawn from the atlanto-occipital hiatus. At each location the voltage was gradually increased from zero to a

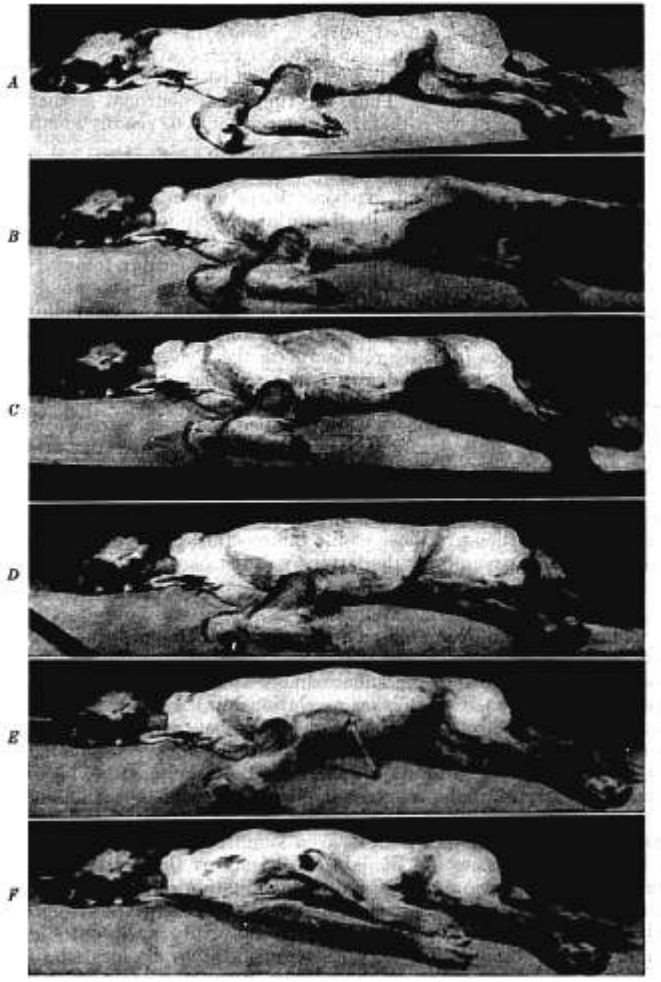

FIG. 2. *A*, Dog with ureteral catheter inserted through the atlanto-occipital membrane and passed down to caudal region of subarachnoid space. No stimulation, relaxed position. *B*, Tetanic stimulation. *C*, Same after slight withdrawal of catheter. *D*, *E*, *F*, Stimulation after further withdrawals of catheter upward (see text).

point at which the first discernible motor response was obtained. This was usually a quite localized activity. Since the exciting electrical potential was greatest at the site of the opening in the catheter, the motor fiber nearest this opening was held to be the one mediating the observed motor response. Thus, the functional neuronal segment at which the opening of the catheter was placed could be readily identified.

RESULTS

The results of a typical experiment are shown in figure 2. The catheter was inserted through the atlanto-occipital membrane and passed down the subarachnoid space until its tip lodged in the sacral area. Threshold voltage resulted in localized muscular tetany. The voltage was then increased slightly so that a more widespread contraction occurred. The result is seen in figure 2B. The motor response was predominantly left-sided, and indicates that the catheter orifice was in more intimate relation with the nerves on the left side. The catheter was then withdrawn 1 inch and the procedure repeated. The result is pictured in figure 2C and shows activity of the quadriceps femoris. Localized responses were obtained as the catheter was withdrawn further, until finally it was drawn out through the atlanto-occipital membrane.

Examples of what was obtained are shown in figure 2D–F. The responses of the extremities are more easily recognized in this series of illustrations than are those of the intercostals, but little difficulty is encountered in recognizing the latter by direct observation.

COMMENT

This method is presented as a technic of functional localization of the catheter orifice through which an anesthetic agent will subsequently be injected into the subarachnoid space. Its advantages are held to be that (a) it establishes a relationship between the tip of the catheter and a neuronal segment rather than between catheter tip and bony structure, (b) the determination can be done in less than 1 minute, (c) it is done prior to the injection, and (d) it obviates the inconvenience and expense of the roentgenologic technic.

It is well to examine the potential disadvantages of the method. Since the technic has not been used in man, it is not possible to know with certainty the amount of pain or discomfort that will accompany the motor stimulation. The greater myelination of the motor fibers with correspondingly lower electrical thresholds suggests, as outlined above, that it should be possible to excite motor fibers without eliciting pain.* It is possible that the catheter orifice may be located signifi-

* Since the preparation of this manuscript this technic has been used in man. Nerve roots in the subarachnoid space have been stimulated at levels varying from the fourth thoracic to the fourth sacral nerves. No pain was encountered at any time. These findings confirm the hope that this technic may prove clinically useful.

cantly closer to a posterior root than an anterior root. In this case, the voltage required to excite the latter at a distance may be high enough also to excite the nearer sensory root despite its higher threshold. This can be determined only by clinical trial.

It frequently happens that, when the voltage reaches the response threshold, the localized motor response is unilateral. This may make it more difficult to observe properly if it should happen to be on the down side of a patient in the lateral decubitus position. On the other hand, it is of help in determining whether the catheter orifice is in more intimate contact with the right or left nerve roots.

If one is to use the technic with confidence, he must be satisfied that the electrical stimulation of nerves will not injure them. It is, of course, possible to destroy nerves with excessive electrical current, just as it is possible to cause respiratory paralysis by injecting excessive amounts of procaine. With appropriate electrical potentials, however, it is possible to stimulate nerves for prolonged periods of time without deleterious effect. Fender (7) continuously stimulated sympathetic nerves in the dog eight hours per day, six days per week for six months. No diminution in the response occurred, and microscopic examination failed to reveal evidence of injury. Kubicek (8) stimulated sympathetic fibers in the dog twenty hours per day for thirty days. The response at the end of that time was the same as at the beginning, indicating lack of functional impairment of the nerve. The same result was observed when stimulation was carried out twenty-four hours per day for twelve days. Recently, in the management of the respiratory irregularity of a case of bulbar poliomyelitis, we had occasion to perform unilateral electrophrenic respiration continuously for three days and intermittently for another four days. The amount of current used in the catheter localization technic described is extremely small in comparison with the amounts delivered in the above circumstances. Six to twelve motor twitches should be enough to localize the end of the catheter accurately.

The spinal cord in man is significantly longer than that of the dog, and the distance between the nerve roots correspondingly greater. Assuming the electrical conductivity of human spinal fluid to be about the same as that of the dog, it is reasonable to expect that a given catheter displacement will produce a smaller change in the relative segmental placement of that catheter in man. The anatomic spectrum of segmental nerve root emergence being wider in man, precise localization should therefore require even less critical catheter placement than in the dog.

Recently, several investigators (9, 10) have found it possible to record intracardiac electrocardiograms through venous catheters without inserting a stilet or having the catheter wired in any special way. The conductivity of the saline column contained in the catheter was sufficient to permit the accurate recording of intracardiac potentials.

This gave rise to the hope that subarachnoid stimulation could be performed without the presence of the metal stilet in the catheter. This did not prove to be the case with twice to three times the voltages used for stimulation with the stilet. The cross sectional area of a number 9 venous catheter is about ten times that of a number 3½ spinal catheter. Since the resistance of any conductor is inversely proportional to its cross sectional area, it is apparent that the electrical resistance of the saline column in a spinal catheter is many times as great as that of the saline column in a venous catheter. This difficulty is further amplified by the fact that, in the above-described intraspinal technic, one is attempting to pass much larger amounts of current than that required for the recording of an electrocardiogram. It is probably true that the high resistance of the small column of saline solution in the spinal catheter could be overcome by utilizing much higher potentials, but the inherent difficulties involved in such a system made it seem unwise to attempt to use such a system clinically. It would seem feasible to attempt localization of an epidural catheter as well.

SUMMARY

A technic has been presented for the precise segmental localization of a catheter orifice after it has been introduced into the subarachnoid space. This consists of introducing a threshold electrical potential which is most concentrated at the catheter orifice, thus stimulating the most proximal motor fibers. The observed motor response is then interpreted in terms of the functional neuronal segment closest to the catheter orifice. The entire procedure requires less than one minute for any given catheter location.

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