# EPIDURAL CATHODAL STIMULATION OF THE SPINAL CORD

## TEMPORARY AND PERMANENT

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## Summary

The evolution of epidural spinal cord stimulation is outlined. Concepts leading to the employment of cathodal stimulation are indicated. The technique and equipment employed in cathodal epidural stimulation is described. Specific advantages of the technique are suggested.

## Introduction

Since 1973, we have employed epidural bipolar electrical stimulation of the spinal cord, temporary and permanent, in problems of motor control and pain. This procedure evolved because of problems inherent in general anesthesia, and a surgical procedure (Laminectomy) and unpredictability of response. A percutaneous trial technique of epidural stimulation was devisèd. Subsequently, the methods of conversion of the same implanted electrodes were devloped (1). The first report of use of spinal cord stimulation for motor control was in 1973 (2). The potential effectiveness of the procedure in control of the neurogenic bladder (3), peripheral vascular disease (4) in Multiple Sclerosis, and pain (5) were recorded thereafter. With increasing experience, it was apparent that modification of the technique was necessary because of movement of electrodes and electrode separation. In addition, methods of handling electrode coupling at operation for permanent conversion demanded improvement. So, too, it was felt that the mode of stimulation could be improved. We had always employed a pulsed monophasic current and only on rare occasions did we employ alternate pulse systems. To date, our experience does not permit any conclusions regarding efficacy of the latter. We can say, however, that in the same patient with the same electrode placement, the sensations perceived by the patient with bipolar monophasic and alternate pulse stimulation are quite different. The significance of this is unknown. However, for some time, we have been concerned about the potential existence of excessive polarization and conduction block which might occur with the use of bipolar system over a pathological spinal cord.

## Neuro-Electrical Concepts

In an attempt to analyze this problem in a recent publication (6) we indicated that when an electrical field is placed about the human spinal cord in an unanesthetized patient the following can be anticipated: 1. Most if not all neurons in the resting nervous system will display infrequency of discharge per unit. The precise time of discharge is not predictable. 2. The response of neurons to a stimulus, such as electric current will be indeterminant and any relationship between stimulus and response can only be viewed in terms of probability. 3. The stimulus would probably cause the same response in hundreds of redundant neurons. This suggests, of course, that any effect would be nonspecific. The specificity of effect which occurs may be related, then, to the condition of the nervous system and its response in terms of polarization phenomena. Since we witness change in behavior and motor control with electrical stimulation of the spinal cord in certain pathological states, it was reasoned that a changed polarization state must be present in neural areas mediating such phenomena. We elected to identify dendritic bundles as the site wherein a motor program may be present for certain types of motor activity, such as gait. Dysfunction seemingly could result from abnormal polarization in these areas. Such concepts demanded that more recognition be given to the manner in which current was delivered. It is known that steady cathodal current induces sub-threshold depolarization of membranes and raises the resting potential. Actually, the stimulus simply completes the process by inducing extra polarization of the membrane under the cathode. This suggested to us the possible advantage of employing cathodal stimulation in contrast to bipolar stimulation. The modification of the bipolar system necessary was simply to use a cathode in the epidural space and a ground elsewhere in the back. Avery Laboratories modified the existing equipment and our first trials were, indeed, successful in that the clinical response was equal to or better than that with bipolar stimulation in the same patients.

Description of Technique

With local anesthesia and the patient in a prone position, a spinal needle (16 gauge modified Hustead-type point) is introduced into the spinal epidural space at the desired level. The usual site has been the mid-thoracic spine.

The tip of the electrode is controlled radiographically. With a stylet in the electrode, it can be directed more appropriately. Most important is the correct placement of spinal needle. With increasing experience, this can be accomplished with facility. It is important that the initial puncture of the supraspinous ligament and plane of needle be directly in the midline. As the needle passes through the interspinous ligament, it follows the caudally angled plane of the spinous processes. When the tip of the needle is advanced beyond the interspinous ligament, different resistance is perceived. Attempts to pass the electrode through the needle at this time may indicate, as viewed under image intensification that the electrode will extend out of the needle for only a short distance. Continued advancement of the needle will traverse the semilunar space between the lamina in the midline and engage the ligamentum flavum where again an increased resistance will be felt. Further advancement of the needle results in a feeling of release of the needle, and at this point, the advanced tip of the needle is in the epidural space. It now can be advanced a minimum distance to clear the bevel of needle. Introduction of the electrode will now find little resistance. Repeat radiography is always necessary. The electrode is passed more rostrally, initially, so that the withdrawal of the needle later over the electrode does not result in loss of the desired level. Finally, the stylet is withdrawn from electrode and a specially adapted fitting is introduced into tip of electrode and fixed with a plastic jacket. This lead wire is then attached to the plastic holder carrying the receiver. A lead wire from a surface (skin) is then attached to positive side of receiver. The antenna leading from the transmitter is finally fitted into the plastic receiver carrier. A sterile dressing is applied. The transmitter parameters used are varied but have been as follows: 7-200 pulses/sec., fixed pulse width of 200 USEC. Gradually, increasing voltages are tried. The conversion to a permanent assembly is carried out in a manner previously described. The new electrodes when cut off at the proper level can now be attached to lead wire from the receiver by a specific fitting. This reduces operative manipulation and reduces danger of displaying electrode intraspinally. The ground is connected to the receiver at the positive pole and placed subcutaneously in the back. The electrode employed is usually nine inches in length with a one-quarter inch platinum tip. The body of the electrode is a platinum iridium wire coated with polyurethane. The indifferent electrode consists of a one inch disc of polished titanium covered with medical grade silicone rubber. The lead wire from the ground is stainless steel, which is also covered with medical grade silicone rubber. (Fig. 1)

Comment

The present modifications 1. eliminate the need for repeated spinal punctures for placement of more than one electrode. 2. Avoid the problems of movement of electrode, one to another, which may occur in the bipolar epidural technique. 3. Reduce the risk of electrode separation to one instead of two electrodes. 4. Facilitate conversion of the implanted electrode by use of special junction adaptors. In all, the process of trial and permanent spinal cord stimulation is simplified greatly. There is little risk and minimal trauma to the patient. The overall effectiveness of spinal stimulation in appropriate patients has not been reduced.

In 1962, Eccles, Kostyuk, and Schmidt reported experiments in the cat, which may have great relevance to the present human model of cathodal stimulation of a diseased spinal cord. They found that when a positive stimulating electrode was placed over the dorsum of the spinal cord that there was: 1. Hyperpolarization of primary afferent fibers. 2. Decrease excitability of these fibers down to 40% of control. 3. Increased excitability of these fibers in the ventral horn. 4 Increase of size of excitatory postsynaptic potential (EPSP). The reverse occurred when the electrode over the posterior columns was a cathode. Specifically, in this instance there was increased excitability of primary afferent fibers in the dorsum of the cord and decreased excitability of these fibers in the ventral horn with resultant increased presynaptic inhibition and a decrease in EPSP. In essence, with cathodal stimulation over the dorsum of the spinal cord in the cat, there was increased or invocation of pre-synpatic inhibition.

Previous studies in man with MS have indicated that with dorsal cord stimulation, there is reduction of spasticity towards normal and in the human neurogenic bladder model, return of more appropriate central inhibition (7). Clinically with stimulation of the spinal cord in MS during the gait cycle, reduction of inappropriate contraction of muscles such as the quadriceps occurs. Specifically, with stimulation during walking, the knee shows increased flexion, more appropriate for this phase of walking cycle. This again signifies the return of more appropriate central inhibition.

As suggested by Eccles et al, the return of inhibition in presynaptic fibers results in reduced EPSP, and this probably is the result of decreased release of transmitter, therefore reduced firing of motor neurons. Seemingly then, this provides a satisfactory explanation of the effects of cathodal stimulation over the dorsum of the cord on tonic relationships. What is not explained is why with return or innocation of presynaptic inhibition by depolarization of primary afferent fibers, there occurs return of voluntary control over movement not possible previously. Quite obviously, the assumption could be made that under ordinary circumstances, suprasegmental structures operate by regulating semental and intersegmental inhibition. If, with an upper motor neuron lesion, there is reduction of this regulation, one would expect to see phenomena, such as spasticity where there is inappropriate contraction and failure of relaxation of muscle appropriate to a movement. Spinal cord cathodal stimulation in this setting would return elements of central inhibition and, therefore, permit regulatory effect of supra segemental structures. This may represent the difference between the presence or absence of "willed" movement.

Footnote

Figure 1. System employed for epidural cathodal stimulation illustrating junctional elements between electrode, ground, and receiver leads. Antenna and transmitter in place.

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