Dorsal Column Electroanalgesia*

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Currently available techniques for relief of chronic intractable pain have left many patients without satisfactory relief. Despite the great advances with percutaneous spinal cordotomy, there is a risk inherent in this procedure; it is most satisfactory only when there is unilateral pain, and it is no better than the older more risky surgical procedures in giving lasting relief. The frequency with which pain returns after a year or more has discouraged most neurosurgeons from performing cordotomy for "benign pain." Spinal comissurotomy offered an attractive alternative particularly if it could be performed with focused ultrasound; yet our experimental studies have demonstrated that although feasible it is technically a cumbersome procedure and difficult to control.7 Rhizotomy is of use in only a very few selected types of pain. Thus, we have been impressed with the continuing need for a means to relieve chronic intractable pain which would be non-addicting, would not affect the patient's personality or mind, and would not destroy normal neural tissue. The use of electrical stimulation of some portion of the nervous system to inhibit pain is currently a popular field of related investigation. Because experimental work1 has shown that activation of the largest sensory fibers, the A-beta group, inhibits spinal input through the smaller pain fibers capable of evoking pain, it has seemed to us that stimulation of the dorsal columns of the spinal cord which have almost pure beta input might give significant relief of pain.

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Experimental Background

We have previously described2-8 a physiological response concentrated throughout the phylogenetically oldest portion of the cord, the propriospinal tract, and not present at all in the dorsal columns of the cord. This response consists of prolonged firing of many units in response to pinching, heat, pinprick, and high voltage electrical stimuli known to activate "C" fibers. It is found throughout the entire spinal axis through the medulla into the medial reticular formation of the midbrain and has strong projections into the cerebellum. It is never seen when only large fibers are activated either electrically or mechanically. Thus, as far as we have been able to determine, prolonged small fiber afterdischarge (PSAD) is uniquely related to pain, and indeed we have demonstrated that if one blocks the large and intermediate beta-gamma and delta peripheral nerve fibers there is an increase in the amount of prolonged afterdischarge with stimulation of the isolated "C" fiber in a peripheral nerve. This result is similar to the Melzack and Wall1 report of inhibition of the response to "C" fiber input by concomitant large fiber stimulation.

Using this physiological system in acute experiments, we found that dorsal column stimulation totally abolished PSAD as recorded in the upper cervical cord, tegmentum, or cerebellar sites.10 Evoked potentials in the thalamus, indicating that significant large fiber activity still travels through the dorsal columns, remain intact during low-level dorsal column stimulation. If an electrical stimulus is applied to the dorsal column of the spinal cord in an acute experiment, total blockade of PSAD occurs during the period of stimulation.8

In continuing experiments, a pulsed average current of 0.5 to 1.0 mA was applied to the dorsal columns of cats. This is well below threshold for tissue damage. During dorsal
Dorsal Column stimulation we were able to pinch and apply intense heat without any apparent pain response in awake animals. In fact, on several occasions the animals began to purr or groom themselves while the noxious stimulus was applied during dorsal column stimulation. However, if the noxious stimulus was continued and the dorsal stimulation removed, the animals would react with the normal violent reaction within 5 seconds of cessation of dorsal column stimulation. Chronic stimulations at 0.5 to 1.0 mA average current for periods of several months led to no histological spinal cord damage; therefore, we felt that it was reasonable to apply this experimental method in man.

Clinical Experience

Dorsal column stimulators have been implanted in six patients. The first two patients were suffering pain from metastatic carcinoma. One died within a short time, of complications due to his cancer. A second patient is still alive and doing well as far as her cancer is concerned 25 months after the insertion of a dorsal column stimulating system. The third patient, a man who had been rendered physically inactive because of severe pain in both legs after a disc space infection 7 years prior to his current procedure, had evidence of L-5 and S-1 dermatome loss bilaterally as well as severe limitation of straight leg raising. The fourth patient has multiple sclerosis and painful paraplegia with severe muscle spasms. The fifth patient has carcinoma of the bladder, and the sixth, cauda equina damage from a misplaced Herrington rod.

All our placements have been in the thoracic spine, 4 to 8 segments above pain input. The electrodes used were square platinum plates about 5 mm square, arranged longitudinally for bipolar stimulation. The platinum plates were attached to silicone-impregnated dacron which was sutured to dura, separated 1 to 3 mm dorsal to the dorsal columns. In one patient both a subarachnoid electrode nearly touching the dorsal columns and another epidural electrode were inserted. The signal or stimulus was delivered to the implanted radio receiver transcutaneously from an external battery-powered radiotransmitter supplied to us by Medtronic, Incorporated (Figs. 1 and 2).

Pulse widths of 0.3 msec with repetition rates ranging from 50 to 275 pulses per sec were available to the patient and under his control; the intensity of voltage delivered was similarly controllable by the patient. In brief experimental runs with alternative external stimulators, a variety of pulse shapes has been used, including sine waves, triangular biphasic pulses, etc. The wave form used in the implanted model is a capacitor-coupled (biphasic) square wave. Repetition rates up to 1000 per sec have been used and have not appreciably altered the response in various patients. Patients prefer a pulse rate between 100 and 200 per sec.

Voltages have varied from 0.3 to 3.0 V, the higher levels being used only with monopolar electrodes. We now use a bipolar arrangement (Fig. 1). In these patients, less than 0.5 V is adequate for stimulation. This current, measured in one patient with a special receiver, was about 0.5 mA average current. With the large surface area of our electrodes, the total power density is well below 0.05 W/in², the level for threshold damage in experimental studies.