Reprinted From
HEADACHE
Volume 9 July, 1969 Number 2
PRINTED IN U.S.A.

DORSAL COLUMN ELECTROHYPALGESIA

C. NORMAN SHEALY, M.D.

ANATOMICAL PAIN pathways have been thought to be well known for many years. It has long been thought that pain information is transmitted into the spinal cord where is crosses within four spinal segments to the opposite anterolateral quadrant of the cord. Fibers are supposed then to travel in the anterolateral quadrant of the spinal cord to the thalamus. Such simplicity of anatomical evidence gained from almost ancient degenerative studies totally ignore the unmyelineated nature of most pain input fibers. Even more important, the majority of fibers within the cord make multiple synaptic connections so that degeneration studies are doomed from the beginning. The mere fact that some degeneration is seen leading to the thalamus after anterolateral cord section is hardly proof that these fibers are at all concerned specifically with pain.

GREAT CONCERN HAS been expressed over the "nature" of pain and yet by its very nature pain is not a simple phenomenon. It is not a simple sensation. It is not invariably the result of a given stimulus. Pain is a disagreeable sensation occurring spontaneously or as the result of some provocation which could be potentially harmful to the organism. "Normally" pain is a warning that the stimulation being received is in fact dangerous.

THERE ARE MANY stumbling blocks in this system most of these being psychiatric. Indeed the greatest problem in understanding pain in man is the great-phychiatric or emotional overlay. As far as conscious perception of pain is concerned, however, there is great doubt from clinical observations that pain can even be consciously perceived if a painful stimulus is not accompanied by non-pain input. In patients who have had a major non-dominant or right hemispheric stroke with total loss of motor and apparently of sensory function we find that intense stimulation of the "anesthetic" left limbs or body leads to physiological changes in the patient suggesting that he is in distress or pain. The patient writhes about on the bed looking as if he is in the most intense pain. His pupils may dilate. His pulse and blood pressure go up. Occasionally he may exclaim, and yet if asked specifically if he is in pain, he denies that there is any pain whatsoever. As proprioceptive stereognostic sensation returns so that gross localization of touch and heavy pressure can be perceived by the patient he begins to appreciate pain of an intense pinch, and yet even at this stage he cannot localize the origin of the pain. He may growl at the physician "You're hurting me" but be totally unable to tell where the hurt is applied. And indeed accurate localization of the pain in this individual occurs *only* when the patient has regained enough large fiber proprioceptive information to enable him to tell you exactly which finger is being touched.

IF WE EXAMINE THE physiological work of all investigators who have worked with central nervous system pain physiology we find a reproducible physiological response to intense electrical stimulus capable of producing pain in man or to mechanical stimuli which would be painful in man.[1,2,3,4,5] A firing of cells occurs beyond 500 milliseconds after the ceasation of the stimulus, and indeed not a single cell has been found to fire after a noxious stimulus which does not fire in this fashion of repetitive firing, lasting for a relatively prolonged period after ceasation of stimulus. Of

Department of Neurosurgery, Gundersen Clinic, Inc., 1836 South Avenue, La Crosse, Wisconsin 54601.

This work supported by the Adolf Gundersen Medical Foundation and the Boothroyd Foundation.

even greater importance is the fact that these same cells responding to the noxious stimuli fire also to non-painful stimuli and they discharge to stimuli from many body areas. There is not a single exception in recorded results; in other words, no cell which responds to pain is "specific" for pain. All cells responding to pain are multimodal, multifiring and indeed within the spinal cord itself cells responding to pain can be activated almost equally well by stimulation from forelimb or hind limb as far as twelve spinal segments caudal to sensory input.

NORMALLY BALANCE exists between the the input of large beta sensory fibers, intermediate gamma delta fibers and the smallest 'C' fibers; large fiber activity predominates within the central nervous system. It travels fastest, never elicits a sensation of pain and inhibits at the first spinal synapse input from the smallest fibers.[6] Damage to the largest fibers with resultant uninhibited input from 'C' fibers results in abnormally low thresholds for pain such as in postherpetic neuralgia. Thus one might say that it is possible that all activity in "C" fibers would be painful if concomitant large fiber information did not tell the true nature of the stimulus.

THE COMMON PROBLEMS of "referred pain"or "sympathetic pain" are almost more common than focal pain. Those organs with primary 'C' fiber innervation are notorious for their problems in localization of pain.

THERE ARE A NUMBER of abnormal nerve input situations when the body is deprived of basic information such as in spinal cord or peripheral nerve injuries. In many of these patients pain results from non-painful stimulation. In other words, *sensory deprivation* results in pain or hyperalgesia.

THUS, THREE IMPORTANT factors emerge from this brief condensation of pain physiology. First, that pain is the result of uninhibited 'C' fiber activation and may result because of excessive tissue damage, or threatened tissue damage, or because of sensory deprivation following damage to large sensory fibers. Secondly, cells within the nervous system which respond to pain are always multimodal and are activated from a variety of somatotopic areas. And thirdly, localization of a sensation of pain is entirely dependent upon the integrity of large fiber proprioceptive and stereognostic information.

USING THIS INFORMATION three years ago we advanced the theory that stimulation of dorsal columns, which contain almost pure beta fiber input, would inhibit pain.[7,8]

OUR BASIC RESEARCH IN cats demonstrated physiologically and clinically that this was indeed true. We now have clinical experience with four patients in whom dorsal column stimulation has been carried out over prolonged periods.

THE FIRST PATIENT, a man with carcinoma of the lung metastatic to pleura and liver, had intense pain which was apparently relieved by stimulation of dorsal columns in the upper thoracic region. Unfortunately he lived only a short time after the spinal cord implant was performed and expired from complications of his cancer.

THE SECOND PATIENT, a lady with metastatic carcinoma of the endometrium throughout the pelvis, had a dorsal column stimulating electrode with radio-receiving pacemaker implanted almost seventeen months ago.

THE THIRD PATIENT is a 55-year-old man almost completely confined to bed for the past seven years because of pain in his legs following a disc space infection.

THE FOURTH PATIENT has multiple sclerosis with paraplegia and painful muscle spasms.

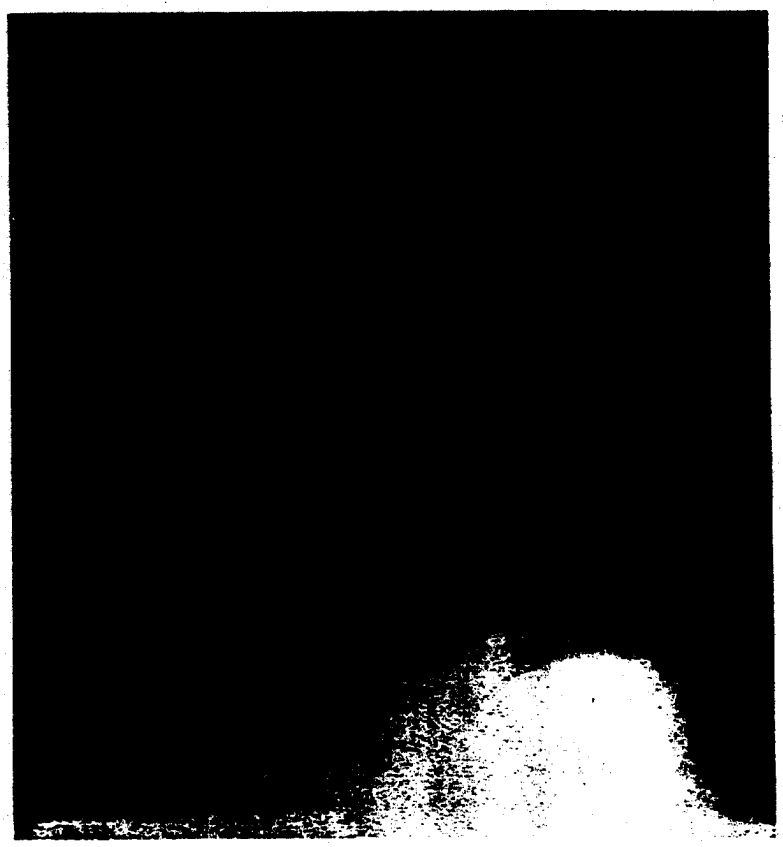

FIG. 1—X-ray of implanted spinal cord electrode and subcutaneous pacemaker.

THE IMPLANTED system (Fig. 1) consists of platinum electrodes applied intradurally so as to touch the dorsal columns; in one patient a second electrode system was also implanted epidurally. The patients themselves can control stimulation by an external radiotransmitter which is of miniature size. A capacitor-coupled biphasic pulse is delivered with a pulse width of 0.3 milliseconds. Pulse widths of 20 to 150 and voltages from 0 to 5 volts are under control of the patient. Patients have preferred the higher frequencies of stimulation and have worked with currents which have ranged upwards to 0.5 milliamps. On several occasions we have tested the effectiveness of sine wave, of biphasic square wave or triangular biphasic pulses with frequencies ranging up to 2,000 cycles per second. No significant improvement in pain relief or alteration in sensation is achieved by these more marked variables.

ALL PATIENTS HAVE felt the puzzling sensation radiating into both legs, if the intensity of stimulus is high enough. this has not been interpreted as pain.

PAIN THRESHOLD AS tested by electrical stimulation of the skin has been raised from 50 to 200% over base levels. Light touch remains intact as does vibration and position sensation. Patients are able to walk without difficulty. Bladder and bowel function are not affected. Erections and ejaculations are possible during stimulation. Pinprick, at least in some patients, is felt as hyperalgetic despite maintenance of normal function in non-painful spheres, and despite the increase in pain threshold to electrical

stimulation of the skin and despite the decrease in appreciation of deep pain such as pinching of the Achilles tendon.

PAIN RELIEF HAS been excellent in one patient, with stimulation of 6 to 8 hours per day. A second patient has excellent relief but becomes "bored" with the buzzing stimulation and uses the stimulator for relief only half time. The patient with multiple sclerosis had good pain relief for several months but has recently had an excaberation of her primary disease with little effect by dorsal column stimulation at this time.

ANALGESIA HAS NOT been produced and indeed one might expect that analgesia could be produced by counter stimulation only if total peripheral anesthesia is achieved. Such anesthesia can be produced by stimulation of peripheral nerve.[9] Such is undesirable for there would probably be paralysis with total anaglesia produced by excessive large fiber stimulation. Hypalgesia must be accepted as the maximum that can be expected from stimulation of dorsal columns. It is entirely possible, of course, that stimulation of the anterolateral or ventral portion of the spinal cord might yield analgesia without anesthesia. In cats our physiological studies suggested that stimulation of the ventral spinal cord inhibited physiological response to pain as satisfactorily as did dorsal column stimulation. In this instance we must assume that we are blocking transmission by a direct depolarization or hyperpolarization of tracts in the anterior cord, rather than by turning off the "gate"[10] through large fiber stimulation as is suspected with dorsal column stimulation.

SUMMARY

USING PHYSIOLOGICAL evidence gained from studies of our own and of other investigators we have tested the theory that dorsal column stimulation would produce relief of pain. Prolonged stimulation has been carried out in four patients with improvement in pain and a significant increase in pain threshold without production of analgesia. The lack of any significant complications in the patients who have been treated with such stimulation for periods up to almost seventeen months should now allow application of this treatment to a large number of patients with chromic pain states.

REFERENCES

1. Collins, W. F., and Randt, C. T.: Evoked Central Nervous System Activity Relating to Peripheral Unmyelinated or 'C' Fibers in Cat. *J. Neurophysiology*, 21:345-352,
2. Collins, W. F., and Randt, C. T.: Midbrain Evoked Responses Relating to Peripheral or 'C' Fibers of Cat. *J. Neurophysiology*, 23:47, 1960.
3. Poggio, G. F., and Mountcastle, V. B.: A Study of the Functional Contributions of the Lemniscal and Spinothalamic Systems to Somatic Sensibility. *Bulletin of the Johns Hopkins Hospital*, 106:226-316, 1960.
4. Mendell, L. M., and Wall, P. D.: Responses of Single Dorsal Cord Cells to Peripheral Cutaneous Unmyelinated Fibers. *Nature*, 206:97:99, 1965.
5. Shealy, C. N.: The Physiological Substrate of Pain. *Headache*, 6:101-108, 1966.
6. Wall, P. D.: Presynaptic Control of Impulses at the First Central Synapse in the Cutaneous Pathway. *Progress in Brain Research*, 12:92-118, 1963.
7. Shealy, C. N., Taslitz, N., Mortimer, J. T., and Becker, D. P.: Electrical Inhibition of Pain: Experimental Evaluation. *Anesthesia and Analgesia—Current Researches*, 46:299-305, 1967.
8. Shealy, C. N., Mortimer, J. T., and Reswick, J. B.: Electrical Inhibition of Pain by Stimulation of the Dorsal Columns: Preliminary Clinical Report. *Anesthesia and Analgesia—Current Researches*, 46: 489-491, 1967.
9. Wall, P. D., and Sweet, W. H.: Temporary Abolition of Pain In Man. *Science*, 155:108-109, 1967.
10. Melzack, R., and Wall, P. D.: Pain Mechanisms: A New Theory. *Science*, 150:971-979, 1965.