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Dorsal Column Stimulation: Optimization of Application

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Although the basic efficacy of dorsal column stimulation (DCS) has been shown, its optimal use remains to be defined. Since 1970, a program designed to maximize clinical success with DCS has been under way at Temple University Health Sciences Center. This article reviews patient screening, operative technique, new instrumentation and postoperative adjustment in DCS. Clinical results and long-term impressions of 90 implants in 75 patients are reported.

Patient Screening

In determining candidates for DCS prior to implantation, a comprehensive screening program was established consisting of psychiatric and psychologic evaluation and patient response to electrical nerve stimulation.

Personality factors were considered through psychiatric and neurosurgical interviews and the Minnesota Multiphasic Personality Inventory (MMPI). We attempted to screen out patients who had significant emotional problems beyond those due only to intractable pain, patients in whom pain had a financial reward and patients who required their pain for personal survival. A study of the first 42 patients[4] indicated that the experienced neurosurgeon's opinion was as valid as the psychiatrist's. The MMPI has consistently proved valuable in documenting the common association of depression, hysteria and hypochondriasis with intractable pain. It has been of great assistance in identifying patients with significant emotional problems not initially evident to the interviewer.

At present, potential DCS implantation candidates have a neurosurgical interview, complete a pain questionnaire and the MMPI, are reviewed by a panel of physicians with an interest in pain problems (at a weekly conjoint pain conference) and receive psychologic consultation when required. Despite these measures we retrospectively estimate that 8-10% of patients who received implants should not have been candidates on the basis of emotional factors evident postoperatively. Because of their need for a high dosage of pain relief medications over a long period, most of our patients are drug abusers; drug rehabilitation is attempted in all patients. The patient's long-term ability to discontinue pain medications has related directly to DCS success.

Electrical nerve stimulation (ENS) was used to acclimate the patient to the sensation and to determine the degree of pain relief. No patient was considered a DCS candidate from this standpoint unless he experienced significant pain relief with ENS.

ENS has been used basically in the transcutaneous mode (TENS). A crude but effective battery-operated stimulator operating on the inductorium principle was used initially. The need for more sophistocated instrumentation led to the design of compact, solid-state, single- and multichannel battery-operated complex waveform generators.* Skin electrodes consist of pads and paint-on ("epiductive") systems.[3] A patient being screened undergoes TENS two to three times a day over a four-day period under the supervision of an experienced technician. The degree of pain relief and its duration following cessation of stimulation are carefully documented (Fig. 1).

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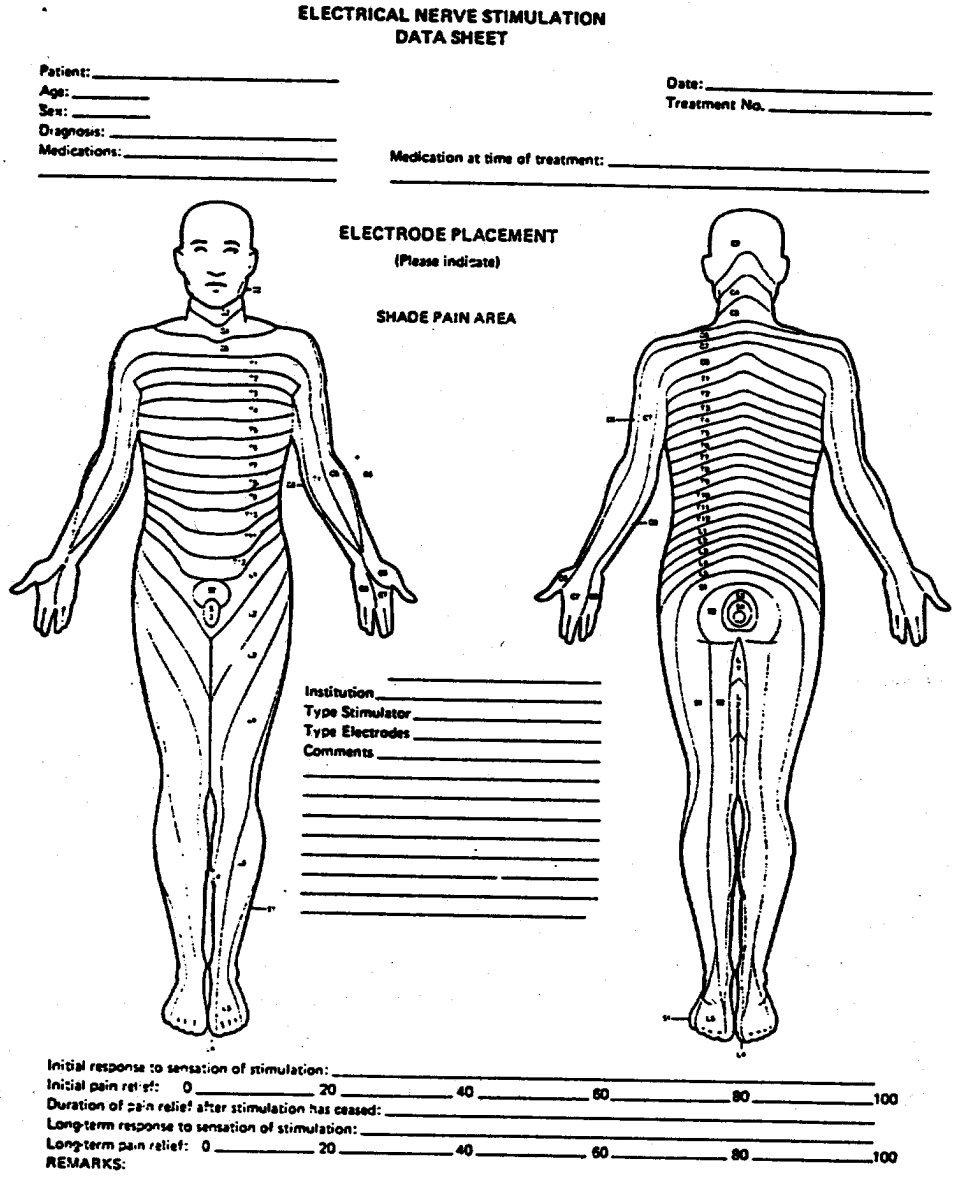

FIG. 1. Data sheet used to document degree of pain relief and its duration after cessation of stimulation.

Our experience indicated that ENS not only was one of our most valuable screening tools but also showed significant potential as a therapeutic modality in its own right.[3] Generally, patients with peripheral neuropathy (i.e., diabetic) are unable to obtain pain relief.

Percutaneous ENS of peripheral nerves and trunks was also used in our DCS screening. This screening modality has found greater application, however, in determining candidates for implanted peripheral nerve stimulators (i.e., sciatic, brachial plexus, etc.) than for DCS units.

Direct stimulation of the dorsal columns of the spinal cord by a subarachnoid "floating" electrode introduced in the cervical or lumbar area has been used when site of stimulation was considered a crucial factor. This has been shown particularly in patients with traumatic transection lesions of the spinal cord. In one patient with T3-4 postherpetic neuralgia, the spinal cord was insensitive to stimulation of the T2-5 segments.

Operative Technique

The sitting position is used during cervical electrode placement, while thoracic placement is accomplished in two stages. The receiver is always placed in a subclavicular pocket. For thoracic insertion, the receiver is implanted with the patient in the supine position. The lead wire and electrode are brought out at the shoulder and wrapped in sterile gauze. The patient is turned to the prone position on the operating table, the dorsal thoracic field is draped and the laminectomy with electrode implantation is carried out. All patients are maintained on antibiotics starting 24 hours before surgery.

The first four electrodes in our series were implanted subdurally. In the fourth patient, transient spinal cord compression developed and was relieved by electrode removal. Because of this complication and other considerations to be discussed, a better anatomic placement site was considered necessary.

In an experimental study to determine dural reaction to implanted material of low-biologic reactivity (Teflon®), 19 adult cats were used. Pentobarbital (Nembutal) was used while each animal's skull was stabilized in a sereotaxic device and bilateral 2.5-cm^2 cranial defects were created. In 18 animals a bilateral 1.0-cm^2 area of dura was removed and microporous and woven Teflon® patches 0.005 to 0.032 inch thick were applied over the dural defects with Eastman adhesive. Bilateral implants were placed in 16 animals, no implants were placed in two animals and dural defects were not created in one animal. Animals were sacrificed, and fixative per-

* Supplied by General Plastic Corporation, Bloomfield, New Jersey, and United States Catheter and Instrument Corporation, Glens Falls, New York.

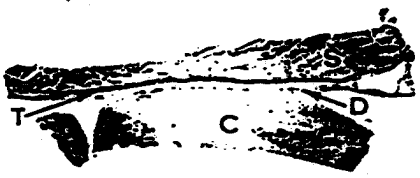

FIG. 2. Representative photomicrograph showing cross section of scalp muscle (S), dura mater (D), Teflon® (T) and cortex (C). Teflon® implant 0.005 inch thick is entirely enveloped in dura mater, with parietal layer thinner than visceral layer. Enclosure and minimal reaction was characteristic of all specimens studied.

fused, 55 to 90 days after surgery (mean survival 69.5 days). The block area of scalp, dura and brain was then removed from each side and serially sectioned in thicknesses of 20μ after fixation and embedding in paraffin. Sections were alternately stained with hematoxlyn-eosin, Nissl and myelin stains.

Histologic examination of all specimens revealed regrowth of dura within 55 days. In control animals, dural regrowth was complete. All Teflon® implants were completely enveloped by proliferating dura and only a minimal leukocytic reactive response was evident (Fig. 2).

This study showed experimentally the high-grade dural response to an implant material of low reactivity. It was felt that subdurally placed silicone encapsulated electrodes would also initiate the same dural response and perhaps even arachnoiditis. The endodural (initially referred to as "intradural") implant site was devised[2] to avoid this reaction as well as spinal cord compression, cerebrospinal fluid accumulation around the electrode, cerebrospinal fluid fistula, meningitis and damage to the electrode sutures passing through it in implants in contact with the dura.

It was theorized that the single layer of spinal dura, developed from primordial mesenchymal condensation, could be split into "two" layers. In this way a pocket could be created into which the electrode could be placed. The reactive dural (fibroblastic) proliferation would be minimal, since the electrode was essentially encapsulated (by dura) to start. In addition, the subarachnoid space would not be entered and the electrode would be uniformly supported without sutures passing through it when the outer layer of dura was closed. This support would tend to avoid the rare but surely most serious DCS problem—spinal cord compression.

FIG. 3. Platinum tinsel bipolar electrode in endodural pocket created by microdissection. Electrode is sealed in place by four 6-0 Prolene sutures closing external dural layer.

As of the fourth case in September 1971 the remaining 86 implants were endodural (Fig. 3). In two patients the opportunity arose to examine the implant site at eight and 18 months after surgery. In both cases there was no significant dural thickening anywhere beneath the electrode or evidence of arachnoiditis. In all 86 implants endodural placement avoided cord compression from the electrode, cerebrospinal fluid leak fistula, meningitis and electrode damage.

Instrumentation

To facilitate the subcutaneous passage of DCS lead wires and electrodes and to avoid damaging the delicate silicone insulation, a guide dissector called a "Zorro" (Fig. 4) was designed. The tip of this instrument is tunneled beneath and exited through the skin. A No. 2 silk suture is passed through the tip, knotted and pulled back, or a ¾ inch diameter Penrose drain is tied to the collar of the tip with a No. 2 silk suture. The DSC electrode is passed into one end of the Penrose drain and tied down with sutures on either end of the electrode. The Zorro is used to pull the opposite end of the Penrose drain directly through the subcutaneous space or the passed No. 2 silk is tied to the opposite end of the drain for traction. The elasticity of the drain allows the operator to exert only that degree of force necessary to pull the encapsulated electrode through the subcutaneous tunnel, thus protecting the device.

An instrument dubbed a "Frazie" (Fig. 5) is a microdissector using the advantageous features of the Frazier and Kurze dissectors. It has been particularly useful in developing the endodural space after partial incision into the dura with a No. 15 scalpel. The procedure is

FIG. 4. "Zorro" tunneling instrument. Channel at tip permits insertion of No. 2 silk suture (waxed) which is then knotted and drawn subcutaneously. Arrow shows groove at which Penrose drain can be held directly to tip.

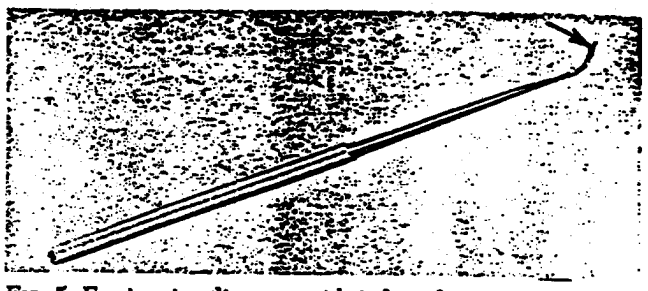

FIG. 5. Frazie microdissector with indented groove on concave surface (*arrow*) to permit passage between dural leaves to further incise them with a No. 15 blade.

performed using operating telescopes with a magnification of 4.5 and a fiberoptic headlight. Once the endodural plane has been established, dissection with the Frazie must extend from that point in all directions, as multiple endodural planes can otherwise be developed.

Postoperative Adjustment of Stimulation Parameters

In addition to routine postoperative care, variation of stimulation parameters can alleviate a number of postoperative DCS problems. Often the requirement is beyond that allowed by the standard commercially available transmitter units (Medtronic or Avery). Variation in configuration of balanced waveform appears to be the least important parameter.

Comparison of stimulation characteristic of subdural versus endodural electrodes based on our own data and that of other investigators has indicated that endodural electrodes are initially less efficient electrically (in terms of power used versus cord penetration) than are subdural electrodes. In time, however, this situation frequently reverses, and when it does, it is probably due to a progressive fibroblastic response around the subdural electrode. Evidence now indicates that subdural implants often end up with less electrical efficiency than do endodural implants. Further, endodural electrodes tend to stabilize electrically after a few months, but subdural implants may require increasing voltage to maintain the same level of stimulation for as long as a year or more. A review of the surface area of electrodes presently in use indicates a variation of 1-50 mm^2 for a single pole. In electrodes with small surface area, voltage requirement for adequate stimulation may be higher than that delivered by standard commercial units (Medtronic 8 V, Avery 12 V [effective]). Under these circumstances, custom units with higher output may be required.

A significant number of patients with thoracic implants complain of excess stimulation in the chest or abdomen or on one side of the body. Changes in the pulse duration (p.d.) of the stimulation waveform can frequently modify or alleviate this problem. This often requires a p.d. above the output of the standard DCS transmitter (Medtronic 0.35 msec, Avery 0.4 msec) and frequently involves the 0.6-1.5 msec range, for which customized units are required.

Because clinical success may depend on stimulation parameters beyond the capability of standard transmitters, it is recommended that neurosurgeons interested in endodural DCS implantation obtain and use testing units having a voltage capability of 14 V and a pulse duration of up to 1.5 msec. Care must be exercised with electrodes located in close proximity of the spinal cord, as the potentially toxic levels of stimulation have not yet been determined.

Results

Our first DCS was implanted in June 1971, and to date 88 thoracic and two cervical DCS units have been implanted in 75 patients. Both Medtronic and Avery systems have been used; double implants were performed in 15 patients. This was done to salvage poor results and to compare different electrodes and systems. After the fourth case, all implants were endodural. The 3-plate bipolar electrode was used in the first nine patients. In March 1972, a change was made to the platinum tinsel monopolar electrode because of its small size. This turned out to be an error in judgment, as most of these patients noted within weeks after surgery a shift of the stimulation pattern to the intercostal area. In September 1972, we returned to exclusive use of bipolar systems except when the adverse stimulation pattern of the monopolar system was deemed desirable.

Table 1 lists the diagnoses of the 75 patients, who each had an average of 3.3 previous operations. Most (55) had adhesive arachnoiditis, almost exclusively of the

TABLE 1
CLINICAL DIAGNOSES IN 75 PATIENTS BEFORE DCS IMPLANT

adhesive arachnoiditis	55
causalgia	6
lumbar spondylosis	2
spondylolisthesis	2
cancer	1
miscellaneous	9

lumbar spine (one cervical). The diagnosis was established by direct observation, myelographic interpretation or inference from symptoms occurring in approximately equal numbers.*

The first 63 patients who received DCS implants have been observed through follow-up an average of 11.9 months; results are shown in Table 2. Success was determined through questionnaires sent out at regular intervals to the patient by a third party.† The determination relates to the patient's estimate of pain, need for pain medication and level of activity. Some patients in the poor category continue to use their DCS, but medication and activity have not changed and they have been included in our group of 19% with unsuccessful results. An excellent result is one in which pain is under control, the patient uses no significant medication and is functioning at a normal level.

Interestingly, these results are worse than those I predicted on the basis of personal impressions and office data.

Clearly, these patients all have complex problems, and therapeutic success has related to many variables, such as "the laying on of hands," drug rehabilitation, rehabilitation and physical therapy and counseling.

Table 3 lists complications. The fourth patient was the only one in whom transient spinal cord compression was due to an electrode (and the only patient in the series with cancer). A second patient had transient compression due to self-curing silicone placed over a monopolar electrode to avoid adverse stimulation. Reexploration with removal of the silicone alleviated the problem.

The most frequent complications in this series related to inadequate stimulation or DCS stimulation without pain relief. Of all previous operations performed on our patients, 31% were destructive to the nervous system (cordotomy alone constituted 12%). These patients appeared to be the ones most frequently experiencing inadequate stimulation after DCS implantation. This characteristically involved the anesthetic body side when cordotomy had been performed. Postoperative changes in stimulation parameters, particularly change to a high pulse duration in the stimulating waveform, saved many of these patients.

Stimulation without pain relief is a much more serious problem and is one we have not solved. Screening tests are designed to eliminate such patients before surgery, but in at least four of our patients this occurred in localized areas after a number of months.

Clearly the long-term effects of DCS remain to be seen. We have been encouraged to see in some of our patients observed longest in follow-up a tendency to require less frequent use of the DCS. We can only hope that this is a statistically significant trend, but only time will tell.

In comparison studies involving dual Medtronic and Avery bipolar systems in the same patients (2) and bipolar systems in matched patients (12), no significant differences could be determined that were directly attributable to the systems.

TABLE 2
RESULTS OF FOLLOW-UP EXAMINATION* IN 63 PATIENTS WITH DCS IMPLANTS

Result	No. of patients	Percentage	
excellent	7	11.1%	
good	30	47.6%	58.7%
fair	14	22.2%	
poor	6	9.5%	19.0%
failed	6	9.5%	

* Average follow-up, 11.9 months.

TABLE 3
COMPLICATIONS IN PATIENTS WITH DCS IMPLANTS

temporary paraplegia	2
inadequate stimulation	14
stimulation with no pain relief	6
extraneous stimulation	4
electrode removed	3
superficial stitch infection	2
seroma at receiver site	2
electrode repositioned	1
lead wire erosion of skin	1
accentuation of spasm	1
pain in lead pathway	1
receiver malfunction	1
lead malfunction	1
implant injury lead wire	1
wound infection-meningitis	none
CSF leak or accumulation	none

Summary

Application of dorsal column stimulation for the relief of intractable chronic benign pain appears to be a reasonable therapeutic approach if patients are carefully screened and managed by experienced physicians willing to assume responsibility for the multiplicity of complicating factors inherent in the management of such problems. From the results presented, acceptable beneficial results evidently can be achieved. It is also evident that a significant failure rate presently exists. Considering this and the fact that DCS is not an innocuous or simple means of therapy, we should limits its use to patients who are functionally incapacitated and in whom all other modes of therapy have failed.

Since DCS has not yet been perfected, it should be considered investigational. I believe that the efficacy of DCS will improve and that other systems employing neuromodulation will replace many of the presently destructive pain relief procedures currently being advocated for the treatment of chronic benign pain.

Acknowledgments

I would like to thank Drs. Leroy Krumperman, Roy Stern, Chester Schneider, Robert Mabel and Nathan Mayer for their help in evaluating our patients. Particular appreciation is directed to Berkley Fogelsonger and Edward Brownell for their exhaustive efforts in screening and assisting our patients and to the technical

* To be reported in detail in a future publication.

† Medtronic, Inc. sent out questionnaires based on DCS study group recommendations. Results are based on our tabulation of these data.

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References

1. Bakken, E., Avery, R.: Personal communication, Oct. 1973.
2. Burton, C.: The Intradural Site for DCS Electrode Implantation. Presented at the Dorsal Column Study Group Meeting, Boston, Mass., April 16, 1972.
3. Burton, C.: "Pain Suppression through Peripheral Nerve Stimulation in Neural Organization and its Relevance to Prosthetics." Miami, Symposia Specialists, 1973.
4. Burton, C.: Seminar on dorsal column stimulation: Summary of proceedings. *Surg. Neurol.* 1973, 1:285-289.
5. Burton, C., Maurer, D.: Neuromodulation by transmitting electrode IEEE. *Trans. Biomed. Engineer. (in press for March, 1974)*
6. Shealy, C. N., Mortimer, J. T., Hagfors, N. R.: Dorsal column electroanalgesia. *J. Neurosurg.* 1970, 32:560-564.

Supplement

Because of the multiplicity of variables inherent in the use of dorsal cord neurostimulators, their clinical value continues to be difficult to assess. As of December 1, 1974 data has been collected on one hundred and ten dorsal cord neurostimulator electrodes placed endodurally. Although other problems have occurred there have been none of the following significant complications: 1) spinal cord compression due to electrode; 2) cerebrospinal fluid fistula; 3) cerebrospinal fluid leakage*; 4) meningitis.

No electrode required repositioning because of progressive arachnoiditis and coincident decrease in spinal cord stimulation. It is the author's firm belief that the endodural implant site is a significant factor in improving clinical efficacy by removing the most significant adversities of dorsal cord neuro-stimulation.

The long-term follow-up series has now been extended to two years and the results noted in the paper are still valid.

The author believes that it is rare when the implantation of a neurostimulator alone suffices to rehabilitate a patient with an intractable pain problem. The best clinical results are obtained when neurostimulation is used in conjunction with a comprehensive and interdisciplinary care program carried out by physicians willing to make a full-time commitment to such patients.

* In one case the subarachnoid space was inadvertently entered and leakage of CSF occurred. This was surgically corrected.

Discussion

Q. *Nashold*

We have also seen profound autonomic changes in some cases. Now I would like to ask, what happens to the patient being stimulated while he is on medication; is he then able to eliminate medication? In our group of patients, although they had gotten relief of pain, they had difficulty in ridding themselves of their medication, whatever that medicine would have been.

A. *Picaza*

Of the 23 cases implanted, 11 absolutely dropped all medication in time. Generally, all cases take very little time to detoxify or wean from their drugs. Now, there are two of the 23 that still take some non-narcotic analgesics. We have some follow-up data on asking patients what happened to their drug use pattern. Since this was in response to a questionnaire, I'm not sure how valid the answers are. There were about ten of our 182 patients who were initially taking narcotics regularly who are now no longer taking narcotics. However, the vast majority of those patients who reported partial relief, as you recall that was all but about 7% of the ones that got any relief, are still using some analgesic medications or some Valium or other psychotropic drug.

None of the patients in my series were addicted in the usual sense of the word. Many were taking codeine and reduced their dosage. A few were taking Percodan and could not be weaned from that particular drug. Several were taking Talwin and again we had great difficulty in withdrawing this drug from the patient; this is reminiscent of some remarks that Dr. Shealy has made regarding the addicting qualities of Talwin.

In the past few years, all modern medicine has practiced a rather ridiculous approach to both drug administration and withdrawal of patients. In a real sense, we found that the majority of the patients who have been brainwashed on drugs, will remain on drugs whether or not they achieve pain relief by stimulation or other means.

Q. *Ray*

Dr. Sheldon this morning mentioned that in a number of the patients who were clearly addicted to narcotics, but who had excellent pain relief, there were no physiologic withdrawal phenomena on cessation of drugs even though such was initially expected. I would like to ask if others also have noted the absence of a drug withdrawal syndrome in patients who got good pain relief by electrical stimulation in whom no further drugs were needed.

A. *Sweet*

We have one rather unusual observation directly bearing on that question. The individual concerned is a 30-year-old male, who was on massive doses of methadone for a pain which was originally related to a meningitis in childhood. A variety of operations had been done, including two or three cordotomies, in an effort to control this pain. The

patient after implantation of his stimulator against the cord, was permitted to continue his methadone dosage on demand. The PRN order was still in force. However, he had the most dramatic relief of his pain of any of the patients in our series. He said that throwing the switch on, to activate the stimulator, resulted in a turn-off of his pain as abruptly as though he turned out a light with a light switch. And he simply didn't ask for any more methadone. Approximately a week post-operatively, he began to behave rather oddly and not until he said to me one morning —having indicated how happy he was about his pain relief—that he was unhappy about the fact that two chaps outside the hospital in that car were saying things about him. He proceeded to develop a florid paranoid psychosis which our psychiatric consultant suggested could conceivably be on the basis of this total and abrupt failure to use any more methadone. When he was put back on his methadone, gradually the psychosis came under control, permitting withdrawal from the methadone without recurrence of the psychosis. In this one individual at least, it would look as though the drug dependence operated essentially independently of the pain and the total relief of that pain by this other modality.

A. *Nashold*

We usually try to wean a patient very slowly off drugs following dorsal column stimulation so that I don't think we ever saw such a situation. But another interesting thing is that in the depressive patient, you might get excellent relief of his pain but he might still be depressed, and you would go on and treat him psychiatrically for his depression perhaps for a long time. We found similar problems when we were doing tractotomies, and so forth. You have to relieve pain and also treat depression.

A. *Shealy*

I have never abruptly withdrawn a patient from narcotics and indeed my position for at least the last few years has been that I don't put narcotics on a PRN basis just as Fordice has emphasized. I agree with him entirely. I put them on a time regulated dose basis and withdraw the patient from them gradually. We find that we can withdraw patients within about two weeks no matter how much they're taking, with a planned program of reduction. However, even if we take a month to withdraw them, we find that most patients who have been heavily habituated to narcotics and tranquilizers have a period of weeks or months of nervousness, agitation, insomnia and depression when they come off these drugs.

It's interesting that in the patients with cancer who come up for a cordotomy, even though they may have been on very heavy medication, almost always these patients can do without their narcotic immediately post-op, and do not seem to have withdrawal syndromes.

A. *Hoppenstein*

I've had similar experiences with many patients with cordotomy where they have been on heavy dosages of narcotics for anywhere from three to nine months and as soon as they have relief with the cordotomy, have gone off narcotics; only two cases out of perhaps 100 had any withdrawal problems. That's with percutaneous cordotomy. With the DCS I have had two notable patients—one with a pancoast syndrome with intractable brachialgia and the second patient also with intractable brachialgia secondary to a carcinoma of the breast infiltrating the brachial plexus—both of whom had been on narcotics around the clock every two to three hours and I think within 24 hours after surgical implantation, in the high cervical region, these patients were able to totally discontinue narcotics and remain so until they died.

A. *Gildenberg*

If I might comment on two points. The procedure that I've adopted for evaluation of patients for implants begins with transcutaneous stimulation and then to percutaneous and only then to dorsal column stimulation. And there are several points about each step. There is a certain small number of patients that do respond so well to the transcutaneous stimulation alone that one need not go any further; I certainly think that if a patient does get relief at that point, it's not justifiable to go any further. Those patients who get either unsatisfactory relief or only temporary relief from the transcutaneous stimulation should have, as I find in dealing with such cases for the last two years, a trial using the percutaneous technique. This technique includes a flexible electrode inserted at the C2 level that is then threaded down the spinal canal, ideally to the lower cervical or upper thoracic level. This has been used in 24 patients having pain syndromes and in 15 patients for other stimulation purposes, such as torticollis. The electrode has been left in for as long as a week and this makes it possible to have the patient up and walking around, to send him to physical therapy with the stimulator in place and to evaluate better whether the patient's activity tolerance may be improved with stimulation. However, it does not rule out the possibility that the patient may have no relief with a permanently implanted unit. The greatest value at this point is to rule out those patients who don't tolerate the sensation, those who don't tolerate the stimulation for a long period of time, and also those patients who have a poor tolerance to appartus. There is a fairly good correlation between the response of the patient at the time the percutaneous electrode is inserted with their eventual outcome; those patients who tolerate having a needle put in the side of their neck least well are those who tolerate the sensation of the stimulation least well, which I

imagine is of no surprise to anyone.

A few words about evoked potentials: We've had the opportunity in two patients to measure thalamic evoked potentials after dorsal column stimulators have been implanted and I'm very happy to see that other people are also finding very fast conduction times. We were a bit confused about the speed of the conduction time, which has been well over 70 meters a second in one of the patients. We also have some preliminary data to suggest that evoked thalamic potential on stimulation of peripheral nerves does change its wave form with this dorsal column stimulation. And this occurs even when the dorsal column stimulation is administered below the roots into which the evoked potential is being introduced to the central nervous system, which may suggest also that some of the gating is done at thalamic rather than at spinal levels. I hope within the next few months we'll have some additional data concerning this.

A. *Mazars*

Listening to these presentations, I am concerned that there is something different between pain problems found in the States and in Europe.

Within the last years, we have looked but couldn't find a single patient necessitating multiple operations for persistent low back pain. Certainly we see patients with backaches but far fewer initial surgery is performed in Europe for such cases and virtually no multiple procedures. This tells us something about our differences of practice, but I'm not quite sure what.

Q. *Nashold*

I would like to ask Dr. Shealy if he could explain what results he has obtained using autogenic training?

A. *Shealy*

Schultz and Luthe have published a six volume book on autogenic training so it would be rather difficult for me to explain it briefly. Essentially it is training the patient to gain control over his autonomic functions. So it is training the patient for example, to control his alpha rhythm, temperature, blood pressure, pulse rate, etc., but not doing it with a biofeedback machine. It is purely a technique of practicing a form of self-induced meditation, hypnosis—but it's a systematic approach to accomplishing it.

Q. *Ray*

Do you see patients who are worsened by the implantation?

A. *Pineda*

In my own experience, there are two patients who have been feeling worse after the implantation of a DCS device.

A. *Nashold*

We asked that directly to the patients by letter and found that not one patient reported that he was worse.

A. *Shealy*

We've seen at least half a dozen patients who felt that their pain state was worse. Not their original pain—they just add a new pain, usually at the site of the surgery for the implantation of the dorsal column stimulation.

A. *Pineda*

In those several surgeons who raised their hands indicating they have used dorsal column implants in paraplegics, how many have had satisfactory results in relieving pain? Only two.

Q. *Baran*

I'm wondering, in regard to recurring pain with diminishing effects of dorsal column stimulation after several months or a year, whether there has been any thought given or investigation done to see whether there were other factors involved than stimulation failure, such as, perhaps, reactivation of some problem at the original site of a lesion. For instance, in chronic back pain, perhaps there may be a recurrence of a large disk extrusion, a new disease developing from malignancies, aneurisms, and so forth. Can dorsal column stimulation mask other disease conditions that may be developing?

Q. *Sweet*

I'd like to confirm the type of observation to which Dr. Sheldon referred, namely, in a situation in which the individual is securing satisfactory relief from one form of relentless pain by stimulation in the spinal canal, then has the appearance of a new clinical problem causing pain. In our case, a patient fell and sustained a fracture at the knee in the zone of the previous pain, which had until then been completely relieved by stimulation. There now began a protracted period of some months with failure to get relief of this new pain referred to the knee. Then gradually, as the fracture healed, that pain subsided and there was once again relief of the original pain. These are rather unusual situations, but I feel it illustrates an important point. I would be interested to know if others have seen this sort of thing?

A. *Nashold*

We had a man who was being relieved of chronic neck pain by stimulation which also produced parasthesia into his extremities. He broke his leg but was not relieved of the new pain in that leg, and yet he continued to be relieved of his old chronic pain!

A. *Shealy*

We have had the same experience and it's been my feeling that dorsal column stimulation itself is incapable of relieving severe acute pain, but may be beneficial in less intense chronic pain. I think that chronic pain probably has a different mechanism involved in its production anyway.

A. *Adams*

In some patients we've operated on for cancer, briefly mentioned this afternoon, it's been interesting that in three of them with pelvic cancer having predominantly unilateral sciatic pain due to lumbosacral plexus involvement, there was initially obtained very satisfactory relief of the pain in the involved leg. As the cancer extended, even though they both had parasthesias in the other leg, they obtained far less satisfactory relief with this new pain as the cancer extended over to the second side. This occurred even though as far as we could tell, the paresthesias were identical in each leg.

A. *Sweet*

We have had one interesting chap with a DCS implant who was able, as he moved his head and neck around into certain strained positions, to alter the zone of reference of his pain relief. On one occasion when he was at work, he accidently tore off his great toenail in an industrial accident. With this intense pain down in his great toe, he proceeded to twist his neck around and finally got into a position where he was getting parasthesias referred down into that lower extremity, down into the foot. He said that within a minute or two, the pain went out of his big toe.

Q. *Shealy*

I'd just like to ask the others who've done DCS implants, how many have seen the problem of excess sexual stimulation with dorsal column stimulation. We have seen this now in at least half a dozen patients, both female and male. One 78-year-old man felt that this was a highly undesirable state since he was unmarried.

A. *Pineda*

We've had one patient, a 55-year-old female, with a dorsal bipolar electrode implanted at the level of C3 who got sensation into the perineal region. Her husband came in a month later and told me he was tired, he could not go back to work because of her increased sexual demands.

A. *Adams*

We've had one male who also seemed to have the same effect.

A. *Hoppenstein*

I have had three such patients, all females. I've done all my implantations in the cervical region as discussed later. The most dramatic occurred two weeks ago with a patient with intractable trigeminal neuralgia where I had implanted the electrode by an anterior percutaneous technique. The electrode drifted posteriorally and four days after surgery, she informed that this was the most fantastic operation and I had done wonders in that she was able to produce orgasms 20 times a day with the stimulator.

Q. *Pineda*

Dr. Nashold, I think you had three parapareses and Dr. Sweet had one paraparesis among their DCS cases. May I ask what do you think was the cause of these parapareses? Was the electrode too bulky, the canal too small, or the dural sutures too tight?

A. *Nashold*

I think in our case, it was due to the pressure of the electrode plate against the cord. We anchored it somewhat like a tent in the earlier cases. All of our paraparetics recovered on removing the electrode. In one case, I went back two weeks later and reimplanted the same electrode at another level and he's been one of our best successes; at re-exploration, there was no evidence of cord damage.

A. *Swcet*

There is unequivocal evidence that there is a substantial difference in the size of the dural sleeve relative to the diameter of the cord, from one patient to another. There are certain individuals in whom the lead-in wire needs to be pushed on in order to get it closer to the cord in order to treat the patient at low stimulus voltage. There may be a several millimeter interval between the electrode and the dorsal aspect of the cord in some individuals. If one finds a 10 or 12 volt stimulus threshold, then just pushing the electrode in a bit will reduce this voltage. This does also bear on evidence for such phenomena as arachnoidal thickening and subsequent failure of the procedure. Our one case of reversible paraparesis was a T7 implant.

A. *Nashold*

Ours were at T4 or T5 and I might add that in the two patients that did develop paraparesis, both had suggested symptoms before surgery. This was part of the neurological finding and I wondered at the time whether or not we had simply aggravated it.

A. *Shealy*

All three of mine were in the upper thoracic area about T3 and all of them were then utilizing the old, thicker 3-plate bipolar electrode.

A. *Adams*

Mine was at T3.

A. *Pineda*

I found that the level T5 is where maybe we should stay away from for the simple reason that there the spinal canal is very narrow.

A. *Picaza*

In all the cases of clinical failures without compression signs but where I know that the electrode is not going to be used, I do not remove the electrodes; I understand that some neurosurgeons do. How many do leave the unused electrode in? Most of you. I think it's an appreciable job just to go back in and try to remove the electrode; we can unnecessarily produce more trauma in this way.