SPINAL CORD STIMUALATION IN DISORDERS OF THE MOTOR SYSTEM

Joseph M. Waltz, M.D.
Kailash C. Pani, M.D.

Department of Neurological Surgery
St. Barnabas Hospital
New York, New York 10457

SPINAL CORD STIMULATION IN DISORDERS OF THE MOTOR SYSTEM

The "Gate Theory" of pain as proposed in 1965 by Melzack and Wall[1], whether fact or fiction, has been the rational and guiding principle that prompted the clinical application of dorsal column stimulation. The initial trials by Wall and Sweet[2] in 1967 and Sweet and Wepsic[3] in 1967 was followed by Shealy, et al[4] in 1970 with the application of surface electrodes to the dorsal columns of the spinal cord for treatment of intractable pain. Until the later part of 1973 the clinical reports which appeared in the literature [5,6,7,8] dealt solely with the application of D.C.S. in pain problems. However, in 1973 Cook and Weinstein[9] reported their serendipitous observations of the motor changes noted in an M.S. patient they were treating for pain with dorsal column stimulation. Thus opening the therapeutic door for wider clinical application of D.C.S.

The reports in the medical literature which have appeared, however, have confined themselves almost exclusively to observations made in cases with Multiple Sclerosis. The exceptions being Cook[10], Dooley[11] and Gildenberg[12]. Cook[10] reported improvement in motor function in 3 cases of motor neurone disease. Dooley[11] reported along with 42 cases of M.S., 2 cases of Olivo-pontocerebellar atropy (one case showing improvement in ataxia), one case amyotrophic lateral sclerosis with no improvement, 1 case primary lateral sclerosis (decreased spasticity and improved motor function) and 1 case with Fredericks Ataxia which showed improvement in voluntary motor function and lessening of ataxia. Gildenberg[12] reported his initial observations of the application of D.C.S. in the treatment of spasmodic torticollis in 16 cases with 3 cases showing improvement.

This report represents our observations in 130 cases of dorsal column stimulation suffering from various neurologic conditions involving the motor systems. Our series is composed of 38 cases Cerebral Palsy, 20 cases of Multiple Sclerosis, 25 cases of Dystonia Musculorum Deformans, 17 cases Spasmodic Torticollis, 13 cases of Post-Stroke neurologic loss, 14 cases with post-traumatic changes and 3 cases of miscellaneous neurologic conditions. All the cases were subjected to dorsal column stimulation in one form or another. The results of this stimulation, correlations and conclusions are presented.

TECHNIQUES OF ELECTRODE PLACEMENT

The placement of the electrodes was carried out in two ways.

1. Percutaneous implantations: - This technique was employed or attempted in every case initially. The procedure is carried out under local anesthetic if at all possible and general anesthetic if necessary. The patient is placed in the prone position with the cervical dorsal junction flexed. Hustead epidural needles are passed paraspinously and close to the midline at the upper or mid-thoracic level. The needles are directed upward and inward at a shallow angle between the lamina. The stylet is withdrawn and the nub filled with saline which will be sucked into the needle when the ligamentum flavum is penetrated and the epidural space entered. The epidural electrodes[2] are then passed cephalad through the epidural space, their course being followed by fluoroscopy to the desired level. (Electrodes-Medtronic 3480 and Avery E-355). The electrodes are positioned in the midline, separated by a distance of 1 - 2.5 cm. The connecting leads are brought out through the skin for a period of test

stimulation. The patient, following this, is then tested over the next 7 - 10 days for any changes in their signs or symptoms. Various frequencies, pulse-widths and anatomical levels of stimulation are tried. If no improvement is noted the system is removed. If sufficient improvement is noted the system is interiorized by connecting the epidural electrodes with a subcutaneously placed receivers for chronic stimulation (Medtronics 3460 or Avery I-108).

2. Open Implantation: In certain cases (because of broken wires, displaced electrodes, inability to achieve satisfactory electrode placement) it has become advantageous to place the electrodes in position via a laminectomy. The electrodes used in this case are a pair of platinum buttons mounted in dacron mesh coated with silicone rubber. (Avery E-328). A laminectomy over 2 levels is carried out and the electrode plate is sutured in place to the dura in the midline. The electrodes are then connected to the subcutaneously placed receiver. No test period is possible with this system.

I CEREBRAL PALSY

Clinical Material - The population consisted of 38 cases of cerebral palsy. There were 12 females and 26 males, with an age range of 7 to 42 years and a mean of 20.4 years. The cases were divided into 4 types (1) spastic diplegia - 9 cases, (2) spastic quadriparesis - 13 cases, (3) spastic quadriparesis with moderate athetosis - 9 cases, (4) spastic quadriparesis with marked athetosis - 6 cases. The implantation of electrodes was carried out as described above and were internalized in 31 cases which showed initial improvement during the trial period. Length of followup was from 6 months to 3 years.

Cases not Internalized - There were 7 cases not internalized. One case was discontinued because of cerebral spinal fluid leak which subsided spontaneously with removal of the electrodes. Six cases showed no effect during the trial period of stimulation. Multiple levels of stimulation were tried and there appears to be no correlation between level of stimulation and failure in these 6 cases. The age perhaps was a factor, 3 cases (50%) were less than 10 years of age. However, the one factor which was common to all 6 cases was the type of cerebral palsy, namely, spastic quadriparesis with marked athetosis. There was not one case in our series of spastic quadriparesis with marked athetosis which responded to spinal cord stimulation.

Cases Internalized - Thirty-one cases were internalized for permanent stimulation. Marked improvement was noted in 11 cases (30%). Moderate improvement was noted in 10 patients (27%), making an overall 57% of the patients showing moderate to marked improvement. Mild improvement was noted in 7 patients (19%). The improvement was therefore noted to some degree in 28 patients or 75% of the population. Three cases (8%) showed no improvement after permanent implantation, while the previously mentioned 6 cases (16%) showed no effect. Nine cases or 34% showing no benefit from epidural stimulation.

Symptoms Relieved - In the 31 cases internalized, decreased spasticity, both objectively and subjectively was observed in 26 patients. Fourteen patients commented on feeling more relaxed, and less nervous. Speech was found to be improved in 14 cases evidenced by improved intelligibility, louder voice, improved articulation and smoother speech delivery. In 13 cases sitting and balance was improved allowing the patient now to sit unsupported without restraining straps. Many patients in this group are now sitting unsupported and unattended in a chair without side supports. Hand function was found to be improved in 13 cases with the patients now carrying out activities which were impossible prior to stimulation, such as feeding themselves, holding a knife, fork, spoon and cup, brushing their teeth, turning on and off electrical appliances. In 9 cases head and neck stability was improved with the patient now able to hold the head erect without it falling forward or to the side. Painful spasms were abolished in all 9 cases which had these spasms. In 8 cases walking was improved, which was characterized by the decrease in spasticity in the lower extremities, feet were more flexible and flatter on the floor, and the speed and smoothness of ambulation increased. In 7 cases balance was improved. The urinary control was improved in 6 cases. In 5 cases adductor spasms were abolished or markedly decreased. In several of these patients obturator neurectomy had been contemplated but was no longer necessary. Alertness was improved in 4 cases, evidenced by increased activity and improved school work. In 3 cases swallowing was improved and drooling was decreased. Startle reflex was decreased to abolished in 3 cases and in 2 cases synkinetic movements were abolished. In 2 cases the motor strength of the hands actually increased. In 1 case in particular the patient could by increasing the level of stimulation change his hand strength from Grade III to Grade V.

Correlations - Correlating results with the type of cerebral palsy revealed that the spastic quadriparesis had no failures. All improved to some degree, 38% (5) being markedly improved, another 38% (5) moderately improved and 24% (3) showing mild improvement. The spastic quadriparesis with mild athetosis had no cases that were markedly improved but 44% (4) showed moderate improvement, with 33% (3) showing mild improvement and 23% (2) showing no improvement. As noted previously, the spastic quadriparesis with marked athetosis had no improved cases and none were implanted permanently. The spastic diplegia cases showed 67% (6) markedly improved, 11% (1) moderately improved and 11% (1) showed only mild improvement. There was 1 (11%) case of spastic diplegia where no improvement was noted. Correlating the level of stimulation with results of the whole C.P. population, does show some correlation between the level of stimulation and the results. The upper cervical area stimulation was responsible for 64% of the markedly improved cases, with the thoracic area being responsible for 36%. The moderately improved cases, the upper cervical, was responsible for 70% with the thoracic area producing 30%. Mild improvement was produced by 58% in the upper cervical level, with 14% being produced by the thoracic level stimulation. In correlating the type of C.P. and results with level of stimulation revealed in the spastic quadriparesis group that 100% (5) of the markedly improved patients had been stimulated at the upper cervical area, ie. C_2, C_3, C_4. Sixty-percent (3) of the moderately improved and 66% (2) of the mildly improved cases were stimulated at the upper cervical level. In the spastic quadriparetic group

13 cases out of 13 cases improved. Of this group 11 or 85% were implanted in the cervical area, 10 or 77% in the upper cervical area. In spastic diplegia 43% of those which were marked or moderately improved were stimulated in the upper cervical area. The remainder of the moderate to marked improved patients being stimulated in the thoracic area equally dispersed between T1 to T5. One case was mildly improved and this was in the lower thoracic level at T5. One failure was noted and this was stimulated at T6 level. Spastic quadriparesis with moderate athetosis had no markedly improved patients, but 50% of the moderately improved patients were stimulated at the upper cervical area, 25% at the lower cervical area and 25% in the thoracic area. Of the patients which were mildly improved 33% were stimulated in the lower cervical area with 66% being stimulated in the upper cervical area. In the cases which showed no improvement all of them were stimulated in the upper cervical area. In looking at the data and correlations it would appear that the patient which has the least chance of improving with chronic epidural stimulation would be that patient with spastic quadriparesis and marked athetosis and being less than 10 years of age. The patient which appears to have the best chance of improving regardless of the type of C.P. would be the patient in the age group between 11 and 20. The patient with spastic diplegia has the best chance of showing marked improvement, and the spastic quadriparesis showing only a slightly less chance of marked to moderate improvement. Patients with spastic quadriparesis with moderate athetosis have the least chance of showing marked improvement. It would appear that stimulation of the upper cervical area, ie. C_2, C_3 and C_4 offers the best overall chance of improvement.

II MULTIPLE SCLEROSIS

Clinical Material - The series consisted of 20 patients in which the diagnostic criteria for multiple sclerosis had been fulfilled. There were 11 males and 9 females, the age range was 24 to 65 years, with a mean age of 44.3 years. The duration of illness was from 3 to 17 years. This series has a followup evaluation of 15 to 36 months. Symptoms were divided into (1) Primary and (2) Secondary. The primary symptoms constituted the major complaint of the patient, while the secondary symptoms were additional symptoms the patient complained of. Primary symptoms consisted of spasticity and weakness in 12 cases, ataxia in 4 cases, tremor in 2 and painful spasms in 2 cases. Secondary complaints consisted of bladder dysfunction in 10, visual difficulty in 10, spasticity in 7 cases, tremor in 5, ataxia in 4, dysarthria in 3, and painful discomfort in 2.

Cases not Internalized - Twenty cases underwent initial percutaneous screening for relief of symptoms, 6 of these were not internalized (30%). In 4 cases there was no benefits from stimulation, 1 case patient-cooperation was poor and 1 case was terminated because of a broken wire. There seemed to be some correlation between the level and ineffectiveness since 5 of the 6 were found to be in the thoracic area and 1 in the cervical area.

Cases Internalized - The remaining 14 cases were internalized with 13 cases (65%) found to be improved and only 1 case was found to show no improvement. Improved cases were divided into 4 categories, namely, 1. functional improvement, 2. improvement in primary and secondary symptoms, 3. primary symptoms only and 4. secondary symptoms only. In the first category functional improvement was found in 4 (29%) patients, while the same number was found in primary and secondary improvement categories (29%) and the same number in primary symptoms only (29%). One case (7%) improved only in the secondary symptoms.

Symptoms Relieved - The primary symptom of spasticity was relieved in 7 of the 12 cases (58%), ataxia was improved in 3 of 4 cases (75%), the 2 cases complaining of pain were improved (100%) and the 2 cases which complained primarily of tremor were not helped (0%). The overall success rate in relieving or improving primary symptoms was 60%. Of those patients which were considered functionally improved which there were 4, 1 had trunkal ataxia and was unable to walk without support prior to stimulation, but could ambulate unassisted following D.C.S. One had much less pain and discomfort following stimulation with improvement in gait and ambulation. A third case functionally improved, the category was converted from wheelchair-bound to walking with assistance. One additional case found markedly improved functional gait with decreased spasticity, ataxia and improved balance.

Correlations - There seemed to be no correlation between stimulation level and the relief of pain since all 4 pain problems were relieved irrespective of the cord level. This also seemed to be true in the case of spasticity since the 10 cases relieved and the 9 cases not helped seemed to be well represented in both the cervical and thoracic areas. However, in the 10 cases of bladder dysfunction, there were 7 failures with 6 (86%) being in the thoracic area or a success rate in the thoracic area of 14% as compared with 50% success in the cervical area. Ataxia was improved in 3 cases all stimulated at C_2 or C_3, with the 5 failures being stimulated at C_4 or below. Walking was markedly improved in 3 cases all being stimulated at the C_2 level. In the 4 cases which were functionally improved 3 cases were stimulated at the C_2 level and 1 case was stimulated at the T_4 level. It would therefore appear that given an M.S. patient with spasticity, bladder difficulty, ataxia and walking difficulty that the ideal location for stimulation which offers the best chance of relieving these symptoms and improving the patient functionally would be at the C_2 C_3 level.

III DYSTONIA MUSCULORUM DEFORMANS

Clinical Material - The population consisted of 25 cases of patients suffering from Dystonia Musculorum Deformans. There were 11 males and 14 females, with an age range of 8 to 54 years and a mean of 25.4 years. Duration of the illness was 1.5 years to 27 years, with a mean duration of 11.1 years. Length of followup was 7 to 38 months.

Cases not Internalized - There were 12 cases which were not internalized after undergoing the initial screening stimulation period. No correlation was noted between age, sex, or duration of the illness. Five cases had had no previous surgery, three cases had had bilateral thalamic surgery and four cases had unilateral thalamic surgery. Although theoretically it was felt that previous thalamic surgery should have a bearing on the outcome of the stimulation procedure, this was not found to be the case and no correlation could be noted between thalamic surgery and failure. Three cases (12%) were not internalized because of increased dystonic symptomatology after undergoing stimulation. Multiple levels of stimulation were tried and there was no correlation between stimulation level and this finding. These cases underwent various stimulation parameters, with no effect on the symptomatology. Three cases were discontinued because of mechanical factors, 2 unable to pass the electrodes into the cervical area and 1 case of cerebral spinal fluid leak. This represented a 12% failure rate because of mechanical factors. Six cases (24%) showed no effect after undergoing a 7 to 10 days of trial stimulation. Various parameters of stimulation were tried in all cases and they failed to show any effect of the stimulation on the dystonic symptomatology.

Correlations - Correlation in patients having had no previous thalamic surgery were made. There were 6 patients which fell into this category of virgin cases. It was hoped that stimulation in these patients would be effective and obviate the necessity of thalamic surgery. However, only 1 case of the 6 showed any improvement and this was moderate, at best, representing a 17% level. No effect was seen in 1 case (17%) in 2 cases (33%) the symptoms were increased with stimulation and in 2 cases implantation was not carried out because of mechanical factors. One case out of the 6 was internalized and this did show improvement, the remaining 5 were not internalized representing an 83% failure rate. There were 9 cases which had undergone unilateral thalamic surgery. Five of this series were improved and internalized, representing a 56% improvement level. Of the 5 cases, 1 was felt to show definite improvement in her dystonic posturing and symptomatology over the unoperated side. However, this improvement was lost within a year and the patient subsequently underwent second-side thalamic surgery with relief of her dystonic symptoms on the left side. One case which showed improvement, however, this was primarily in the residual spastic left side which had followed right thalamic surgery. The remaining 3 cases which showed improvement were all in torticollic dystonic posturing of the head and neck. There were 10 cases of dystonia which had undergone previous bilateral thalamic surgery. In some cases this consisted of not only bilateral thalamic lesions, but also pulvinar and in 1 case a globus pallidus lesion. However, these cases were grouped as bilateral thalamic surgical cases. No correlation between improvement or lack of improvement was noted between these observations and age, sex, duration of illness or level of stimulation. There were noted to be 7 cases (70%) which were improved, 2 cases (20%) where no effect was observed, and in 1 case (10%) inability to pass the electrodes cephalid in the epidural space. Of those 7 cases which did improve the improvements were noted in two areas. The first area was the midline - signs and symptoms involving the spine and head and neck. The improvements noted were the spine became straighter and torticollic, and retrocollic symptomatology improved. The second area of improvement was pseudobulbar symptoms, residual of previous bilateral thalamic surgery. The patients noted improvement in balance and walking stability, with lessening of drooling and swallowing difficulties, along with decreasing spasticity and more

relaxation. The stimulation in the dystonic cases was disappointing, showing an overall improvement in 52%. Of these 13 cases it was felt that only 2 (8%) showed improvement in the peripheral dystonic symptoms in either the upper or lower extremities. Seven cases (18%) showed improvement in midline symptoms of torticollic or retrocollic head and neck dystonia, with the remaining 4 patients (16%) showing improvement in pseudobulbar problems. It would, therefore appear that the use of spinal epidural stimulation in the dystonic patient must be reserved for those cases where the primary problem or the major manifestation of dystonia is segmental of the head and neck with spasmodic torticollis or retrocollis. Otherwise, the use of the epidural stimulation can be used in those cases which have undergone bilateral thalamic surgery and do manifest residual pseudobulbar problems and spasticity.

IV SPASMODIC TORTICOLLIS

Clinical Material - There were 17 patients suffering from spasmodic torticollis, 5 males and 12 females, with an age range of 30 to 61 years, and a mean age of 43.7 years. Duration of the symptoms was from 8 months to 11 years, with a mean duration of 4.2 years. Followup on this series ranged from 6 months to 3 years.

Cases not Internalized - There were 5 cases (29%) which were not internalized because no effect was noted during the trial stimulation period of 7 to 10 days. These cases were stimulated at multiple levels and at varying stimulation parameters. There seemed to be no correlation between level of stimulation and failure. There was 1 or 2 interesting facts related to the sex makeup of this group, in that, 3 cases or 60% of the total male population were not helped initially and were not implanted. The 2 females which were not implanted because of failure to show an effect were over the age of 50, a failure rate of 66% for females over the age of 50.

Cases Internalized - The remaining 12 cases of this series were internalized because of satisfactory response to the initial stimulation. Of these 12 cases, 5 (29%) showed marked improvement, 4 (24%) showed moderate improvement, with a combined moderate to marked improvement of 53%. One case showed mild improvement (6%) with a total improvement population of 59%. Two cases showed no improvement after internalization, with a failure rate here of 12%.

Correlations - Marked improvement in 5 cases all of which were implanted in the C_2, C_3 area. There was rather a marked correlation in this group of age and sex, with all patients in this group being in their 30s and 4 of the 5 being females. In the moderate improvement group there were 4 cases, again all being implanted in the C_2, C_3 level. Three of the four cases being females. The 1 remaining case of mild improvement was a 46-year old female, with the level of stimulation being at C_2. In two cases which showed no improvement, there was no correlation, except for the fact that 1 patient, female, being 36 years of age, should by our previous observations, been in the markedly improved group. This is interesting since the patient did show marked improvement with stimulation but did develop some nerve root irritation which caused her some pain and consequently wished the system removed even though she was

totally relieved of her torticollis. The patient is considering re-implantation in the future. It would appear that treatment of spasmodic torticollis with spinal cord stimulation at the C_2, C_3 level does offer considerable improvement in a particular problem. One could say that a female patient in her 30s suffering from spasmodic torticollis has, according to our series, almost a 100% chance of being improved or helped by the procedure.

V POST-STROKE

Clinical Material - There were 13 patients who had sustained vascular insults to the central nervous system and manifested residual neurologic deficits. The series consisted of 10 males and 3 females, age range was from 21 years to 79 years, with a mean age of 47.2. Duration of illness or symptoms was 2 to 20 years, with a mean of 6.2 years. Followup of the series was from 1 to 3 years.

Unimproved Cases - There were 9 cases in this series or 69% which were unimproved. Six of these cases showed no effect, 2 cases were unable to tolerate the increased pain over the affected side, ie. thalamic pain and 1 case suffered an epidural hematoma which was surgically removed with no residual. There were no correlations noted between age, sex, duration of symptoms or symptom-complex and the ineffectiveness of dorsal column stimulation. However, level of stimulation did seem to show some correlation. In the 9 cases, 6 were stimulated at the thoracic level, while 3 cases were stimulated in the cervical area. Seven cases were stimulated in the thoracic area with none of these showing any improvement. Seven cases were stimulated in the cervical area with 4 cases being helped.

Improved Cases - The improved cases were 4 in number, yielding 31% of the population. There was no correlation noted between age, sex, symptoms, the side of symptoms or symptom duration. However, marked correlation was noted between improvement and the level of stimulation, in that, all 4 cases were stimulated at the cervical level. This coupled with the unimproved cases shows rather conclusively that the cervical area, when stimulated, gave a success rate of 51% (4 of 7). It is also interesting to note that 1 of the successful cervical stimulation had also undergone thoracic stimulation with no help. The success rate in the thoracic level stimulation was 0%. It is interesting to note that there were 2 cases in which thalamic pain was accompanied by spastic hemiparesis and in both of these cases the stimulation had to be discontinued because of accentuation of the pain. In the cases which were improved, the symptoms noted to be altered were, decrease in spasticity, clonus being abolished, improvement in movement with increased range of motion, improved balance and walking, as well as improved speech function in the dysarthric cases. After reviewing the statistics, it would appear that the initial success rate of 31% can, in all probability, be increased to approximately 51% by changing the level of stimulation from the thoracic to the cervical area.

VI POST-TRAUMATIC

Clinical Material - The cases which were included in this group had sustained trauma to the central nervous system and were 14 in number, 10 males and 4 females. Age range was from 13 to 51 years, with a mean age of 25.2 years. Duration of the symptoms were in a range from 2 to 12 years, with a mean range of 6.2 years. Followup on this series was from 1 to 3 years.

Unimproved Cases - There were 4 cases which were not improved or helped by spinal cord stimulation, failure of 29%. No correlation could be made between the failures and age, sex, duration of symptomatology and level of stimulation. However, it was observed that the 4 cases did manifest bilateral symptomatology, in that 3 were spastic quadriparetics and 1 was a spastic paraplegia.

Improved Cases - There were 10 cases 71.4% in the series which were improved. Again, no correlation was found between the results and age, sex, or symptom duration. It is interesting to note that 6 of the 10 or 60% of the improved cases were made up by spastic hemipareses at the symptom complexes it appears that a patient with a spastic quadriparesis has a 43% chance of not being helped and a 57% chance of showing some improvement. A patient with a hemiparetic syndrome has the best chance of success, since all of the patients manifesting unilateral symptomatology were improved. The majority of the patients were stimulated at the cervical area or high dorsal area and, therefore, no conclusion could be made as to level and failure and success rate. However, taking into consideration previous documentation relative to the cervical and thoracic area, it would appear that, again, the relative success is manifested in the cervical placement. The symptoms which were found to be improved in these cases, again, followed similar patterns, in that spasticity was decreased, clonus decreased to abolished, walking improved, hand function showing improvement, with the ability to open and close the hand and, in 1 case, writing was improved. Speech improvement was noted, along with range of motion of extremities increased, with swallowing difficulties showing improvement.

VII MISCELLANEOUS CASES

Clinical Material - We treated one case of anterior spinal artery thrombosis in a 58-year old male with a T_5 plate implantation. There was improvement noted in coordination, balance and walking. However, the patient has been lost to followup.

One case of spinocerebellar degeneration was improved following the placement of a T_6 plate. This was characterized by improved balance with the gait becoming steadier and decrease in spasticity.

One case of post viral encephalitis with a spastic quadriparesis had noted marked decrease in spasticity following dorsal column stimulation at the C_3 level by means of an implanted plate.

No conclusions can be drawn from these three additional cases, except that they did show improvements in the areas previously noted in the other series.

COMPLICATIONS

There were no deaths or serious complications in our series. One potentially serious complication, an epidural hematoma, was evacuated immediately, the plate removed and the patient suffered no residual. There was one additional cord compression which was secondary to the electrode wire becoming looped in a very kyphoscoliotic dorsal cord area. The symptoms resolved as soon as the electrode was removed. Cerebral spinal fluid leak was encountered in 3 cases with no residual after the electrodes were removed. Two delayed (4 months and 1 year) wound infections were encountered which required removal of the system. One hematoma of the receiver site resolved with conservative treatment. There were 3 cases of pain or paresthesias of an uncomfortable level which required removal of the system. Eleven cases or 8.5% incidence of complication connected primarily to technique. There were 14 cases (11%) of broken wires and 14 cases (11%) displacement of electrodes.

REFERENCES

(1) Melzack, R. and Wall, P.D., "Pain Mechanisms: A New Theory." Science 150: pp. 971-979, 1965.

(2) Wall, P.D. and Sweet, W.H., "Temporary abolition of pain in man." Science 155: pp. 108-109, 1967.

(3) Sweet, W.H. and Wepsic, J.G., "Treatment of chronic pain by stimulation of fibers of primary afferent neurone." Tras. Amer. Neurol. Ass. 93: pp. 103-107, 1968.

(4) Shealy, C.N., Mortimer, J.T. and Hagfors, N.R., "Dorsal column electroanalgesia." J. Neurosurg. 32: pp. 560-564, 1970.

(5) Nashold, B.S., Jr. and Friedman, H., "Dorsal column stimulation for control of pain: Preliminary report on 30 patients." J. Neurosurg. 36: pp. 590-597, 1972.

(6) Fox, J.L., "Neuropacemaker for relief of intractable pain." Med. Ann. District of Columbia 40: pp. 577-579, 1971.

(7) Hosobuchi, Y., Adams, J.E., Weinstein, P.R., "Preliminary percutaneous dorsal column stimulation prior to permanent implantation: Technical note. J. Neurosurg. 37: 242-245, August, 1972.

(8) Burton, C., "Proceedings of the seminar on dorsal column stimulation." Surg. Neurol. 1: pp. 285-289, 1973.

(9) Cook, A.W. and Weinstein, P., "Chronic dorsal column stimulation in Multiple Sclerosis: Preliminary Report." New York J. Med. 73: pp. 2868-2872, 1973.

(10) Cook, A.W., Stimulation of the spinal cord in motor neurone disease." Lancet 2: pp. 230-231, 1974.

(11) Dooley, D.M., Kasprak, M. and Stibitz, M., "Electrical stimulation of the spinal cord in patients with demylinating and degenerative diseases of the central nervous system." J. Florida M.A. 63: pp. 905-909, November, 1976.

(12) Gildenberg, P.L., "Treatment of Spasmodic Torticollis by dorsal column stimulation." Rev. Inst. Nal. Neurologia. 10: pp. 11-15, 1976.