Spinal Cord Stimulation for Central Poststroke Pain

Mohamed M. Aly, MD
Department of Neurosurgery,
Osaka University Graduate School of Medicine,
Osaka, Japan

Youichi Saitoh, MD, PhD
Department of Neuromodulation and Neurosurgery,
Center for Advanced Science and Innovation,
Osaka University,
Osaka, Japan

Koichi Hosomi, MD, PhD
Department of Neuromodulation and Neurosurgery,
Center for Advanced Science and Innovation,
Osaka, Japan

Satoru Oshino, MD, PhD
Department of Neurosurgery,
Osaka University Graduate School of Medicine,
Osaka, Japan

Haruhiko Kishima, MD, PhD
Department of Neurosurgery,
Osaka University Graduate School of Medicine,
Osaka, Japan

Toshiki Yoshimine, MD, PhD
Department of Neurosurgery,
Osaka University Graduate School of Medicine,
Osaka, Japan

Reprint requests:
Youichi Saitoh, MD, PhD,
Department of Neuromodulation and Neurosurgery,
Center for Advanced Science and Innovation, Osaka, Japan;
2-2 Yamadaoka,
Suita, 565-0871, Japan.
E-mail: saitoh@nsurg.med.osaka-u.ac.jp

Received, August 28, 2009.
Accepted, January 2, 2010.

BACKGROUND: Although spinal cord stimulation (SCS) has been shown to be effective for treating neuropathic pain of peripheral origin, its effectiveness for central poststroke pain (CPSP) is not well established.

OBJECTIVE: We report our experience with SCS in 30 consecutive patients with intractable CPSP.

METHODS: All patients underwent a percutaneous SCS trial. When patients decided to proceed, they received a permanent SCS system. Pain intensity was evaluated by a visual analogue scale (VAS). The Patient Global Impression of Change (PGIC) scale was also assessed at the latest follow-up visit as an indicator of overall improvement.

RESULTS: During trial stimulation, pain relief was good (≥50% VAS score reduction) in 9 patients (30%), fair (30%-49% reduction) in 6 patients (20%), and poor (<30% reduction) in 15 patients (50%). Ten patients elected to receive a permanent SCS system. Nine of these 10 patients were followed long-term (mean, 28 months; range, 6-62 months). Seven patients reported significant pain relief on the VAS (5 = good and 2 = fair). On the PGIC scale, 6 of these 7 patients reported a rating of 2 (much improved) and 1 reported a rating of 3 (minimally improved). Of the remaining 2 patients, 1 reported a rating of 4 (no change) and 1 reported a rating of 5 (minimally worse). The median VAS score in the 9 patients decreased significantly from 8.6 (range, 6.0-10.0) to 4.5 (range, 3.0-8.0; $P = .008$). There were no significant reported complications.

CONCLUSION: SCS may provide improved pain control in a group of patients with intractable CPSP and may have therapeutic potential for intractable CPSP.

KEY WORDS: Central poststroke pain, Medically refractory, Neurostimulation, Spinal cord stimulation

Neurosurgery 67[ONS Suppl 1]:ons206-ons212, 2010 DOI: 10.1227/01.NEU.0000382965.95819.73

Central poststroke pain (CPSP) is a type of neuropathic pain that affects approximately 1% to 8% of patients after stroke[1,2] and is characterized by pain and sensory dysfunction involving the area of the body that has been affected by the stroke.[3] Once present, CPSP rarely abates, causing a considerable long-term impact on patient's quality of life.[4] Although amitriptyline and gabapentin are usually the drugs of first choice, they are often ineffective. In addition, the utility of amitriptyline is limited by its intolerable side effects, including dry mouth, urinary retention, arrhythmias, and sedation, especially in elderly stroke patients.[5]

The use of neurostimulation techniques has been proposed for severe medically refractory CPSP.[6] Deep brain stimulation has yielded variable results,[7] whereas motor cortex stimulation (MCS) has been reported to achieve pain relief in approximately half of patients.[8] MCS involves implanting electrodes over the motor strip through a craniotomy. Its use is correspondingly restricted to well-established functional neurosurgical centers.[6]

Spinal cord stimulation (SCS) is the most widely used neurostimulation technique for chronic pain because it is minimally invasive, has a low complication rate, and is generally effective.[9] SCS has been proven effective for various types of neuropathic pain of peripheral origin, in particular, failed back surgery syndrome and peripheral neuropathy.[9] In contrast, SCS is considered ineffective for central neuropathic pain, including CPSP.[7] However, the efficacy of SCS for CPSP has not been adequately explored, and there are only a few reports of its use in a small number of patients.[6,7,10,11] To evaluate the efficacy of SCS in CPSP, we retrospectively reviewed our clinical data from SCS in 30 consecutive

ABBREVIATIONS: CPSP, central poststroke pain; **MCS**, motor cortex stimulation; **SCS**, spinal cord stimulation; **VAS**, visual analogue scale

patients with intractable CPSP and report the results of trial as well as long-term stimulation.

PATIENTS AND METHODS

Patient Population

Between May 2002 and July 2009, 87 patients with medically refractory CPSP underwent one or more of the following neuromodulatory procedures at the Department of Neurosurgery of Osaka University Hospital: MCS (13 patients), repetitive transcranial magnetic stimulation (59 patients), or SCS (30 patients). We reviewed the records of the 30 consecutive patients with medically refractory CPSP who underwent SCS trials or implantations. They included 21 men and 9 women, with a mean ± standard deviation age of 64.8 ± 7.4 years and a mean duration of pain before surgery of 44.8 ± 35 months.

All patients were diagnosed with CPSP according to the following findings[12]: (1) development of pain after stroke, (2) sensory disturbance correlated with the cerebrovascular lesion, (3) pain located within the territory of sensory disturbance, and (4) exclusion of other causes of nociceptive and peripheral neuropathic pain, especially lumbar canal stenosis and poststroke shoulder pain caused by contracture deformity. Comprehensive neuropsychological assessment was performed in all patients to rule out serious psychiatric disorder or severe cognitive dysfunction. All patients had a poor response to medical treatment for at least 6 months before the SCS treatment, including antidepressants and anticonvulsant drugs.

We used to recommend MCS as a primary neurostimulation option for patients with medically refractory CPSP. However, we found that some patients refused MCS because of the need for a craniotomy. Another group of patients had a poor response to repetitive transcranial magnetic stimulation, which predicted a poor response to MCS.[13] In these situations, we discussed an SCS trial as an alternative and less invasive option. Moreover, because SCS is most effective in well-localized pain,[12] we considered SCS in patients with restricted pain distribution or when pain had a wide distribution but the area with greatest pain and disability was restricted to a small area like a foot or hand (Figure 1).

The most frequent cause of stroke was putaminal hemorrhage (n = 12; 40%), followed by thalamic hemorrhage (n = 9; 30%). Other less frequent causes (n = 9; 30%) are listed in Table 1. All patients had unilateral pain, which varied in distribution from single limb to hemibody pain (Figure 1). Allodynia was observed in 18 patients (60%) and hyperpathia in 11 patients (37%). Motor weakness was mild in 20 patients (Manual Muscle Test grade 4; 67%) and moderate in 3 patients (Manual Muscle Test grade 3; 10%).

Trial Stimulation

With the patient under local anesthesia and in the prone position, a percutaneous lead with quadripolar electrodes (Pisces Quad, Model 3487A; Medtronic, Inc, Minneapolis, Minnesota) was inserted into the epidural space using a Touhy needle. The tip was advanced to the required spinal level: C4 to C7 for upper limb pain or T9 to T12 for lower limb pain. The electrodes were manipulated with fluoroscopic guidance so that the stimulation-induced paresthesia covered the entire region affected by pain.[14]

Using an externalized temporary lead connected to a test stimulator (Model 3625; Medtronic, Inc), trial stimulation was performed to evaluate the efficacy of pain relief before permanent implantation. During the trial period (2-7 days), patients were allowed to test the pain-relieving effects of several stimulation parameters and combinations of active electrodes. Thereafter, the temporary electrodes were removed, and patients were discharged. After counseling the patients in the outpatient clinic, those who decided to proceed were scheduled for implantation of a permanent SCS system.

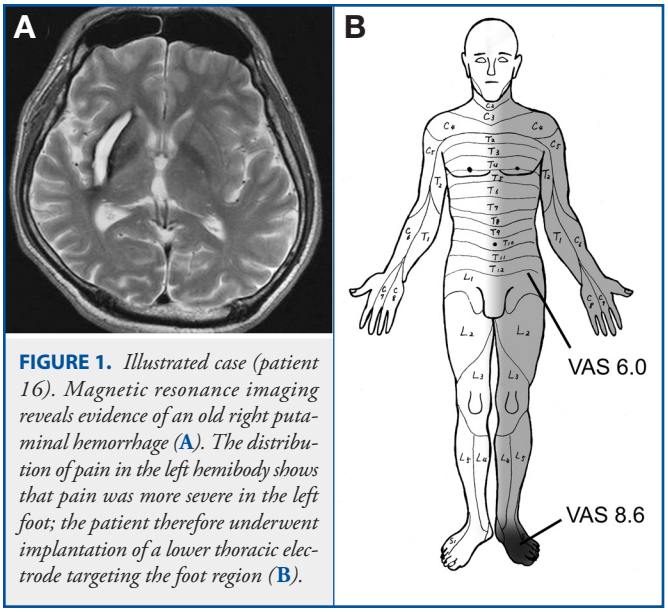

FIGURE 1. *Illustrated case (patient 16). Magnetic resonance imaging reveals evidence of an old right putaminal hemorrhage (A). The distribution of pain in the left hemibody shows that pain was more severe in the left foot; the patient therefore underwent implantation of a lower thoracic electrode targeting the foot region (B).*

Implantation of Permanent SCS System

A permanent lead was implanted in a similar manner as used for the trial lead and was anchored subcutaneously. A second trial stimulation was performed to verify consistent efficacy. Finally, an implantable pulse generator (Itrel III Model 7425 or Synergy Model 7427 V; Medtronic, Inc) was implanted in the left lower abdomen or anterior chest with the patient under general anesthesia.

Evaluation of Pain Relief

Pain intensity was evaluated using a visual analogue scale (VAS) ranging from 0 (no pain) to 10 (worst possible pain) at baseline, during the trial, and at follow-up visits every 6 months. In patients with wide regions of pain, the VAS score was assessed independently for each region, and the target area for SCS was determined based on the area with greatest pain and disability (Figure 1).

In addition, the Patient Global Impression of Change (PGIC) scale was assessed at the latest follow-up visit after the permanent implant. The PGIC scale indicates overall improvement according to a 7-point categorical scale: 1, very much improved; 2, much improved; 3, minimally improved; 4, no change; 5, minimally worse; 6, much worse; and 7, very much worse. The ratings 2 and 1 were considered clinically significant improvement.[15]

During data analysis, the degree of pain relief was classified into 3 categories: good (≥50%), fair (30%-49%), or poor (<30%) based on the percentage of reduction of the VAS score: [% reduction = ($VAS_{pre\text{-}stimulation}$ – $VAS_{post\text{-}stimulation}$/$VAS_{pre\text{-}stimulation}$) × 100%].[13] Pain relief of fair or better was considered clinically significant based on a report documenting that a pain reduction as low as 30% corresponds to clinically meaningful success.[15]

TABLE 1. Patient Characteristics and Results of Trial Stimulation[a]

Patient	Age, y/Sex	Pain Duration, mo	Underlying Disease	Painful Region Treated	Motor Weakness	Sensory Disturbance		Baseline VAS Score	VAS Score After Trial	% Change in VAS Score	Trial Stimulation Result	IPG Implantation
						Allod	Hyperp					
1	59/M	48	L sc inf	R LL	Mild	+	–	7	7	0	Poor	–
2	54/F	12	L thal hem	R UL	Mild	+	+	10	7.5	25	Poor	+
3	59/F	97	R put hem	L LL	Mild	–	+	8	4	50	Good	+
4	65/M	30	R thal hem	L LL	—	–	–	9	4	56	Good	+
5	71/M	19	L thal hem	R UL	Moderate	+	–	10	10	0	Poor	–
6	64/F	68	L put hem	R LL	Mild	+	–	10	7	30	Fair	+
7	74/F	156	L put hem	R LL	Mild	–	–	8	8	0	Poor	–
8	75/F	24	L thal hem	R LL	Mild	–	–	7	3	57	Good	+
9	75/M	24	R put hem	L LL	—	–	–	10	7	30	Fair	–
10	58/M	60	L pontine inf	R LL	Mild	+	–	6	3	50	Good	–
11	66/F	32	R put hem	L LL	Mild	+	–	7	3	57	Good	+
12	67/M	52	L thal inf	R UL	Mild	+	+	8.5	8.5	0	Poor	–
13	57/M	80	R put hem	L LL	—	+	+	6	6	0	Poor	–
14	72/M	83	L thal hem	R LL	Moderate	–	–	8.5	7.5	12	Poor	–
15	65/M	33	L thal inf	R UL	Mild	–	–	9	6	33	Fair	+
16	48/M	11	R put hem	L LL	Mild	+	–	8.6	3	65	Good	+
17	69/M	6	L thal hem	R LL	Mild	+	+	8	8	0	Poor	–
18	66/M	81	R put hem	L LL	—	–	+	8.5	7	18	Poor	–
19	67/M	14	L medullary inf	R LL	—	+	–	5	5	0	Poor	–
20	61/M	29	L pontine inf	R UL	Mild	+	–	9	6	33	Fair	–
21	72/M	16	L put hem	R LL	Mild	+	+	9	9	0	Poor	–
22	76/M	41	L thal hem	R UL	Moderate	–	–	8.5	2.5	71	Good	–
23	62/F	6	R sc hem	L LL	Mild	+	+	8	5.6	30	Fair	–
24	51/F	46	R put hem	L LL & UL	Mild	+	–	7	3	57	Good	+
25	65/F	20	R medullary inf	L LL	—	+	+	9.5	8.5	10	Poor	–
26	64/M	56	R put hem	L LL	Mild	+	+	8	8	0	Poor	–
27	56/M	6	R thal hem	L LL	—	–	–	7.8	5	25	Poor	–
28	74/M	93	L thal inf	R LL	Mild	–	–	8	5	38	Fair	–
29	62/M	19	L put hem	R LL	Mild	–	–	7	7	0	Poor	–
30	71/M	82	R thal hem	L LL & UL	Mild	+	+	6.5	1.5	77	Good	+

[a] Allod, allodynia; Hyperp, hyperpathia, VAS, visual analogue scale; IPG, implantable pulse generator; L, left; R, right; LL, lower limb; UL, upper limb; thal, thalamic; hem, hemorrhage; put, putaminal; inf, infarction; sc, subcortical; +, presence; –, absence. Median VAS score in target regions decreased significantly from 8.5 to 6 after trial ($P < .001$).

Clinical Factors Related to the Outcome of Trial Stimulation

Based on the degree of pain relief during trial stimulation, patients were classified into 2 groups: good and fair in one group and poor in the other. Clinical factors such as age, sex, painful region treated (upper vs lower limb), duration of pain, cause of stroke (putaminal vs thalamic hemorrhage), presence or absence of hyperpathia or allodynia, and degree of motor weakness (absent or mild vs moderate) were compared between the 2 groups using the Mann-Whitney *U* test for age and duration of pain and the Fisher exact test for the remaining factors.

Statistical Analysis

VAS scores before the trial, during trial stimulation, and at latest follow-up were compared using the Wilcoxon signed-rank test for nonparametric data. For the 2 patients with 2 implanted electrodes, VAS score reduction for the thoracic electrode was used for statisti-

TABLE 2. Patient Characteristics and Long-Term Follow-up of 10 Patients With Permanent Implants[a]

Patient	Age, y/Sex	Pain Duration, mo	Underlying Disease	Painful Region Treated	Motor Weakness	Sensory Disturbance		% VAS Score Reduction During Trial	Latest Follow-up		Follow-up, mo
						Allod	Hyperp		%VAS Score Reduction	PGIC Rating	
2	54/F	12	L thal hem	R UL	Mild	+	+	25	20	5	16
3	59,/F	97	R put hem	L LL	Mild	–	+	50	50	2	62
4	65/M	30	R thal hem	L LL	—	–	–	56	50	2	60
6	64/F	68	L put hem	R LL	Mild	+	–	30	30	3	6
8	75/F	24	L thal hem	R LL	Mild	–	–	57	57	2	41
11	66/F	32	R put hem	L LL	Mild	+	–	57	57	2	24
15	65/M	33	L thal inf	R UL	Mild	–	–	33	33	2	25
16	48/M	11	R put hem	L LL	Mild	+	–	65	19	4	12
24	51/F	46	R put hem	L LL and UL[b]	Mild	+	–	57	57	2	12
30	71/M	82	R thal hem	L LL and UL[b]	Mild	+	+	77	ND[c]	ND[c]	ND[c]

[a] Allod, allodynia; Hyperp, hyperpathia; VAS, visual analogue scale; PGIC, Patient Global Impression of Change (scale) (2, much improved; 4, no change; 5, minimally worse); L, left; thal, thalamic; hem, hemorrhage; R, right; UL, upper limb; LL, lower limb; put, putaminal; inf, infarction; ND, not determined.
[b] These patients had 2 electrodes implanted, but in the statistical analysis, only results for the thoracic electrode are included.
[c] This patient had less than 6 months of follow-up at the time of latest follow-up and was therefore excluded from long-term-follow-up analysis.

cal analysis. In all comparisons, findings with $P < .05$ were considered significant.

Ethical Issues

Informed consent was given by each patient, and an approval was obtained from the local Ethical Review Board of Osaka University Hospital.

RESULTS

Trial Stimulation

For trial stimulation, 30 patients had a single lead implanted (24 at the thoracic level for lower limb pain and 6 at the cervical level for upper limb pain). Pain relief was good in 9 patients (30%), fair in 6 patients (20%), and poor in 15 patients (50%). The median VAS score in target areas decreased significantly from 8.0 (range, 5.0-10.0) to 6.0 (range, 1.5-10.0) after the trial ($P < .001$).

Permanent Implantation

Of the 30 patients receiving the trial SCS, only 10 patients decided in favor of a permanent SCS system implantation. Two patients had 2 leads implanted, 1 at the thoracic level for lower limb pain and 1 at the cervical level for upper limb pain (patients 24 and 30; Table 1). The clinical characteristics of the 10 patients who underwent implantation are presented in Table 2.

Of the 10 patients with permanent implants, the degree of pain relief during SCS trial was good in 7 patients, fair in 2 patients, and poor in 1 patient. Only 1 patient with a poor response to trial stimulation decided to have a permanent implant (patient 2; Table 2). That patient was satisfied with a modest degree of pain relief (25% VAS score reduction) and elected to have the implant despite a detailed explanation of the low potential for a favorable long-term outcome.

Results at Latest Follow-up

At the time of the latest check, 1 patient (patient 30) had less than 6 months of follow-up and was therefore excluded from the long-term follow-up analysis. The remaining 9 patients had a mean duration of 28 months of follow-up (range, 6-62 months). At the latest follow-up, 7 patients reported significant pain relief on the VAS scale (5 good and 2 fair). On the PGIC scale, 6 patients reported a rating of 2 (much improved) and 1 patient reported a rating of 3 (minimally improved). All 7 patients used the stimulator regularly (2-10 times daily; Table 2). The remaining 2 patients reported poor pain relief; 1 reported a rating of 4 (no change) and 1 a rating of 5 (minimally worse) on the PGIC scale. The median VAS score in the 9 patients decreased significantly from 8.6 (range, 7.0-10.0) to 4.5 (range, 3.0-8.0; $P = .008$; Figure 2). The mean VAS score reduction in all 9 patients was 41.5% (range, 19%-57%). In the 7 patients with good long-term outcome, the mean VAS score reduction was 46.5% (range, 30%-57%).

Analysis of data from the 2 patients who showed poor long-term results revealed that patient 2 had an initially modest response to trial stimulation. Thereafter, she experienced decreased analgesic efficacy of SCS along with uncomfortable paresthesia in response to stimulation. The other patient (patient 16) had a good response to trial and initial stimulation, but subsequently experienced progressive loss of efficacy of SCS.

The most common stimulation parameters were an amplitude of 1.5 to 3 V (range, 1.5-6 V), a pulse width of 210 μs (range,

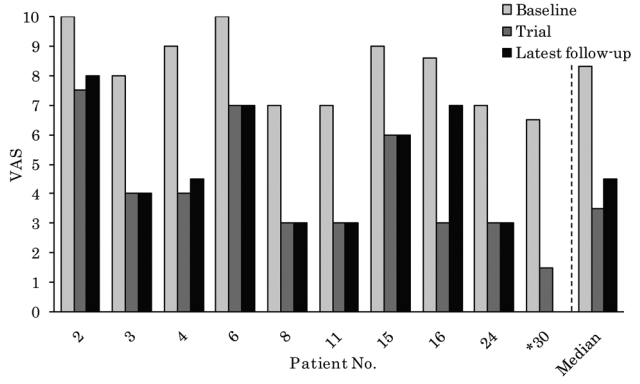

FIGURE 2. *Bar graph showing changes in visual analogue scale (VAS) scores for 10 permanently implanted patients during trial stimulation and latest follow-up The median VAS score in target areas decreased significantly from 8.3 (range, 6.5-10.0) to 3.5 (range, 1.5-10.0) after the trial (*P *< .001) and to 4.5 at latest follow-up (range, 3.0-8.0;* P *= .008). *Patient 30 had less than 6 months of follow-up and was therefore excluded from long-term follow-up analysis.*

210-350 μs), and a frequency of 31 Hz (range, 10-50 Hz) with a bipolar configuration.

Complications

The complications observed included only minor displacement of the electrode tip in 2 patients. This displacement was not associated with a change of efficacy of stimulation, and thus no repositioning was attempted. During the follow-up period, 1 patient (patient 4) died 3 years after implantation of a cause unrelated to SCS.

Clinical Factors Related to the Outcome of Trial Stimulation

There was no significant difference between the 2 groups in any of the factors examined. The incidence of hyperpathia was higher in the poor group than in the good and fair groups, but this result was below the threshold for significance ($P = .074$; data not shown).

DISCUSSION

SCS has previously been considered ineffective for CPSP despite the paucity of data in the literature to support this idea.[6,7] This study is the first to find that SCS may provide improved pain control in a group of patients with medically refractory CPSP. We found that half of the patients exhibited significant pain relief during trial stimulation (Table 1). Moreover, 7 of 9 patients continued to exhibit significant pain relief over a mean follow-up period of 28 months (range, 6-62 months; Table 2). Among these 7 patients, 6 patients reported a rating of 2 (much improved), whereas 1 reported a rating of 3 (minimally improved) on the PGIC scale, and the mean VAS score reduction was 46.5%.

A previous report indicated that 80% of failed back surgery syndrome patients achieve more than 50% pain reduction during trial stimulation.[9] We obtained a lower rate of success during trial stimulation, with 50% of our patients reporting more than 30% pain reduction, and 30% reporting more than 50% pain reduction. However, this modest degree of efficacy is important considering the severity of pain in these patients, the refractory nature of their pain, and the paucity of alterative therapeutic options.

To our knowledge, only 2 previous retrospective studies investigated the use of SCS in CPSP.[6,7,10,11] In agreement with our findings, the first study reported long-term efficacy in 3 of 10 patients,[10] whereas the second study reported long-term pain reduction (≥60%) in only 3 of 45 patients.[11] Using 30% or greater pain reduction as a threshold for success, 6 of our 30 patients (with a mean VAS score reduction of 51.5%) were considered to have a satisfactory outcome, as supported by their choice of much improved on the PGIC scale. The discrepancy between our findings and those of the Katayama et al[11] study may be because of differences in the threshold indicator of a good outcome. Although no consensus exists regarding the definition of a good outcome in chronic pain studies, the criterion of 50% pain relief is increasingly challenged because pain reduction as low as 30% corresponds to a clinically important improvement in many patients.[7,15] We therefore suspect that the clinical efficacy of SCS may have been previously underestimated as a result of the use of an unsuitably high threshold for success.

Therapeutic options for medically refractory CPSP are limited.[16] MCS is reported to provide pain relief in 50% of patients with CPSP.[8] However, because MCS requires a craniotomy, its use is limited to specialized neurosurgical centers.[6] In contrast, the SCS technique is relatively simple, less invasive, and can be mastered not only by neurosurgeons but by many anesthesiologists and pain clinicians as well.[17] Compared with other neurostimulation procedures, percutaneous trial SCS is better tolerated by patients and the electrodes can be removed easily if a trial fails. In our series, the minimal invasiveness and high degree of safety of SCS were demonstrated by the absence of significant complications.

The distribution of CPSP throughout the body may be quite variable. CPSP most often occurs in a hemibody fashion, but may be restricted to distal parts of the body such as the hand or foot.[6] Because coverage of the entire targeted region of pain by stimulation paresthesia is essential for the success of SCS,[18] we selected the most painful region, which is somewhat restricted, as a target for SCS. In this context, a majority of our patients had leg pain most frequently caused by putaminal hemorrhage. Putaminal hemorrhage that affects the posterior part of the internal capsule has the propensity to cause pain that is most severe in, or confined to, the leg.[19] We considered patients with leg-dominant CPSP suitable candidates for SCS because thoracic electrodes are less susceptible to displacement than cervical electrodes.[20] In addition, lower limb pain is not considered a good indication for MCS, given the technical difficulties associated with implanting electrodes on the medial surface of the brain.[8]

In our analysis of clinical factors that may be predictive of response to trial stimulation, we found that patients with hyperpathia tended to respond less well to trial stimulation than those without. This observation is consistent with a previous report in which SCS was less effective for control of evoked pain than spontaneous pain.[21] We also found that the effects of trial stimulation were sustained after permanent implantation in the majority of patients. SCS trial stimulation is thus advantageous for predicting efficacy in a minimally invasive manner before permanent implantation.

The mechanism behind the pain-relieving effects of SCS is still not fully understood. Inhibition at the spinal segmental level and activation of supraspinal mechanisms have been suggested as possible neurophysiological mechanisms.[22] Positron emission tomography and functional magnetic resonance imaging studies have detected brain activation during SCS.[23] Using H(2) 15O positron emission tomography, we recently observed activation not only in somatosensory areas but also in those areas concerned with emotional aspects of pain such as the anterior cingulate cortex and prefrontal areas.[22] CPSP is thought to be caused by abnormal processing of nociceptive information rostral to the level of deafferentation.[11] Therefore, we speculate that the pain-relieving effect of SCS in CPSP may be interpreted in light of its supraspinal mechanisms.

Study Limitations

Two limitations of our study are its retrospective design and small sample size. Unfortunately, it is difficult to recruit a large number of CPSP patients in 1 center owing to the low prevalence and underdiagnosis of this condition.[6] A third limitation is that our study lacked a control arm. Because SCS induces perceptible sensation, it is difficult to conduct prospective, crossover, placebo-controlled studies or blinded evaluations.[24] Therefore, the role of the placebo effect remains an unresolved problem in SCS literature.[24] However, the sustained pain relief in our patients and its correlation to certain stimulation parameters argue against a placebo effect. In the face of unblinded assessment, it may be claimed that placebo effects themselves can run as high as our relatively low threshold of success (30% pain reduction). However, using double-blind testing in MCS patients, Rasche et al[16] found all placebo responders to have less than 30% pain reduction. Therefore, the author concluded that setting the bar at 30% was helpful to discriminate between true and placebo responders. We could not recruit case-matched controls, as our surgical practice allowed us to provide long-term follow-up care only for surgically treated patients. In view of the lack of a control group, one may argue that the long-term pain-relieving effect of SCS may be attributed to spontaneous regression of symptoms; however, in our experience, as in that of others, medically refractory CPSP usually persists over a long time and rarely regresses spontaneously.[4]

Despite these limitations, our data support the idea that SCS may provide improved pain control in a group of patients with severe CPSP that is refractory to other treatments. A prospective, controlled study with a larger population of patients is needed to provide stronger evidence of the efficacy of SCS in CPSP.

CONCLUSION

This study is the first to find that SCS may provide improved pain control in a group of patients with medically intractable CPSP. The efficacy of SCS in CPSP is generally modest, both in terms of the success rate and degree of pain relief. However, this modest degree of efficacy is important considering the severity of pain in these patients, the refractory nature of their pain, and the paucity of alterative therapeutic options. A further prospective, controlled study with a larger population of patients is needed to provide stronger evidence of the efficacy of SCS in CPSP and define the patient population who are most likely to benefit from SCS treatment.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Andersen G, Vestergaard K, Ingeman-Nielsen M, Jensen TS. Incidence of central post-stroke pain. *Pain*. 1995;61(2):187-194.
2. Bowsher D. Cerebrovascular disease: sensory consequences of stroke. *Lancet*. 1993;341:156.
3. Leijon G, Boivie J, Johansson I. Central post-stroke pain—neurological symptoms and pain characteristics. *Pain*. 1989;36(1):13-25.
4. Wider M, Ahlstrom G. Disability after a stroke and the influence of long-term pain on everyday life. *Scand J Caring Sci*. 2002;16:302-310.
5. Finnerup NB, Otto M, McQuay HJ, Jensen TS, Sindrup SH. Algorithm for neuropathic pain treatment: an evidence based proposal. *Pain*. 2005;118(3):289-305.
6. Kim JS. Post-stroke pain. *Expert Rev Neurother*. 2009;9:711-721.
7. Cruccu G, Aziz TZ, Garcia-Larrea L, et al. EFNS guidelines on neurostimulation therapy for neuropathic pain. *Eur J Neurol*. 2007;14(9):952-970.
8. Fontaine D, Hamani C, Lozano AM. Efficacy and safety of motor cortex stimulation for chronic neuropathic pain: critical review of the literature. *J Neurosurg*. 2009;110(2):251-256.
9. Kumar K, Hunter G, Demeria D. Spinal cord stimulation in treatment of chronic benign pain: challenges in treatment planning and present status, a 22-year experience. *Neurosurgery*. 2006;58(3):481-496.
10. Simpson BA. Spinal cord stimulation in 60 cases of intractable pain. *J Neurol Neurosurg Psychiatry*. 1991;54(3):196-199.
11. Katayama Y, Yamamoto T, Kobayashi K, Kasai M, Oshima H, Fukaya C. Motor cortex stimulation for post-stroke pain: comparison of spinal cord and thalamic stimulation. *Stereotact Funct Neurosurg*. 2001;77(1-4):183-186.
12. Klit H, Finnerup NB, Jensen TS. Central post-stroke pain: clinical characteristics, pathophysiology, and management. *Lancet Neurol*. 2009;8(9):857-868.
13. Hosomi K, Saitoh Y, Kishima H, et al. Electrical stimulation of primary motor cortex within the central sulcus for intractable neuropathic pain. *Clin Neurophysiol*. 2008;119(5):993-1001.
14. Stojanovic M, Abdi S. Spinal cord stimulation. *Pain Phys*. 2002;5(2):156-166.
15. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole RM. Clinical importance of change in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain*. 2001;94(2):149-158.
16. Rasche D, Ruppolt M, Stippich C, Unterberg A, Tronnier VM. Motor cortex stimulation for long-term relief of chronic neuropathic pain: a 10 year experience. *Pain*. 2006;121(1-2):43-52.
17. Devulder J, Vermeulen H, De Colvenaer L, Rolly G, Calliauw L, Caemaert J. Spinal cord stimulation in chronic pain: evaluation of results, complications, and technical considerations in sixty-nine patients. *Clin J Pain*. 1991;7(1):21-28.
18. Holsheimer J. Effectiveness of spinal cord stimulation in the management of chronic pain: analysis of technical drawbacks and solutions. *Neurosurgery*. 1997;40(5):990-996.
19. Kim JS. Post-stroke central pain or paresthesia after lenticulocapsular hemorrhage. *Neurology*. 2003;61:679-682.

20. Kumar K, Wilson JR. Factors affecting spinal cord stimulation outcome in chronic benign pain with suggestions to improve success rate. *Acta Neurochir Suppl*. 2007; 97(Pt 1):91-99.
21. Kim SH, Tasker RR, Oh MY. Spinal cord stimulation for non specific limb pain versus neuropathic pain and spontaneous versus evoked pain. *Neurosurgery*. 2001; 48(5):1056-1064.
22. Kishima H, Saitoh Y, Oshino S, et al. Modulation of neuronal activity after spinal cord stimulation for neuropathic pain; H215O PET study. *Neuroimage*. 2010; 49(3):2564-2569.
23. Stancák A, Kozák J, Vrba I, et al. Functional magnetic resonance imaging of cerebral activation during spinal cord stimulation in failed back surgery syndrome patients. *Eur J Pain*. 2008;12(2):137-148.
24. Camerons T. Safety and efficacy of spinal cord stimulation for the treatment of chronic pain: a 20-year literature review. *J Neurosurg*. 2004;100(3)(suppl):254-267.

COMMENT

This article reports the authors' experience using spinal cord stimulation to treat central poststroke pain. This pain syndrome is quite difficult to treat using typical pain management techniques such as physiotherapy and pharmacologic measures. The few reports in existence describe fairly unimpressive results for the efficacy of spinal cord stimulation in poststroke pain. I applaud the authors' persistence in providing additional evidence of the use of this technique. Apparently there may be hope yet for this technique in poststroke pain.

Of the 30 patients who underwent a trial of spinal cord stimulation, 10 underwent permanent placement, and 9 were available for follow-up. Good or fair pain relief was seen in 7 of 9 patients (78%) with just over a mean 2-year follow-up. Outcome measures were change in visual analogue scale scores and a patient satisfaction rating (Patient Global Impression of Change). Minor, clinically insignificant migrations were seen in 2 patients.

These results are not all that different from results of spinal cord stimulation used to treat other neuropathic pain syndromes. Given that poststroke patients who do not respond to less invasive pain management strategies have few remaining treatment options, an overall 30% (9/30) success rate, as seen in this study, is better than nothing. At least most of the treatment failures can be screened by the trial process, thus reducing the overall cost of the therapy. Patients with permanent implants had nearly an 80% success rate at 2 years.

Additionally, regarding the authors' belief that a 50% response rate as a definition of a "successful" implant, I agree that this is arbitrary and restrictive. It is a reasonable number, however, for research purposes and allows a degree of standardization of outcomes between studies. As noted by these authors, in clinical practice, patients will often be satisfied with less than 50% pain relief. I routinely see this in my practice, and this issue should be kept in mind when interpreting the outcomes of any pain study.

I completely agree with the authors' belief that spinal cord stimulation should be one of many neurostimulation techniques available to treat the medically-refractory post-stroke pain patient. Depending upon the distribution of pain, motor cortex stimulation, spinal cord stimulation, spinal nerve root stimulation, peripheral nerve stimulation, and subcutaneous peripheral nerve stimulation should all be considered as reasonable options. Generally, I favor the least invasive, safest, and most effective technique that covers the pain most completely. This study provides evidence that spinal cord stimulation, like these other forms of neurostimulation, should not be excluded a priori as a treatment option, but should be used when appropriate when less invasive measures fail.

Christopher J. Winfree
New York, New York

NEUROSURGEONS' LIBRARY

The neurosurgeons' Library presents reviews of publications that are of interest to neurosurgeons. Although most reviews will be solicited by the book review editor and will focus on books provided for review by publishers, other media including video, audio, and computer software may be reviewed when appropriate. An occasional unsolicited review may be published when the editors think it is of unusual interest and merit. This will usually occur when the reviewer brings to the attention of the neurosurgical community a publication of interest that might not otherwise be noticed by neurosurgeons.

Submissions should be sent to:

Arun P. Amar, M.D.
E-MAIL: amar@aya.yale.edu