

Effectiveness of Cervical Spinal Cord Stimulation for the Management of Chronic Pain

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Introduction: Scientific evidence supports spinal cord stimulation (SCS) as a cost-effective treatment option that, for many disease states, should be employed earlier in the treatment continuum. Reimbursement for SCS in the cervical spine has recently been challenged based on supposed lack of clinical literature. To refute this assumption, we analyzed data from an international registry to support the use of cervical SCS.

Materials And Methods: The following outcomes were collected as part of an institutional review board-approved, prospective, multicenter, international registry: pain relief, Pain Disability Index (PDI) score, quality of life (QoL), and satisfaction at 3, 6, and 12 months post-implantation. Descriptive statistics are provided for all measures. Changes from baseline in PDI scores were analyzed using Tukey's pairwise comparisons.

Results: Thirty-eight patients underwent implantation of SCS leads in the cervical spine at 16 study sites in the United States and 3 international study sites. Direct patient report of percentage of pain relief was 54.2%, 60.2%, and 66.8% at 3, 6, and 12 months post-implantation, respectively. Pain relief was categorized as excellent/good by 61.6% of patients at 3 months, with similar results observed at 6 and 12 months. PDI scores were significantly reduced at all time points. At 3 months post-implantation, 92.4% of patients indicated they were very satisfied/satisfied with the SCS device. No patients indicated that they were dissatisfied. Overall QoL was reported as improved/greatly improved by 73.1% of patients at 3 months. Similar results for QoL and satisfaction were reported at 6 and 12 months.

Conclusion: The results suggest that the use of SCS in the cervical spine is a medically effective method of pain management that satisfies and improves the QoL of most patients. The use of SCS can reduce the high cost of direct medical treatment of pain, as well as increasing the productivity of patients, and therefore should be reimbursed in appropriately selected patients.

Keywords: Cervical radiculopathy, cervical spinal cord stimulation, complex regional pain syndrome, failed neck surgery syndrome, registry

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INTRODUCTION

According to the Institute of Medicine in their landmark 2011 report on chronic pain, common chronic pain conditions affect approximately 100 million adults in the United States, costing \$560–635 billion each year in direct medical treatment costs as well as lost productivity (1). Research indicates that chronic pain rates are likely to continue to rise for several reasons: the aging of the US population, the rising prevalence of obesity, progress in saving the lives of individuals with catastrophic injuries, the risk to surgical patients of acute and chronic pain, and a possible increase in the number of individuals seeking treatment owing to improved general understanding of chronic pain syndromes and the development of new treatments (1). Causes of chronic pain include injuries, chronic disorders (e.g., cancer, arthritis, and diabetes), primary pain disorders (e.g., neuropathic pain, fibromyalgia, and chronic headache), and autonomic nerve disorders (e.g., complex regional pain syndrome [CRPS]). Pain that involves the cervical spinal cord

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and its associated dermatomes (head, upper limbs, neck, anterior/posterior shoulders) may occur because of specific disease states or trauma or may be idiopathic, rooted in an etiology that remains unknown.

Successful treatment of CRPS, cervical radicular pain, ischemic pain, and injury or disease of the peripheral nerves has been achieved with thoracic spinal cord stimulation (SCS), a reversible treatment that employs low-intensity electric impulses to stimulate nerve fibers in the spinal cord and create a neuromodulatory effect on the nervous system to change the perception of pain. Treatment with SCS has been associated with long-term favorable clinical outcomes (2–5) and has been reported to demonstrate substantial long-term economic benefits (6–9). However, whether these results can be extended to use of SCS in the cervical spine remains unknown. Recently, reimbursement for use of cervical SCS has been challenged based on supposed lack of clinical evidence. Considering that the clinical use of neuromodulation, including the use of cervical SCS, continues to increase, it is important to accumulate scientific data in order to further understand the overall effectiveness of neuromodulation on patient outcomes. Potential options for obtaining this data include case reports, case series, retrospective studies, and prospective studies. Another possible option is a patient registry. The impact of a registry is very significant because it allows a prospective, real-time clinical evaluation of the use of the therapy as it is actually applied in daily patient care. In order to determine the effectiveness of cervical SCS and potentially provide real-world clinical evidence to support reimbursement for the therapy, we evaluated patient outcomes through a large, multi-center international registry.

METHODS

The following outcomes were collected as part of an institutional review board (IRB)-approved, prospective, multicenter, international registry in which patients were enrolled after implantation of the SCS system: direct patient report of percentage of pain relief; categorical ratings of pain relief (excellent, fair, good, poor, unable to decide); pain-related disability as assessed by the Pain Disability Index (PDI) questionnaire; categorical ratings of quality-of-life (QoL) measures including health, sleep, walking ability, mood, and overall QoL (greatly improved, improved, neither improved nor deteriorated, deteriorated); categorical ratings of patient satisfaction (very satisfied, satisfied, neither satisfied nor dissatisfied, dissatisfied, very dissatisfied); patients' willingness to undergo the procedure again (yes, no, unsure); and patient recommendation of the procedure to others (yes, no, unsure).

These outcomes were collected at 3, 6, and 12 months post-implantation. PDI scores were retrospectively collected to reflect patient status at baseline. Descriptive statistics are provided for all measures. Results are expressed as means and standard deviations where appropriate. Additionally, changes from baseline in PDI scores at all time points were analyzed using Tukey's pairwise comparisons.

RESULTS

Demographics/Patient History

Diagnosis, pain area, and implant information are provided for 38 patients who received implantation of the SCS lead in the cervical spine at 16 study sites in the United States and 3 international study sites. Follow-up data are provided for 26 patients who completed

Table 1. Patient Diagnoses.

Diagnosis	N (%)
Complex regional pain syndrome I or II	9 (23.7)
Failed back surgery syndrome	9 (23.7)
Failed neck surgery syndrome	5 (13.2)
Radiculopathy	4 (10.5)
Cervical degenerative disc disease	2 (5.3)
Neuralgia	2 (5.3)
Axial neck neuropathy	1 (3.4)
Disc displacement	1 (3.4)
Brachial plexopathy	1 (3.4)
Neck pain	1 (3.4)
Raynaud's syndrome	1 (3.4)
Unknown	2 (5.3)

the 3-month visit, 21 patients who completed the 6-month visit, and 16 patients who completed the 12-month visit.

Diagnoses are shown in Table 1. The most common diagnoses were CRPS I or II and failed back/neck surgery syndrome, with almost 50% of the patients falling into these categories. Other diagnoses included radiculopathy (10.5%). Diagnosis was unknown in 2 patients. The area of pain indicated most often by patients was either unilateral shoulder/arm only ($N = 9$), unilateral shoulder/arm and cervical spine/neck ($N = 7$), or bilateral shoulder/arm and cervical spine/neck ($N = 8$). Other areas included cervical spine/neck only ($N = 5$); bilateral shoulder/arm only ($N = 2$); thoracic spine only ($N = 1$); bilateral leg and cervical spine/neck ($N = 1$); bilateral leg and foot ($N = 1$); bilateral leg and lumbar spine ($N = 1$); back of the head, unilateral shoulder/arm, and cervical spine/neck ($N = 1$); bilateral shoulder/arm, thoracic spine, and cervical spine/neck ($N = 1$); and thoracic spine, unilateral shoulder/arm, and cervical spine/neck ($N = 1$).

Implant Information

Twenty-eight patients (73.7%) were implanted with percutaneous leads, and 10 patients (26.3%) received paddle leads. These leads were implanted with the tip at C2 in 50.0% of patients ($N = 19$), at C3 in 28.9% of patients ($N = 11$), at C4 in 10.5% of patients ($N = 4$), and at C5 ($N = 2$), C6 ($N = 1$), and C7 ($N = 1$) in the remaining patients.

Pain Relief

At 3 months post-implantation ($N = 26$), the mean patient-reported percentage of pain relief was $54.2 \pm 21.4\%$, and at 6 months ($N = 21$), the mean patient-reported percentage of pain relief was $60.2 \pm 24.8\%$. Data were available at 12 months post-implant for 16 patients, and these patients reported a mean percentage of $66.8 \pm 22.5\%$. Patients also were asked classify their pain relief in the following categories: excellent, fair, good, poor, or unable to decide. At 3 months, the majority of patients categorized their pain relief as excellent (23.1%) or good (38.5%). Only 1 patient reported their pain relief as poor. Similar results were observed at the 6- and 12-month follow-ups. Results are depicted in Figures 1 and 2.

Patient Disability/Quality of Life

PDI scores were collected as baseline by asking the patients to recall information regarding their pain prior to implantation of the

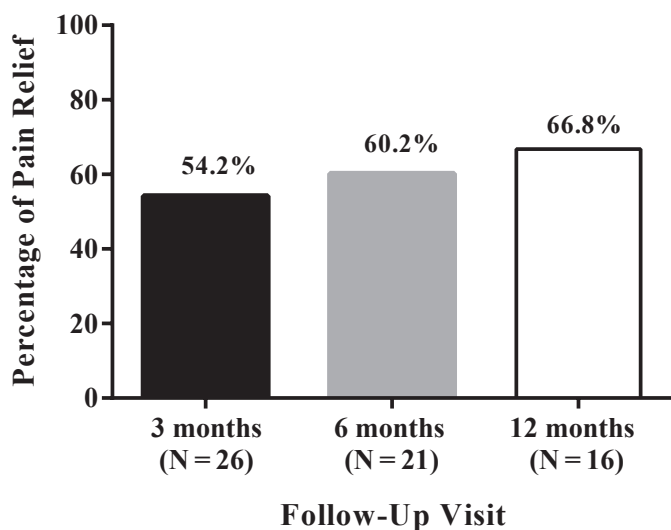


Figure 1. Direct patient-reported percentage of pain relief.

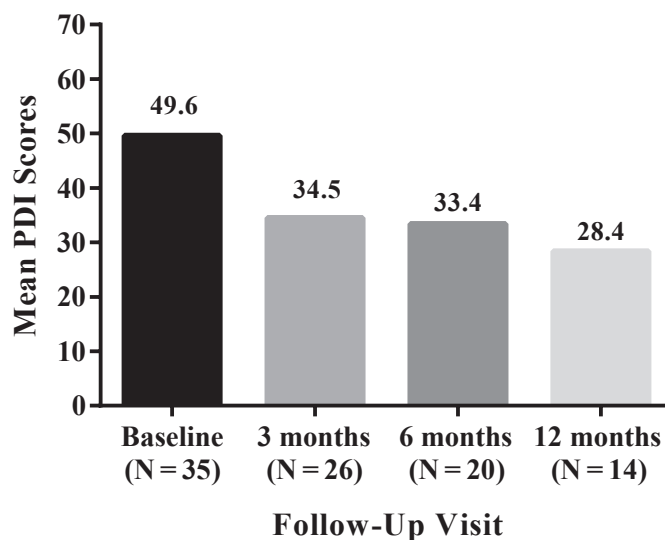


Figure 3. Pain Disability Index (PDI) scores.

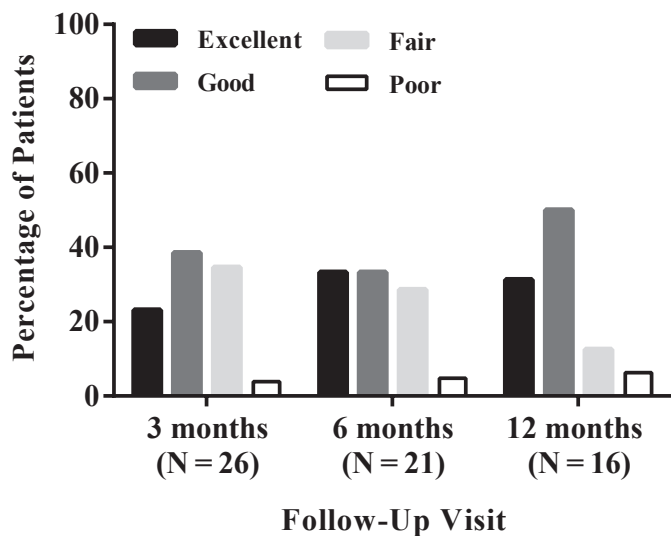


Figure 2. Categorical ratings of pain relief.

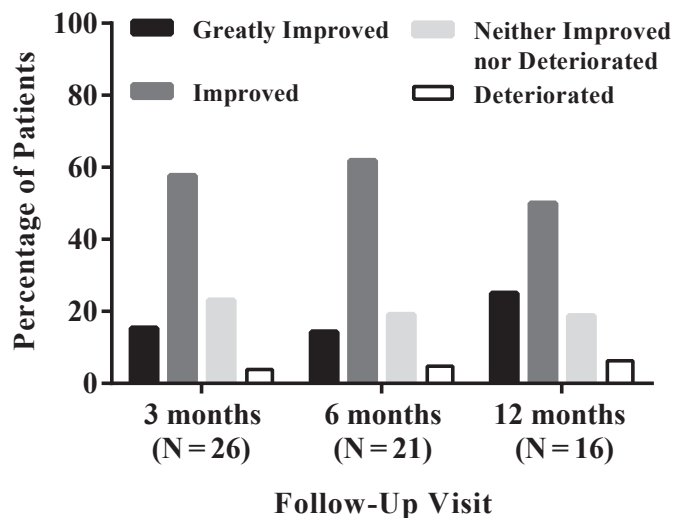


Figure 4. Overall quality of life.

SCS system. Scores were then collected again at 3, 6, and 12 months post-implantation. The mean baseline PDI score was 49.6 ± 14.4 . This score was significantly reduced to 34.5 ± 15.7 at 3 months ($p = 0.0013$), to 33.4 ± 15.5 at 6 months ($p = 0.0014$), and to 28.4 ± 13.4 at 12 months ($p = 0.0001$). These results (Fig. 3) indicate a significant improvement in pain-related disability at all time points post-implantation.

QoL measures including health, sleep, walking ability, mood, and overall QoL also were assessed (Fig. 4). Overall, most patients reported that their health, sleep, walking ability, mood, and overall QoL were improved or greatly improved at 3, 6, and 12 months post-implantation. The percentage of patients reporting their health as improved or greatly improved was 80.7% at 3 months, 80.9% at 6 months, and 62.6% at 12 months. For sleep, 53.9% reported it as improved or greatly improved at 3 months, 52.4% reported the same at 6 months, and 56.3% reported sleep as improved or greatly improved at 12 months. The percentage of patients reporting their ability to walk as improved or greatly

improved was 57.7% at 3 months, 61.9% at 6 months, and 81.3% at 12 months post-implantation. Improved or greatly improved mood was reported by 76.9% of patients at 3 months, 76.2% of patients at 6 months, and 50.1% of patients at 12 months. Overall QoL was reported as improved or greatly improved by 73.1% of patients at 3 months, 76.2% of patients at 6 months, and 75.0% of patients at 12 months.

Patient Satisfaction

Patients were asked to indicate their overall level of satisfaction with the SCS device as well as whether they would choose to undergo the procedure again and whether they would recommend the procedure to someone else with a similar condition. At 3 months post-implantation, 92.4% of patients indicated that they were very satisfied or satisfied with the SCS device. Similar results were seen at both 6 and 12 months post-implantation, with 85.7% and 87.6% of patients indicating the same at 6 and 12 months, respectively. No

patients indicated that they were dissatisfied with the SCS device. When asked if they would undergo the procedure again, 76.9%, 76.2%, and 75.0% of patients indicated yes at 3, 6, and 12 months, respectively. The percentage of patients that indicated that they would recommend the procedure to others also was 76.9% at 3 months, 76.2% at 6 months, and 75.0% at 12 months post-implantation. Only 1 patient indicated that they would not recommend the procedure to others.

Adverse Events

Six of the 38 cervical patients (15.8%) experienced 6 adverse events (AEs). These events included persistent pain or numbness at the electrode or implantable pulse generator (IPG) site ($N=3$), infection ($N=2$), and suboptimal IPG placement ($N=1$). Five of these events required an additional surgery to resolve the issue, and 3 were classified as serious.

DISCUSSION

In this IRB-approved, prospective, multicenter, international registry, direct patient report of percentage of pain relief was greater than 50%, and pain relief was categorized as excellent or good by the majority of patients at all time points assessed. In addition, PDI scores were significantly reduced, and the majority of patients indicated they were very satisfied or satisfied with the SCS device and reported overall QoL as improved/greatly improved. The most commonly observed AE was persistent pain or numbness at the electrode or IPG site, which comprised half of all AEs (3/6) in 7.9% (3/38) of patients. Collectively, the results indicate that the use of SCS in the cervical spine is safe and efficacious.

The findings from this analysis of registry data are comparable with those observed in other registries designed to evaluate thoracic SCS for the management of chronic pain. For example, improvement in QoL was shown for 63% of patients in a large Italian registry of SCS patients with vascular and neuropathic pain. In addition, 94% of patients were satisfied with the therapy, and 87% would undergo the procedure again (10). In a registry of patients implanted with an SCS system for the management of chronic pain from spinal stenosis, the mean overall pain reduction was 63% at 24 months, and a significant reduction in consumption of opioid medications was noted (11).

In order to supplement our own data from the international registry to support the appropriateness of use and efficacy of SCS in the cervical spine, we also conducted a systematic literature review. An extensive literature search was performed using the MEDLINE database (PubMed) to systematically search for all published articles within publicly available literature using specified limits and keywords as search criteria. Approximately 321 articles were identified and reviewed to determine inclusion in the literature review. Inclusion/exclusion criteria were as follows: 1) patients were treated with SCS; 2) patients were human and ≥ 18 years of age; 3) patients were diagnosed with pain and/or disability associated with CRPS, cervical radicular pain, ischemic pain, or injury or disease of the peripheral nerves; 4) the study was conducted to examine the efficacy of treatment for chronic pain; 5) the article was not a review, case study, or non-English-language article; 6) means, percentages, or statistics were reported; 7) the number of patients was stated; and 8) outcome measures included the visual analogue scale (VAS) or patient-reported pain relief. From a total of approximately 321 articles identified in the search, a total of 12 studies (4 prospective,

non-randomized, uncontrolled studies; 4 retrospective studies; and 4 case series) complied with all inclusion/exclusion criteria. These 12 articles reported on 211 patients. The following is a detailed review of these articles, which provide valid scientific evidence for the efficacy of cervical SCS.

The first of the four prospective studies sought to determine whether SCS improves quality of life in patients diagnosed with progressive systemic sclerosis (PSS) and Raynaud's syndrome (12). Fifteen patients affected by PSS were recruited; six with type II were in the edematous stage, eight with type I in the sclerotic stage, and one with type III in the atrophic stage. Raynaud's syndrome had been present in all patients for 10 years or more. The electrode was placed between C4 and C7 in order to achieve paresthesia in both upper limbs. Patients were trialed for a 2-week period to ascertain who would most likely benefit from a permanent implant. In all cases, the stimulation was beneficial and the system was internalized. After a follow-up period ranging from 12 months to 6 years, a noticeable clinical improvement was demonstrated in all patients. Specifically, the Raynaud's episodes improved in 93% of the patients, the edema was reduced and hand motility improved in 86% of the patients, there was ulceration improvement in 100% of the patients, and arthralgic pain was reduced in 86% of the patients. In all cases, a minimum of 50% pain relief was reported during cold test and in winter. Additionally, 10 patients who frequently took analgesic or anti-inflammatory drugs reduced the daily doses, and 100% of the patients were satisfied with their new therapy.

The second, a prospective study by Calvillo et al. (13), reported longitudinal pain ratings in 36 patients in advanced stages of CRPS who were managed with SCS and/or peripheral nerve stimulation (PNS). Twenty-four patients were implanted with the SCS device, 7 patients received SCS and PNS, and 5 patients received PNS only. SCS leads were placed in the cervical region of the spine. Patients reporting 50% or greater pain relief during the trial period were permanently implanted. The VAS was used to assess pain relief prior to implant and 36 months after implant in all groups. Immediately after implant, the PNS group reported 75.7% pain relief, the SCS group reported 63.5% reduction in their pain, and those with both SCS and PNS reported 78.1% pain relief. Analysis at 36 months after implantation revealed significant reduction in VAS scores for all groups, with the SCS group reporting a 45.3% pain reduction, the PNS group reporting a 51.3% reduction, and the PNS/SCS group reporting a 63.5% reduction. Additionally, narcotic intake decreased by about 50% in 44.4% of the patients. In the remaining patients, a significant reduction was not observed, but the analgesic was about 80% more effective in relieving pain. QoL also was reported as improved by most patients, and 41% of patients returned to work. Based on their findings, the authors recommend cervical SCS as a reasonable option when other therapies have failed in late stages of CRPS.

The third prospective study was conducted by Simpson and colleagues (14) to assess the effectiveness of cervical SCS in the management of intractable neuropathic or ischemic pain syndromes affecting the upper limb and face. In 41 patients with different pain indications, pain relief (using the VAS) and pain medication use were evaluated before the surgery and then again at a mean follow-up of 55 months (range 5 to 135 months). In total, 61% of patients achieved results from the SCS device that were categorized as "significant" or "moderate." In the patients with brachial plexus damage, CRPS I and II, spinal cord damage, failed neck surgery syndrome, and Raynaud's syndrome, more than 50% reported significant effects from the stimulation. The authors note that the only category in

which cervical SCS was not found to be effective was in facial pain. They also conclude that the SCS system used in the study provides reliable and sustained cervical SCS and that the outcomes are comparable with thoracic cord stimulation for neuropathic and ischemic syndromes.

The fourth and most recent prospective study evaluated the impact of epidural lead location on clinical outcomes in SCS in 36 CRPS I patients, 19 of whom were implanted with leads in the cervical region of the spine (15). SCS leads were placed in the lumbar region in the remaining 17 patients. Patients were assessed for pain relief using the VAS, improvement in quality of life using the EuroQoL-5D (EQ-5D), and patient impression of improvement through the global perceived effect scale. These assessments occurred before surgery and at 6, 12, and 24 months post-implantation. Both groups, regardless of lead placement, reported a significant reduction in pain from baseline at all follow-up appointments, with 40% of each group reporting a pain reduction of at least 50%. All patients also experienced a significant increase in QoL at each follow-up. Fewer patients reported feeling depression or anxiety following the surgery, and the number of patients with "extreme problems with usual activities" also fell. The authors note that there were no significant differences in scores or outcomes between the cervical and lumbar groups.

Results from several retrospective studies have been published more recently and include a study by Whitworth and Feler (16) that examined the impact of cervical SCS in upper-body chronic pain. They reviewed the medical records of 20 patients with upper extremity pain to obtain presurgery VAS scores and conducted a follow-up appointment to assess poststimulation VAS scores (average follow-up time 26 months, range 3 to 48 months). Indications included reflex sympathetic dystrophy, brachial plexus injury, neuralgia, neuropathic pain, and cervical hemangioblastoma. Eighteen of the 20 patients reported a significant benefit from the SCS procedure for pain, and the authors report an average pain reduction of 63%, with mean VAS scores decreasing from 8.2 to 3. Additionally, 70% of patients achieved an outcome that was classified as "good" or "excellent." Based on their findings, the authors endorse cervical SCS using retrograde placement of paddle leads at C1–C2 as a safe and effective way of treating neuropathic pain phenomena involving the upper extremity.

A retrospective study by Kumar et al. (17) looked at the safety and efficacy of SCS in the treatment of CRPS I. The researchers analyzed the medical records and data of 10 patients who had SCS leads placed in the cervical region of the spine (C7 to C2). These patients were evaluated using the VAS, the Oswestry Disability Index (ODI), and the Beck Depression Inventory (BDI). Evaluations occurred at baseline and at 3 and 12 months post-implantation. In addition, long-term follow-up of these patients occurred at mean follow-up of 88 months. Before surgery, all 10 patients exhibited ODI, BDI, EQ-5D, Short Form (36), and VAS scores that classified them as physically impaired, depressed, having a low QoL, and having a significant amount of pain, respectively. However, at the final follow-up, patients showed marked improvement in the majority of these categories, with a 34% improvement in VAS scores, 9.2% improvement in ODI scores, and 29.6% improvement in BDI scores. The authors conclude that SCS, including cervical SCS, should be considered earlier in the treatment continuum, based on their results showing improvement in pain, QoL, and functional status over the long term.

In two related retrospective studies, Wolter and Kieselbach (18) and Wolter and Winkelmüller (19) assessed the efficacy of cervical SCS in treating patients diagnosed with neuropathic pain syndromes, including Raynaud's syndrome, shoulder pain, phantom

limb pain, CRPS, radial neuropathy, causalgia, plexus lesion, cervicobrachialgia, and nerve injury. Medical records were reviewed and follow-up was conducted through telephone interviews in this study of 18 patients. During the interview, patients were asked questions regarding their pain with and without stimulation, time intervals of stimulation, paresthesia coverage, changes in paresthesia coverage by head movements, unwanted paresthesia of the trunk and legs, treatment satisfaction, and medication intake. At an average follow-up time of 5.8 years after SCS implantation, the average pain score was 6.8 without stimulation, and this number decreased to 2.8 with stimulation. Average daily stimulation time was 14.4 hours. Eleven patients experienced total paresthesia coverage of pain areas, and four patients experienced undesirable trunk/leg paresthesia; however, they did not report this stimulation as bothersome. Interestingly, 11 patients experienced changes in their paresthesia due to head movements, but only 4 found this bothersome. Based on the results of their studies, the authors conclude that cervical SCS may be effective in the treatment of neuropathic upper limb pain and that the complications associated with cervical SCS are not significantly more frequent than in SCS for lower limb pain.

The first of the four case series was conducted to assess the impact of cervical SCS on pain resulting from severe vasospastic disorders in the upper limbs (20). In this study of 11 patients diagnosed with reflex sympathetic dystrophy (8 patients) and idiopathic Raynaud's syndrome (3 patients), pain was assessed using the short-form McGill Pain Questionnaire and categorical ratings of pain relief, where a 90–100% reduction in pain was classified as excellent, a 75% pain reduction with no analgesics and only some adjuvant psychotropic drugs needed was categorized as good, a 50% reduction in pain with analgesic drugs being necessary to control residual pain was classified as fair, and no or minimal pain relief was categorized as poor. At a mean follow-up of 27 months, a total of 90.9% of patients had good or excellent results. The authors state that they believe that SCS is a useful therapy for the management of pain in the late stage of reflex sympathetic dystrophy based on the result of their case series.

Another case series by Vallejo and colleagues (21) reported on 5 patients who underwent a trial of a cervical SCS system for the management of neck and/or upper limb pain. In all cases, patients had previously undergone anterior cervical fusion surgeries without successful reduction or adequate control of their pain. Four out of the 5 patients moved to the permanent implant and went on to report approximately a 70% reduction in pain, including axial neck pain and upper extremity pain, at a follow-up of between 1 and 9 months. Interestingly, 2 patients reported that cervical SCS significantly improved axial low back pain. Based on the results from their study, the authors conclude that SCS could be an effective treatment in patients with failed cervical fusion surgery who have persistent axial neck pain, with or without upper extremity pain.

Hayek et al. (22) conducted a prospective case series of 12 patients to determine the feasibility of stimulation coverage of all limbs with two percutaneous leads placed in the cervical region of the spine. Patients had the following diagnoses: CRPS type I ($N = 6$), peripheral vascular disease ($N = 1$), neuropathic pain persisting after cervical laminectomy and lumbar laminectomy ($N = 2$), chemotherapy-induced neuropathy ($N = 1$), myelopathy post-cervical fusion ($N = 1$), and multiple system atrophy ($N = 1$). Before the procedure, VAS and PDI scores were obtained and the areas of pain were mapped. VAS scores were obtained at the end of the trial period, and VAS and PDI scores were collected 1 month post-implantation. Eleven of 12 patients experienced paresthesia in all

four extremities (91.6% of patients), and 5 underwent permanent implantation of the SCS device in the cervical region of the spine. Prior to the trial, the mean VAS score was 8.9 for these patients, and 1 month after implantation, VAS scores dropped to 5.6, a significant (38%) reduction. Additionally, PDI scores prior to the start of the trial ranged from 48 to 68/70, with a mean value of 64.4. At 1 month after implantation, PDI scores ranged from 32 to 46, with a mean value of 35. This represents a significant (nearly 40%) improvement in function. Based on these results, the authors concluded that it is possible to achieve stimulation that covers both the upper and lower extremities with placement of SCS leads at C4–C7.

A more recent case series by Moens et al. (23) reported on 7 patients with intractable neuropathic neck and upper limb pain who were treated with high cervical SCS. All patients had uncontrolled neck and upper limb pain despite optimal analgesic medication and aggressive interventional procedures before implantation of the SCS device. In all 7 patients, anterior cervical fusion had been unsuccessful for the control of neck and upper limb pain. In this cohort of patients, 6 (86%) indicated significant (>75%) pain relief at trial and underwent permanent implantation of the device. At a mean follow-up of 10 months, all reported that SCS not only alleviated pain in the shoulders and arms but also decreased axial pain. The authors conclude that retrograde placement of SCS leads in the cervical spine results in adequate stimulation of the upper cervical region, based on their results.

AEs were reported for 180 patients across 10 of the 12 studies identified in the systematic literature review. Among these patients, there were 32 hardware malfunctions (17.8%), 25 lead migrations (13.9%), 12 lead breakages (6.7%), 8 patients with pain over implant (4.4%), 4 infections (2.2%), 2 patients with over-/understimulation (1.1%), 1 with intermittent stimulation (0.5%), and 15 patients with other complications (8.3%). Patients could report more than one AE. Additionally, AEs were collected over a range of 1–88 months. In general, it was observed that cervical implantation is not associated with a higher complication rate than thoracic implantation; the two implant techniques are essentially equal. One of the major concerns in the field of neuromodulation has been increased risk of spinal cord compression during implantation of SCS leads in the cervical region of the spine. Among the 180 patients for whom AEs were reported in the literature and the 38 patients in the current study, there were no reports of neurologic insult. Based on these results, we conclude that the risk is low and essentially equivalent to rates of spinal cord compression observed with thoracic SCS.

In summary, a systematic literature review identified 321 articles, 12 of which complied with all inclusion/exclusion criteria. These articles assessed 211 patients and included 4 prospective, non-randomized uncontrolled studies, 4 retrospective studies, and 4 case series. The majority of patients across all studies achieved ≥50% pain relief. The most commonly reported adverse events were hardware malfunction and lead migration. The results of the systematic literature review revealed comparable efficacy rates for cervical SCS and thoracic SCS.

SCS has become a mainstream modality for treatment of certain specific neuropathic pain conditions such as those mentioned in this report. Although this study provides preliminary support for the effectiveness of cervical SCS for treatment of certain specific indications such as CRPS, failed back/neck surgery syndrome, cervical radicular pain, ischemic pain, and injury or disease of the peripheral nerves, additional studies are warranted. These studies should ideally include a randomized controlled study; however, placebo-controlled studies of SCS are plagued with design issues related to

the paresthesia induced by stimulation. Thus, a randomized, matched cohort study may be more appropriate, though not without methodologic limitations.

Because SCS has been shown to provide superior pain relief to other treatment modalities, and because of the minimally invasive and reversible nature of neuromodulation, these results warrant additional assessment and re-evaluation by providers of the inclusion of cervical SCS as a treatment option for their members, where appropriate.

Authorship Statement

All authors contributed to the design or conduct of the study, including patient recruitment, data collection, and data analysis. Dr. Deer, Ms. Archacki, and Dr. Washburn prepared the manuscript draft, with important intellectual input from Dr. Skaribas. All authors approved the final manuscript. St. Jude Medical also provided funding for editorial support. We also thank all the research teams, including the study coordinators, device programmers, and research nurses, for all the time and support spent enrolling and assessing the patients and collecting all data for this registry.

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REFERENCES

1. Institute of Medicine. *Relieving pain in America: A blueprint for transforming prevention, care, education, and research*. Washington, DC: The National Academies Press, 2011.
2. Kumar K, Taylor RS, Jacques L et al. Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain* 2007;132:179–188.
3. Kumar K, Taylor RS, Jacques L et al. The effects of spinal cord stimulation in neuropathic pain are sustained: a 24-month follow-up of the prospective randomized controlled multicenter trial of the effectiveness of spinal cord stimulation. *Neurosurgery* 2008;63:762–770.
4. North RB, Kumar K, Wallace MS et al. Spinal cord stimulation versus re-operation in patients with failed back surgery syndrome: an international multicenter randomized controlled trial (EVIDENCE study). *Neuromodulation* 2011;14:330–335.
5. Manca A, Kumar K, Taylor RS et al. Quality of life, resource consumption and costs of spinal cord stimulation versus conventional medical management in neuropathic pain patients with failed back surgery syndrome (PROCESS trial). *Eur J Pain* 2008;12:1047–1058.
6. North RB, Kidd D, Shipley J, Taylor RS. Spinal cord stimulation versus reoperation for failed back surgery syndrome: a cost effectiveness and cost utility analysis based on a randomized, controlled trial. *Neurosurgery* 2007;61:361–368.
7. Hord ED, Oaklander AL. Complex regional pain syndrome: a review of evidence-supported treatment options. *Curr Pain Headache Rep* 2003;7:188–196.
8. Taylor R, Buyten J, Buchser E. Spinal cord stimulation for complex regional pain syndrome: a systematic review of the clinical and cost-effectiveness literature and assessment of prognostic factors. *Eur J Pain* 2006;10:91–101.
9. Kemler MA, de Vet HC, Barendse GA, van den Wildenberg FA, van Kleef M. Effect of spinal cord stimulation for chronic complex regional pain syndrome type I: five-year final follow-up of patients in a randomized controlled trial. *J Neurosurg* 2008;108:292–298.
10. Soldati E. National Italian Register of Implantable Systems for Spinal Cord Stimulation (SCS): analysis of preliminary data. *Neuromodulation* 2002;5:7–15.
11. Costantini A, Buchser E, Van Buyten JP. Spinal cord stimulation for the treatment of chronic pain in patients with lumbar spinal stenosis. *Neuromodulation* 2010;13:275–279.

12. Francaviglia N, Silvestro C, Maiello M, Bragazzi R, Bernucci C. Spinal cord stimulation for the treatment of progressive systemic sclerosis and Raynaud's syndrome. *Br J Neurosurg* 1994;8:567–571.
13. Calvillo O, Racz G, Didie J, Smith K. Neuroaugmentation in the treatment of complex regional pain syndrome of the upper extremity. *Acta Orthop Belg* 1998;64:57–63.
14. Simpson BA, Bassett G, Davies K, Herbert C, Pierri M. Cervical spinal cord stimulation for pain: a report of 41 patients. *Neuromodulation* 2003;6:20–26.
15. Forouzanfar T, Kemler MA, Weber WEJ, Kessels AGH, van Kleef M. Spinal cord stimulation in complex regional pain syndrome: cervical and lumbar devices are comparably effective. *Br J Anaesth* 2004;92:348–353.
16. Whitworth LA, Feler CA. C1–C2 sublaminae insertion of paddle leads for the management of chronic painful conditions of the upper extremity. *Neuromodulation* 2003;6:153–157.
17. Kumar K, Rizvi S, Bishop S. Spinal cord stimulation is effective in management of complex regional pain syndrome I: fact or fiction. *Neurosurgery* 2011;69:566–580.
18. Wolter T, Keiselbach K. Cervical spinal cord stimulation: an analysis of 23 patients with long-term follow-up. *Pain Physician* 2012;15:203–212.
19. Wolter T, Winkelmüller M. Continuous versus intermittent spinal cord stimulation: an analysis of factors influencing clinical efficacy. *Neuromodulation* 2012;15:13–19.
20. Robaina FJ, Dominguez M, Diaz M, Rodriguez JL, de Vera JA. Spinal cord stimulation in vasospastic disorders of the upper limbs. *Neurosurgery* 1989;24:63–67.
21. Vallejo R, Kramer J, Benyamin R. Neuromodulation of the cervical spinal cord in the treatment of chronic intractable neck and upper extremity pain: a case series and review of literature. *Pain Physician* 2007;10:305–311.
22. Hayek SM, Veizi E, Stanton-Hicks M. Four-limb neurostimulation with neuroelectrodes placed in the lower cervical epidural space. *Anesthesiology* 2009;110:681–684.
23. Moens M, De Smedt A, Brouns R et al. Retrograde C0–C1 insertion of cervical plate electrode for chronic intractable neck and arm pain. *World Neurosurg* 2011;76:352–354.