



# Spinal cord stimulation in the treatment of neuropathic pain: Current perspectives of indications, cost-effectiveness, complications, and results

Bruno Camporeze<sup>1,2\*</sup>, Renata Faria Simm<sup>3</sup>, Iracema Araújo Estevão<sup>1</sup>,  
Luis Roberto Mathias Junior<sup>4,5</sup>, Paulo Henrique Pires de Aguiar<sup>4,5,6,7,8</sup>, Sylvine Carrondo-Cottin<sup>9</sup>

<sup>1</sup>League of Neurosurgery of Medical School of Sao Francisco University, Bragança Paulista, São Paulo, Brazil, <sup>2</sup>Scientific initiation scholarship program, Institute of Medical Assistance of the State Public Servant (IAMSPE), São Paulo, Brazil, <sup>3</sup>Division of Neurology of Santa Paula Hospital, São Paulo, Brazil, <sup>4</sup>Division of Neurosurgery of Santa Paula Hospital, São Paulo, Brazil, <sup>5</sup>Division of Neurosurgery of Oswaldo Cruz Hospital, São Paulo, Brazil, <sup>6</sup>Department of Surgery, Post Graduation Section in Surgery Program of Federal University Rio Grande do Sul, Porto Alegre-RS, Brazil, <sup>7</sup>Department of Neurology of Pontifical Catholic University of São Paulo, Sorocaba, São Paulo, Brazil, <sup>8</sup>Department of Neurosurgery, Public Servant Hospital of São Paulo, São Paulo, Brazil, <sup>9</sup>CHU de Québec Research Center (Enfant-Jésus Hospital), Department of Neurosciences of Faculty of Medicine, Laval University, Quebec, Canada

## ABSTRACT

**Introduction:** The spinal cord stimulation (SCS) has been described as a valuable neuromodulating procedure in the management of chronic and medically untreated neuropathic pain. Although many studies have discussed the use of this technique, a question still remains regarding its efficacy in different medical conditions with different etiology in the long term. The aim of this paper is to discuss the risks, complications, cost-effectiveness, and results of SCS in patients affected by chronic neuropathic pain based on the comprehensive literature review.

**Methods:** Bibliographic search of references from 1950 to 2016 using the databases MEDLINE, LILACS, SciELO, PubMed, and applied language as selection criteria, choosing preferably recent articles written in Portuguese, Spanish, or English.

**Results:** Based on literature review, SCS is a safe, reversible, adjustable, and non-destructive surgical procedure demonstrating a significant effect in the reduction of pain intensity and improvement in the quality of life in these patients. Furthermore, in spite of the initial high cost to its application, SCS has been associated with lower rates of complications and high rates of cost-effectiveness when compared to standard therapies.

**Conclusion:** Although used in medical conditions with different etiology, the procedure is still an effective and a cost-effective approach to neuropathic pain, mainly in patients affected by Failed Back Surgery Syndrome (FBSS) and complex regional pain syndrome.

**Key words:** Spinal cord stimulation; neuropathic pain; pain management; neurosurgical procedure; electric stimulation therapy

\*Corresponding author: Bruno Camporeze, Boa Esperança Street  
184 Vitel, 03408-000, São Paulo, Brazil.  
Phone: +55-11-97312-9070, E-mail: bruno4971202@hotmail.com

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## INTRODUCTION

Pain is defined as an unpleasant sensation and emotional experience related to actual or potential tissue damage. It may be divided into nociceptive, caused by activation of pain receptors related to

tissue damage, or neuropathic pain, caused by a primary lesion or dysfunction in the central, peripheral, or both nervous systems (1-5).

Recent studies have reported a significant increase in the number of patients affected by refractory neuropathic pain. The actual prevalence of neuropathic pain in general population has been estimated from 6.9% to 8%. About 74% of neuropathic pain cases present with moderate-to-severe intensity. Neuropathic pain comprises more than 17% of patients' pain complaint (3,4,6-12).

Management of neuropathic pain is a challenge often associated with high rates of disappointment. Usually, neuropathic pain is managed by the multidisciplinary team and includes pharmacological treatment by opioids, anticonvulsants, tricyclic antidepressants, and corticosteroids. In a few scenarios, non-steroidal anti-inflammatory drugs are used. Furthermore, occupational therapies can be conducted (1,4,9,10).

The surgical management of neuropathic pain includes ablative and non-ablative neurosurgical approaches. These include rhizotomy, sympathectomy, cordotomy, hypophysectomy, regional infusion of sympatholytic infiltrations, and intrathecal administration of drugs. Recently, electrical stimulation therapies such as spinal cord stimulation (SCS), motor cortex stimulation, and deep brain stimulation have been described (13-23).

SCS, also known as dorsal column stimulation (24,25), is a reversible, adjustable, and non-destructive surgical approach. Painful symptoms are controlled through the spinal electrical stimulation, using epidural electrode placed in the posterior horn of the spinal cord (13,15,16,22,26-28).

SCS was firstly described by Shealy et al. (29), in 1967, as an alternative for ablative neurosurgical procedures in the management of refractory pain. Since then, it has been estimated that more than 12,000 SCS systems are sold annually worldwide. SCS has shown significant results in the treatment of a wide range of pain disorders (27).

Our aim is to clarify the indications, risks, complications, and prognosis of patients treated with SCS for neuropathic pain. We will discuss the efficacy of SCS in the control of pain and cost-effectiveness of the procedure.

## METHODS

We searched MEDLINE, LILACS, SciELO, and PubMed databases using "neuropathic pain" and "SCS" keywords. We included articles published between 1950 and 2016, written in Portuguese, Spanish, or English language and involving only human subjects. Only the relevant studies were selected for this review (Figure 1).

### Physiological mechanisms of SCS

SCS mechanism is complex and involves more than just one model or mechanism. SCS is associated with sequential or simultaneous interactions of multiple physiological mechanisms of pain conduction (30-36). The classical mechanism of pain was described in 1965 by Melzack and Wall (36). Recently, the effect of SCS on blood flow and the somatosensory system had been described (Figure 2) (16,30-33).

In 2000, Kemler et al. (32) described the possible relationship between SCS and changes in microcirculation blood flow in patients ( $n = 36$ ) affected by unilateral complex regional pain syndrome (CRPS). The study showed that 66.7% ( $n = 24$ ) of the patients were responsive in the stimulation test with the SCS system. The total of 91.7% of these patients ( $n = 22/24$ ), whose pain was located in the hand (58%) and in the foot (33.4%), had undergone the previous unsuccessful sympathectomy. The authors concluded that patients with lower vasoconstriction rates had a significant pain improvement ( $p < 0.01$ ) when compared to control patients. This has indicated a decrease in sympathetic tone and an increase in vasodilation during the use of the SCS system. Nevertheless, SCS did not result in any microcirculatory changes as there was no difference when compared to baseline values of patients or the contralateral, clinically unaffected side.

In 2016, Deogaonkar et al. (31) presented the results of the functional magnetic resonance imaging in patients ( $n = 10$ ) affected by CRPS in the lower limbs, who had previously undergone SCS. The results of this study showed significant differences ( $p < 0.05$ ) in resting-state connectivity between SCS off and optimal state in several regions related to pain perception. The regions included the left frontal insula, right primary and secondary somatosensory cortices, as well

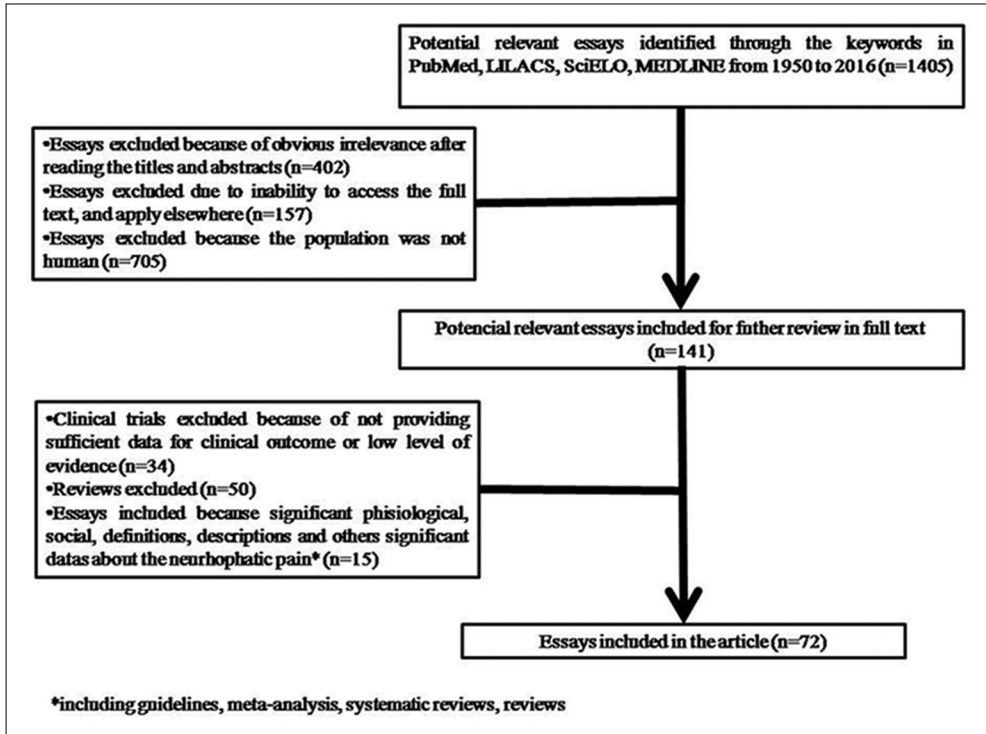


FIGURE 1. Articles were searched in several databases, using the keywords “neuropathic pain” and “spinal cord stimulation.” After applying the relevance, completeness and quality criteria, 72 out of 1405 identified articles were selected.

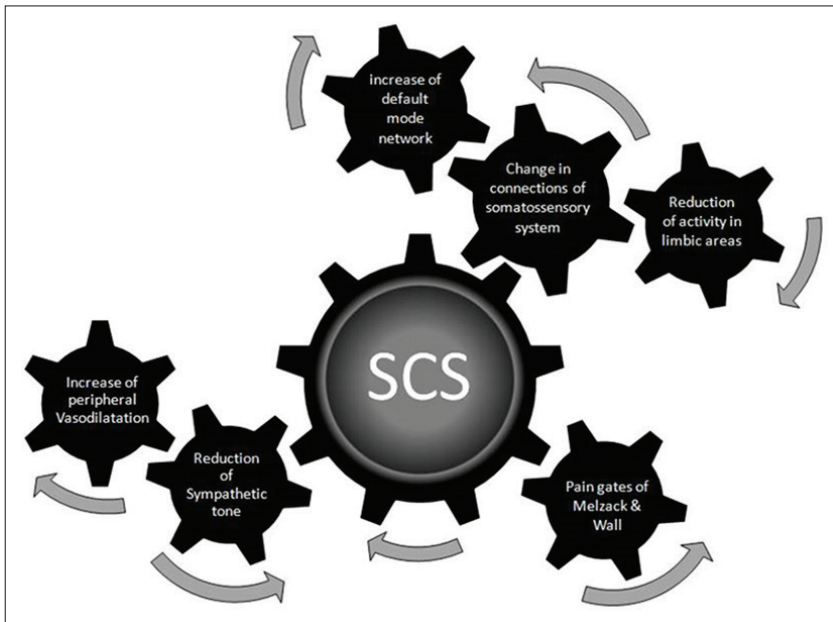


FIGURE 2. Physiological mechanisms of spinal cord stimulation (SCS) include more than just one model or mechanism, illustrating the association between the classical mechanism of pain described by Melzack and Wall (36) and the effect of SCS on blood flow and the somatosensory system (16,30-33).

TABLE 1. Key points of the patient selection criteria

Medically intractable pain	Failure of other surgical procedures of pain control
Pain reduction higher than 50% in trial stimulation	Absence of malignant neoplasms, psychiatric disorders, or other treatable organic or functional etiology

as in regions involved in the default mode network (DMN), such as the precuneus. In addition, these changes in the connectivity across the entire brain during the optimal SCS were found to result in pain relief. Furthermore, the results indicated the increased connection strength between the somatosensory and DMN, and the decreased connection strength between somatosensory and limbic areas. The authors suggested that pain relief from SCS may be reducing a negative emotional processing associated with pain, allowing somatosensory areas to become more integrated into the default mode activity.

In 2012, Moens et al. (37) showed similar results to those discussed by Deogaonkar et al. (31) in patients ( $n = 20$ ) affected by failed back surgery syndrome (FBSS). The authors investigated the deactivation of the bilateral medial thalamus and its connections to the rostral and caudal cingulate cortex and the insula. The study also showed immediate pain relief obtained by short-term SCS correlated negatively with activity in the inferior olivary nucleus, the cerebellum, and the rostral anterior cingulate cortex.

### Selection of patients

The adequate selection of the patients directly affects the success of the SCS approach. During the selection, different factors have been considered, such as the etiology of pain, type and localization of pain, age of the patient, and the radiological and neurological findings summarized in Table 1 (20-22,28,30,31,37-44).

Patients considered for SCS procedure are required to comply with the following criteria:

- Patients with medical intractability of neuropathic pain (20,22,26,32,38,45-49);
- Patients that reported the reduction of 50% or more in pain intensity in the trial simulation (3-15 days) by percutaneous implantation when compared with the

baseline (20-22,26,32,38,45-49);

- Patients diagnosed with complex regional pain syndrome (CRPS), Type I - A level of evidence (20-22,27,28,30,38-43);
- Absence of the major psychiatric disorder including somatization disorder complaints (20-22,38);
- Patients with unsuccessful control of neuropathic pain after the repeated functional or ablative surgical procedure for pain treatment (20-22,38,45);
- Patients with pain not associated with malignancy (38).

During the surgical procedure of trial implantation, patients should be asked to indicate the location of parenthesis (change of sensibility correlated to the spinal segment stimulated) since it is relevant to confirm that the resultant parenthesis overlaps with the painful area to achieve good analgesia (20-22,26,28,45).

### RESULTS IN PAIN MANAGEMENT

It is essential to determine the cause of pain to effectively manage it. In terms of the neuropathic pain etiology, SCS has been applied in the treatment of deafferentation pain, central pain, phantom limb pain (PLP), causalgia, myelopathy, oncologic pain, lumbosacral fibrosis, postherpetic neuralgia (PHN), FBSS, CRPS, reflex sympathetic dystrophy (RSD), spinal cord, brainstem or brain injury, and others (3,13-15,22,32,33,38,42,43,46-49,50-57). Since there are many different types of neuropathic pain, there is no reason to believe that one procedure will be effective in the treatment of all conditions.

In 2006, Lee and Pilitsis (38) reported that SCS is an effective treatment for pain associated with FBSS, refractory angina pectoris, peripheral vascular disease, and CRPS Type I. Between 60% and 80% of patients with FBSS, peripheral vascular disease and CRPS Type I had a significant improvement in the quality of life related to returning to daily activities. The SCS procedure in patients affected by refractory angina pectoris resulted in a significant decrease in hospital admissions and chest pain, as well as an increased exercise duration. In addition, the comparison between SCS and open surgical procedures showed that SCS demonstrated less morbidity rates

and similar or higher rates of pain control and improvement in the quality of life.

In 2008, Olsson et al. (50) presented the results of SCS in children ( $n = 7$ ; 100% girls) diagnosed with CRPS Type I, within the mean age  $13 \pm 1.1$  years (ranging from 11 to 14 years). Regarding the location of the pain, this paper showed in feet (57.1% of cases;  $n=4$ ), hands (14.3%;  $n=1$ ), unilateral knee (14.3%;  $n=1$ ), and bilateral knees (14.3%;  $n = 1$ ). Complications were reported in 14.3% ( $n = 1$ ) of patients affected by subcutaneous infection, which resulted in the surgical removal of the SCS system. All the patients were treated with sympathetic blocks (SB), without a therapeutic effect. However, the SCS procedure had a pain relieving effect after 1 or 2 weeks of trial stimulation. The pain alleviation was complete in 71% ( $n = 5$ ) of the patients, ranging from 1 to 8 years after the intervention, after another 2-6 weeks.

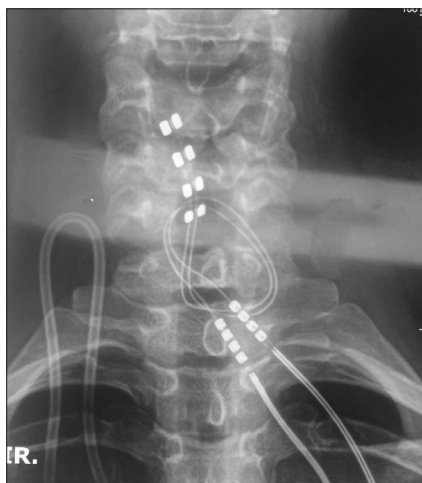
In their article in 2008, Kemler et al. (47) described the SCS results in patients diagnosed with CRPS Type I ( $n = 36$ ), whose follow-up lasted 5 years. The authors demonstrated an effective long-term pain treatment for 63% ( $n = 24$ ) of the implanted patients. The total of 100% ( $n = 36$ ) and 53% ( $n = 19$ ) of these patients presented more than 50% of pain reduction and more than 80% of pain intensity by the visual analog scale in the first post-operative year, respectively. The percentage of patients who reported at least 30% reduction in pain with SCS was reduced from 100% to 41% in the fifth post-operative year. During the 5-year treatment, 29 technical complications were reported, including lead migration, pulse generator replacement, explanation, and reimplantation of the system. About 72% ( $n = 21$ ) of the complications took place in the 1<sup>st</sup> 2 years, while the annual complication rate in the remaining 3 years was 5%. Geurts et al. (48), Williams et al. (55), Harke et al. (56), Kumar et al. (58), Kemler and Furnée (46), Kemler et al. (47,49), and Van-Eijs et al. (54) reported similar results on pain management.

In 2012, Van-Eijs et al. (54) described the results of the comparison between the standard therapy and the use of SCS in patients ( $n = 61$ ) affected by CRPS. The standard therapy included physical therapy (PT), topical dimethyl sulfoxide, analgesics, transcutaneous

stimulation, and sympathetic blockade. In these patients, 90.1% ( $n = 55$ ) were treated with the standard therapy and 9.9% ( $n = 6$ ) were included for the SCS treatment. The overall mean pain relief after 1 year was 35% and the mental component improved in both groups, while none of the SCS-treated patients showed a clear improvement in the functional outcome. No significant difference of effect on the physical component was demonstrated as well.

In their 2016 study, Kim et al. (14) presented the results of the continuous thoracic sympathetic ganglion block associated with SCS in patients ( $n = 3$ ) diagnosed with unilateral CRPS in their upper limbs. The mean age of patients was 53.6 years, ranging from 49 to 56 years. The authors concluded that the thoracic SB was efficient in the treatment of neuropathic pain of upper extremities once the approach was associated with improvement higher than 50% of basal pain. Nevertheless, this procedure often had temporary effects. Although the authors indicated that SCS did not achieve the total control of pain, this approach avoided several complications taking place in the continuous SB.

In 2011, Sears et al. (42) described the results of SCS in patients ( $n = 35$ ) diagnosed with CRPS ( $n = 18$ ) and FBSS ( $n = 17$ ). A total of 18 male and 17 female patients participated in the CRPS and FBSS groups,

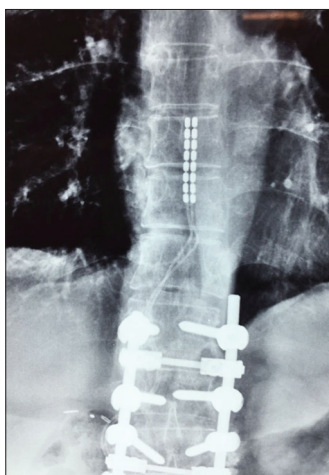


**FIGURE 3.** A patient affected by chronic phantom-limb pain was implanted with a cervical medullary electrode. The intraoperative radiography shows the positioning of the adequate electrode in the middle of vertebral column, inside the epidural.





**FIGURE 4.** A patient diagnosed with chronic FBSS after lumbar arthrodesis underwent spinal cord stimulation implantation. The intraoperative radiography, in the sagittal plane, shows the positioning of the adequate electrode in the middle of vertebral column, inside the epidural.



**FIGURE 5.** A patient affected by chronic FBSS after lumbar arthrodesis underwent SCS system implantation. The intraoperative radiography, in the sagittal plane, shows the positioning of the adequate electrode in the middle of the vertebral column, inside the epidural.

respectively. The mean age was 44.3 years and 51.6 years, the duration of pain at the time of the surgery was 9.6 years and 8.5 years, and the duration of a follow-up after the surgery was 5.0 years and 3.8 years in CRPS and FBSS groups, respectively. More than 50% of the patients with CRPS reported more than 50% pain relief at a mean follow-up of

4.4 years, while 30% of the FBSS patients reported a 50% or greater improvement at a mean follow-up of 3.8 years. The review reported more than 50% pain relief in 55.6% of CRPS patients ( $p < 0.01$ ) and 30% of FBSS patients ( $p < 0.01$ ). Furthermore, 77.8% of CRPS patients ( $p = 0.15$ ) and 70.6% of FBSS patients ( $p = 0.01$ ) indicated that they would undergo a SCS surgery again for the same outcome. In this respect, Cruccu et al. (13), Kumar et al. (41), Taylor et al. (40), Cameron (27), North et al. (59), and Kumar et al. (60) reported similar results on pain management obtained by conducting SCS in patients affected by FBSS.

Simpson et al. (52) in 2009 and Wills et al. (61) in 2015 provided the results of the systematic review on the clinical effects of SCS in patients affected by neuropathic and ischemic pain. Their studies were based on more than 600 quotes identified from 13 databases from 1950 to 2014. The authors showed in this study that the presence of clinical benefits for refractory angina is showed in a short-term treatment. Furthermore, this also applies to the improvement of the quality of life, enhancement of physical performance, reduction in the use of nitroglycerine, decrease in hospitalization admissions, and reduction in pain intensity and frequency in these patients. With this regard, in 1999, Vaarwerk et al. (62) presented the results of the SCS use in patients ( $n = 517$ ) diagnosed with refractory angina pectoris. The study included 71% male patients ( $n = 367$ ), a median follow-up was 23 months (ranging from 0 to 128), within the mean age  $63.9 \pm 10.1$  years. Therefore, this study and other authors, such as Murphy and Giles (24) demonstrated the improvement ranging from 3.5 to 2.1 ( $p < 0.01$ ), based on the New York Heart Association Functional Classification. In addition to the improvement, the total percentage of hospital admissions was reduced to 30% ( $p < 0.001$ ).

Numerous literary sources report variable success rates in the neuropathic pain management with SCS in patients affected by the section of the spinal cord conus and cauda equina, complete transverse section of the spinal cord, injury in multiple radicular roots, and PLP as shown in Figure 3 (5,13,21,22,63,64). Patients diagnosed with CRPS, FBSS (Figures 4 and 5), and PHN have shown significant success rates in pain management

**TABLE 2.** Pain control rates of SCS

Authors	Year	n	Etiology	Complete pain relief with SCS	Mean pain relief higher than 50% of baseline	Mean follow-up
Olsson et al. (50)	2008	7	CRPS	71% of patients	100% of patients	8 years
Kemler et al. (47)	2008	36	CRPS	63% of patients	83% of patients	5 years
Van-Eijs et al. (54)	2012	61	CRPS	0% of patients	0% of patients	1 year
Kim et al. (14)	2016	3	CRPS	0% of patients	100% of patients	1 year
Sears et al. (42)	2011	35	FBSS (n=17) CRPS (n=18)	0% of patients 0% of patients	>50% of patients >50% of patients	4 years 5 years
Harke et al. (56)	2002	28	PHN	0% of patients	82% of patients	3 years
Kumar et al. (60)	2002	104	FBSS	0% of patients	88% of patients	5 years
Williams et al. (55)	2009	1	CRPS	100% of patients	100% of patients	1 year
Geurts et al. (48)	2012	84	CRPS	0% of patients	64% of patients	11 years
Viswanathan et al., (41)	2010	4	PLP	25% of patients	100% of patients	1 year

\*n: Number of patients; PHN: Postherpetic neuralgia; CRPS: Complex regional pain syndrome; FBSS: Failed back pain syndrome; PLP: Phantom limb pain. SCS: Spinal cord stimulation

**TABLE 3.** Long-term complications rates of SCS

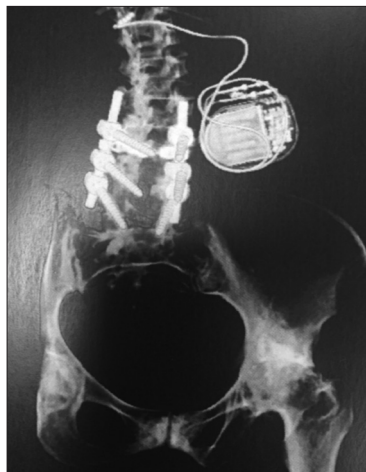
Complication	Incidence rates (%)	n (510 patients)*
Absence of complications	59	301
Lead migration	17.4	89
Hardware malfunction	7.5	38
Lead breakage	4.9	25
Hematomas	3.5	18
Infection	2.8	14
Discomfort at the pulse generator	1	5
Cerebral fluid leak	1	5
Aseptic meningitis	0.8	4
Muscle spasms	0.6	3
Rotation of the pulse generator	0.6	3
Rejection of the system	0.4	2
Headache, asthenia, dizziness	0.4	2
Paralysis	0.1	1

\*Franzini et al. (69) and Meglio et al. (66). SCS: Spinal cord stimulation

and cost-effectiveness associated with low rates of complications. The total pain management was rarely obtained by the use of SCS as therapy as indicated in Tables 2-4 (22,38,39,41,50,58,60,65-67).

**Complications**

Although long-term complications rates of SCS can vary in this type of surgical procedure, such as the



**FIGURE 6.** A patient diagnosed with chronic FBSS after lumbar arthrodesis underwent spinal cord stimulation implantation. The intraoperative radiography, at the coronal section, shows the displacement of the implanted electrode.

presence of electrode migration (Figure 6), battery or pulse generator failures, hardware malfunction, also, the paresthesia in other body parts, and superficial infections were associated to SCS approach. Furthermore, the low rates of electrode breakage, change of amplitude of pulse by bodily movements, unwanted stimulation, unsatisfactory positioning of the electrode or generator, urinary disturbances, cerebrospinal fluid leakage, subcutaneous hematomas, epidural hematomas, deep infections, aseptic meningitis, paralysis, spinal cord injury, headache,

**TABLE 4.** Cost-effectiveness of main neuropathic pain therapies

Authors	Number of patients	Etiology	Treatment	Mean treatment cost
Kemler and Furnée (46)	18	CRPS	SCS+PT	EUR 171,153.00 (in 1 year of follow-up)
Kemler and Furnée (46)	36	CRPS	PT	EUR 229,624.00 (in 1 year of follow-up)
Kemler and Furnée. (46)	24	CRPS	SCS	EUR 193,580.00 (in 1 year of follow-up)
Manca et al. (57)	50	FBSS	SCS+CPT	EUR 12,653 (in 0.5 year of follow-up)
Manca et al. (57)	50	FBSS	CPT	EUR 2,594 (in 0.5 year of follow-up)
Manca et al. (57)	50	FBSS	SCS+CPT	EUR 1,692 (in 1 year of follow-up)
Manca et al. (57)	50	FBSS	CPT	EUR 2,664 (in 1 year of follow-up)
Kumar et al. (41)	52	FBSS	CPT	USD 38,029.00 (in 5 years of follow-up)
Kumar et al. (41)	52	FBSS	SCS	USD 29,123.00 (in 5 years of follow-up)

\*SCS: Spinal cord stimulation; CPT: Conventional pharmacological treatment; PT: Physical therapy; CRPS: Complex regional pain syndrome; FBSS: Failed back surgery syndrome

asthenia, dizziness, muscle spasms, and pain located at the incision, electrode, or receiver site are risks to be considered during and after the surgical act (13,27,32,38-40,46-49,68).

In 2004, Cameron (27) summarized the 20-year application of SCS, including the data obtained from 51 research papers, comprising 2972 patients in total. This study specified complications related to technical or biological plots. The most common technical complications are battery or pulse generator failures and electrode breakage and dislocation (27). The most frequently reported biological complications are cerebrospinal fluid (CSF) leakage, infections, and pain located at the incision, electrode, and receiver site (27). It is important to underline that this study identified paralysis and electrode migration as the most serious and the most common SCS complication, respectively. In addition, this assessment showed that the majority of complications were not considered as life-threatening and could be mainly solved by removing the device.

In 2005, Franzini et al. (69) presented the results of a retrospective analysis of a 22-year experience in 410 patients who underwent the SCS implantation. The authors reported displaced electrode, fractured electrode, other hardware malfunctions, subcutaneous hematomas, infection, CSF leakage, rotation of the pulse generator, and discomfort at the pulse generator site in 21.5% ( $n = 89$ ), 5.9% ( $n = 25$ ), 8.1% ( $n = 34$ ), 4.4% ( $n = 18$ ), 3.4% ( $n = 14$ ), 0.5% ( $n = 2$ ), 0.7% ( $n = 3$ ), and 1.2% ( $n = 5$ ) patients, respectively.

In their study in 1989, Meglio et al. (66) presented the results of the use of SCS in a case series ( $n = 100$ ) of patients. The examined patients were affected by obstructive peripheral vasculopathy ( $n = 40$ ), previous herpes zoster infection ( $n = 10$ ), incomplete traumatic spinal cord lesion ( $n = 15$ ), root and/or nerve damage ( $n = 9$ ), cancer ( $n = 11$ ), earlier back surgery ( $n = 19$ ), and undetermined pain etiology ( $n = 5$ ). This study reported complications related to aseptic meningitis, infection, paralysis (paraplegia), rejection of the electrode leads, CSF leakage, and the system failure in 4% ( $n = 4$ ), 4% ( $n = 4$ ), 1% ( $n = 1$ ), 2% ( $n = 2$ ), 3% ( $n = 3$ ), and 4% ( $n = 4$ ), respectively. In this respect, all the cases of meningitis were treated with no permanent damage. Side effects, such as headache, asthenia, and dizziness were identified in 2% ( $n = 2$ ) of the patients. About 3% ( $n = 3$ ) of the patients presented muscle twitching due to the radicular stimulation and 1% ( $n = 1$ ) reported signs of muscular contraction caused by the activation of the pyramidal tracts. In terms of pain improvement, no clinical benefits of SCS in cancer pain or in central deafferentation pain were identified. Significant results were reported for vasculopathic pain and PHN. Similar results were also found by Meglio et al. (67) and Cioni et al. (65).

The authors reported high rates of patients with the absence of complications (more than 50% of patients) and the presence of lead migration (17% of patients) as the main complication of SCS procedure. The technical complications affected more than 30% of patients and represented the most common complication of this procedure. Paralysis indicated the lower incidence



rate (<0.1%) and the most severe complication of this procedure. Furthermore, SCS has reported low rates of system rejection (<2% of cases).

Benefits of the neuropathic pain treatment by the SCS system include short hospitalization time, high rates of pain reduction following the procedure related to the reduction of pharmacological treatment costs, low rates of long-term complications, and the resources optimization. These factors, in addition to an increase in the life expectancy of the inhabitants of emerging countries, indicate the need for more clinical studies on this procedure.

### Cost-effectiveness

In 2006, Taylor et al. (39) presented the results of the systematic review and the meta-analysis of the clinical SCS cost-effectiveness in the management of CRPS patients. This study comprised 25 case series, 1 randomized controlled trial and 1 cost-effectiveness study. During the median follow-up period of 33 months, patients affected by CRPS Type I or Type II presented a significant pain relief higher than 50% in intensity in 67% of patients implanted with SCS system. The economic analysis based on the randomized controlled trial indicated a lifetime cost-saving of approximately €58,470 (US \$60,800) using SCS plus PT compared to PT. The mean cost per quality-adjusted life-year at a follow-up period of 12 months amounted to €22,580 (US \$23,480). SCS has been proven a cost-effective and an efficient treatment of CRPS Type I (A level evidence), while Type II presented D level evidence with regard to cost-effectiveness.

In 2002, Kemler and Furnée (46) described the results of a cost-effectiveness analysis on the use of SCS in patients affected by chronic RSD ( $n = 54$ ) in the 1<sup>st</sup> year of the post-operative follow-up. This study demonstrated that the SCS costs were mainly related to the implantation costs (€202,986), while the remaining costs were generated by test stimulation (€30,128) and complications (€11,904). Therefore, the authors concluded that the mean cost per patient for SCS procedure achieving significant results was €193,580. SCS associated with PT and medical pain management was estimated to €171,153 and €229,624, respectively.

In their study in 2008, Kemler et al. (47) presented the results of a cost-effectiveness analysis on the use

of SCS in patients affected by chronic RSD ( $n = 54$ ) in the 5<sup>th</sup> year of the post-operative follow-up. It has also been concluded that SCS would be less expensive than alternative therapies after 3 years of the successful treatment, and in 2 years, it would be cost-effective for another period of 2-3 years. The study reported 99% ( $n = 52$ ) of the patients who affirmed to repeat the treatment, if necessary, for the same outcome. Similar results were found by Turner et al. (53), Hollingworth et al. (70), Dario et al. (71), and Ohnmeiss et al. (72) in their studies on pain management of FBSS, and Simpson et al. (52) in their research papers on patients affected by ischemic pain.

Recent studies show that SCS has been associated with significant cost-effectiveness rates when compared to the conventional pharmacological pain management (Table 4). Regardless of the initial high cost of SCS, this treatment resulted in significant rates of pain reduction, and a lower cost of conventional therapies after the 1<sup>st</sup> year of the treatment.

### CONCLUSION

SCS is an initial and a controversial procedure, in which the substantial assessment demonstrated heterogeneous patients and methodologies, implying the high degree of difficulty related to the analysis of results. In this light, Kemler et al. (47) presented that only 56% ( $n = 20/54$ ) of patients with an implanted system were reported at the final 5-year follow-up, despite the high patient satisfaction.

Based on the literature review and authors' experience, recent studies have shown that SCS is an effective adjunctive therapy in patients with medically refractory neuropathic pain. Although the total control of pain with SCS has not been commonly described, this procedure has been associated with significant improvement in the life quality of these patients.

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