



Retrograde Epidural Spinal Cord Stimulation for the Treatment of Intractable Neuropathic Pain Following Spinal Cord and Cauda Equina Injuries: A Case Report and Literature Review

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Abstract

Spinal cord stimulation (SCS) offers an alternative treatment for refractory pain resulting from various etiologies. Generally, SCS electrodes are inserted in an anterograde fashion, moving from caudal to rostral direction. However, there are instances where anterograde placement is unfeasible due to technical limitations. We present the use of retrograde surgical electrode placement in SCS for a patient with extensive epidural fibrosis at the site intended for electrode insertion. A 48-year-old female suffering from refractory neuropathic pain caused from injuries to the conus medullaris and cauda equina opted for SCS. During the SCS trial procedure, challenges emerged when attempting percutaneous electrode insertion at the site of a prior T12 laminectomy. However, the trial stimulation resulted in significant pain relief. For the permanent placement of the stimulator, utilizing a surgical electrode centered at T11 vertebral level, a considerable amount of epidural fibrosis was encountered at the entry of the spine, particularly at the T12 vertebral level. To avoid dural injury and ensure accurate electrode positioning, a retrograde technique for surgical electrode was employed via partial laminectomies at the T9-T10 level. The final electrode positioning was in accordance with the preoperative plan, well-centered at the T11 vertebral level. The patient experienced sustained relief from neuropathic pain over the long term. Retrograde epidural SCS is a suitable option for cases characterized by extensive epidural fibrosis resulting from a previous spinal surgery or when the anterograde placement of the electrode is unattainable due to aberrant vertebral anatomy.

Keywords

- ▶ cauda equina injury
- ▶ neuropathic pain
- ▶ retrograde placement
- ▶ spinal cord injury
- ▶ spinal cord stimulation
- ▶ surgical electrode

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Introduction

Spinal cord stimulation (SCS) is a neuromodulation therapy aimed at alleviating chronic intractable pain by stimulating the dorsal column of the spinal cord. The mechanism underlying SCS is based on the gate control theory of pain, as postulated by Melzack and Wall. According to this theory, concurrent activation of large, myelinated fibers transmitting cutaneous touch signals inhibits transmission of afferent pain signals into the spinal cord, thereby reducing the perception of pain.^{1,2} This neuromodulation method should be considered when pain persists despite multimodal treatments, including medical management, physical therapy, and pain intervention treatments.

SCS therapy is particularly relevant in various pain conditions, such as failed back surgery syndrome, complex regional pain syndrome, critical limb ischemia, and refractory angina pectoris.³ Furthermore, this procedure is effective in alleviating pain following spinal cord injury (SCI), cauda equina syndrome, and sacral root lesions.⁴⁻⁶

In the SCS procedure, electrode insertion and placement are typically conducted in an anterograde (caudorostral) direction. However, in specific situations, retrograde placement in a rostrocaudal direction is essential. In this context, the authors present a case of SCS using a rare technique; retrograde placement of surgical (paddle) electrode due to anatomical restrictions. The study also reviews existing literature on retrograde placement of SCS electrodes.

Case Report

A 48-year-old female with no preexisting medical conditions was involved in a motor vehicle accident, resulting in a fracture of the L1 vertebra 9 years ago. Both clinical assessments and spinal magnetic resonance imaging confirmed injuries to the conus medullaris and cauda equina. Subsequently, the patient underwent a complete T12 laminectomy and partial L1 laminectomy. Spinal fixation was performed using pedicular screws and rods at the T11-T12 and L2-L3 vertebrae. Additionally, a cross-linking device was placed between bilateral rods at the L1 vertebral level. In the weeks following the injury, the patient developed severe neuropathic pain affecting both lower extremities. The pain was characterized by paroxysmal burning, squeezing, and electric shock-like components with a continuous pain component. Despite treatment by a pain specialist with high-dose gabapentin (3,600 mg daily), tramadol for breakthrough pain, and an antidepressant, the pain remained refractory to treatment. Consequently, the patient was transferred to Siriraj Pain Management Unit for the management of this type of refractory neuropathic pain.

Upon physical examination, the patient exhibited grade 0/5 motor power of the left lower limb, grade 3/5 motor power in the right proximal lower limb, and no motor power in the right distal lower limb, respectively. According to the sensory grading scale established by the American Spinal Injury Association, the patient displayed grade 0/2 in the left lower extremity and 1/2 sensory function in the right lower

extremity, respectively. Severe pain was distributed across the right knee and calf, entire left lower extremity, and perianal region. The maximum, minimum and average pain scores were 9 out of 10, 5 out of 10, and 7 out of 10, respectively.

SCS was chosen as the treatment for the patient's intractable neuropathic pain. A trial of the spinal cord stimulator was conducted with the patient in an awake and prone position. A detailed description of the trial procedure is provided in ►Fig. 1. During the intraoperative phase, extensive epidural fibrosis was encountered at the sites where the trial electrode was inserted. Over the course of the 10-day stimulation, there was a 60% reduction in pain compared to the baseline neuropathic pain experienced before the procedure. The electrode contacts that provided the most significant pain relief were located at the T11 spinal level. Consequently, implantation of the spinal cord stimulator, using a surgical electrode, was performed under general anesthesia 4 weeks after the trial stimulation. The level for electrode placement was chosen to be centered at the T11 vertebra. A detailed account of the second stage procedure can be found in ►Fig. 2.

After complete implantation of the stimulator, the patient experienced satisfactory pain reduction. When the stimulator was activated, approximately 50 to 70% reduction in neuropathic pain was achieved. The patient was able to return to sitting in a wheelchair for extended periods and resume her usual activities. Occasionally, she experienced increased pain when sitting for several hours, but this discomfort could be relieved by resting or changing her posture. The positive outcome was sustained throughout the follow-up period, extending to 18 months postoperatively.

Discussion

Neuropathic pain is characterized as "pain caused by a lesion or disease of the somatosensory nervous system," as defined by the International Association for the Study of Pain.^{7,8} Mechanisms of neuropathic pain involve sensitization of both the central and peripheral nervous systems, abnormal signals from injured axons and normal nociceptive receptors that share the neural distribution with the injured axons.⁹ Neuropathic pain can result from various etiologies. Central neuropathic pain is caused by lesions or diseases affecting the brain or spinal cord, such as stroke, SCI, or demyelinating diseases. Peripheral neuropathic pain is associated with conditions or diseases affecting the peripheral nerves, including traumatic or iatrogenic nerve injuries, diabetes mellitus, immune and inflammatory disorders, or channelopathies.¹⁰ Neuropathic pain is typically managed with pharmacological therapies; however, in some cases, it requires multimodal methods, such as physical, psychological, procedural pain, or surgical interventions. These therapeutic modalities should be customized to individual patients' needs.

Regarding surgical treatment for neuropathic pain, neuroablative and neuromodulation procedures are typically reserved for cases where conventional therapies have failed to achieve sufficient pain relief. In patients with paraplegia caused by traumatic spinal cord or cauda equina injuries, dorsal root entry zone lesion (DREZotomy) is a viable

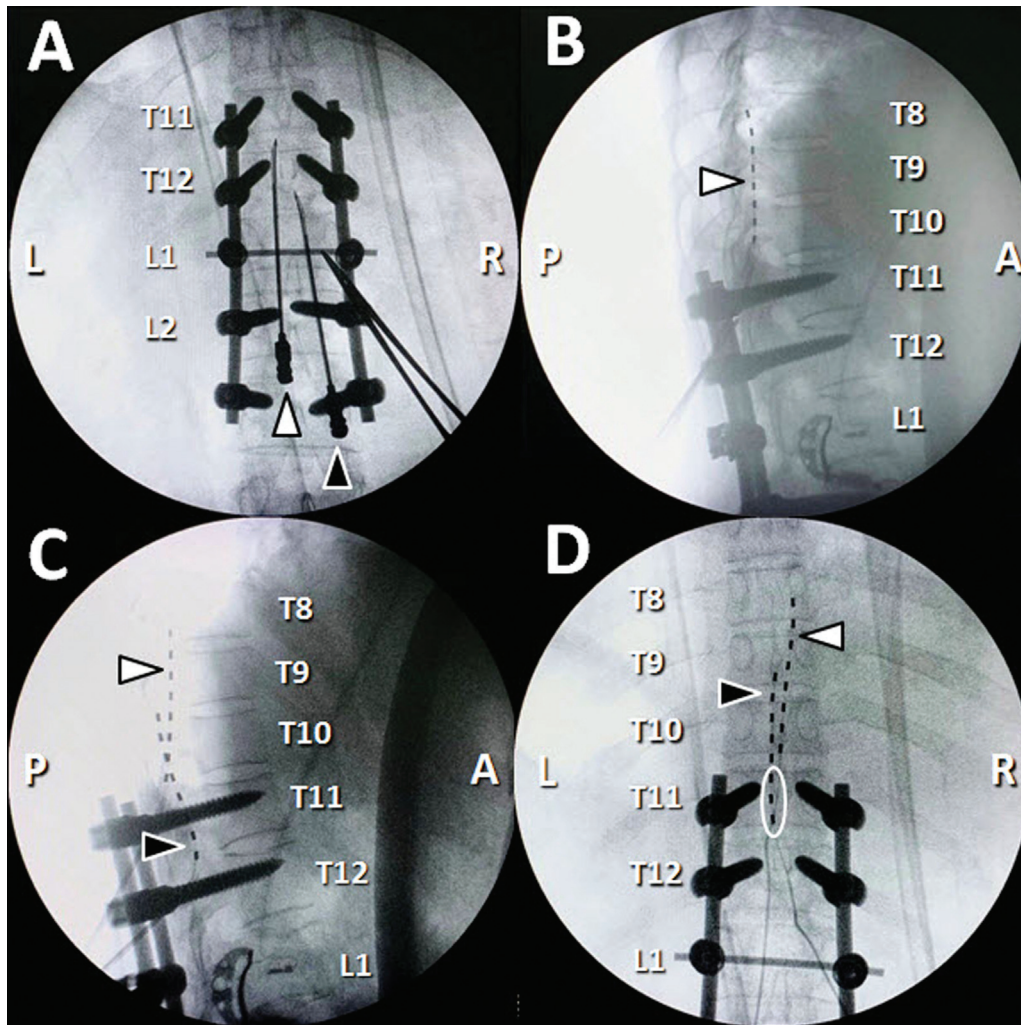


Fig. 1 Intraoperative fluoroscopic images in anteroposterior (A, D) and lateral (B, C) views of the spinal cord stimulation (SCS) trial procedure in a prone position. (A) Accessing the epidural space using a 14G Tuohy epidural needle, 12 cm in length (Medtronic, Fridley, Minnesota, United States) (black and white arrowheads), through the interlaminar spaces. The epidural space was accessed superior to the cross-linking device and the approach was rather difficult due to extensive epidural fibrosis following T12 laminectomy. (B) Placement of a trial 8-contact electrode, 60 cm in length (Medtronic) (white arrowhead). (C and D) The final position of the right (white arrowhead) and left (black arrowhead) trial electrodes with the three lowermost contacts (in oval-shaped line) showing significant pain relief during the trial period. Permanent paddle (surgical) lead implantation centered at the T11 vertebral level was planned. A, anterior; L, left; P, posterior; R, right.

option for alleviating refractory neuropathic pain and spasticity.¹¹⁻¹⁴ DREZotomy disrupts nociceptive input entering the spinal cord and also inhibits the hyperactive function of neurons in the superficial dorsal horn, resulting in relief of severe pain or chronic pain syndromes that do not respond to pharmacotherapy.¹⁵⁻¹⁷ Nevertheless, this procedure is relatively invasive and carries the risk of complications, such as cerebrospinal fluid leak or additional sensory impairment. It is also challenging to perform in patients with a history of spinal surgery and fusion, as seen in our patient. SCS, involving the placement of an electrode in the epidural space to stimulate the dorsal column of the spinal cord, can relieve pain by activating dorsal column A β fibers.¹⁸ Compared to DREZotomy, SCS is less invasive, reversible, and does not involve the destruction of neural structures. Therefore, SCS was a more advantageous option for our patient, who retained some residual sensory function in one lower extremity.

Placement of the SCS electrode can pose challenges, particularly when encountering unexpected anatomical variations. Generally, SCS electrodes are inserted and positioned in caudorostral direction. In our case, multiple attempts to place the electrode using the conventional caudorostral approach were unsuccessful due to extensive epidural fibrosis at the T12 vertebral level resulting from prior surgical interventions. To avoid the risk of dural injury and ensure proper electrode positioning, a retrograde technique for electrode placement was subsequently utilized. The retrograde technique provides the advantage of allowing the insertion of the electrode at desired levels, particularly in cases where extensive epidural fibrosis is present or when the patient's skin condition is unsuitable for the conventional anterograde approach, such as in cases of skin eczema or extensive keloid scarring. Additionally, this technique can be beneficial in patients with preexisting aberrant vertebral anatomy that is not conducive to the anterograde technique.

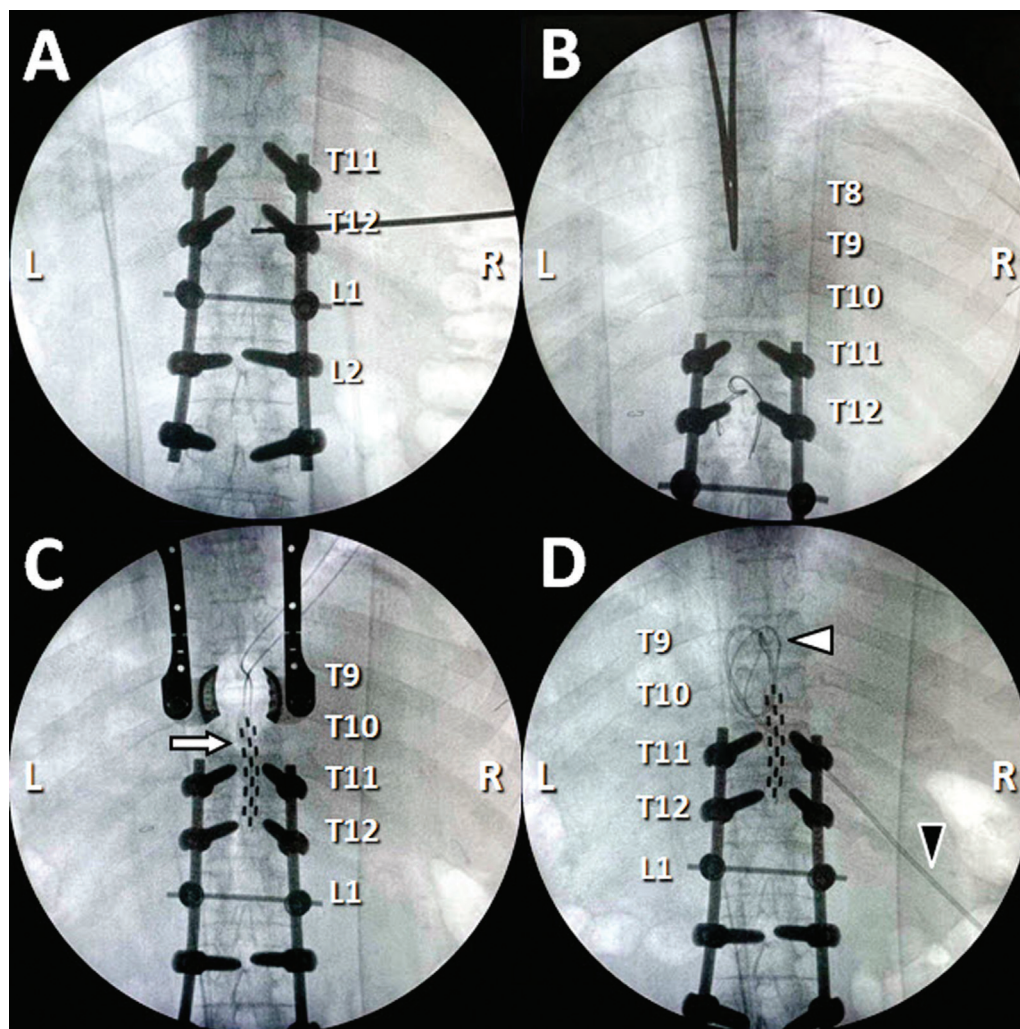


Fig. 2 Intraoperative fluoroscopic images in anteroposterior view (A–D) of spinal cord stimulator implantation in a prone position. (A) The initial location at the T12 spinal level for the insertion of a surgical electrode centered at the T11 spinal level; however, this location was filled with extensive epidural fibrosis and posed a risk for dural injury. Therefore, it could not be used as an insertion point and the authors decided to change the insertion point of surgical electrode. (B) The new location at the T9 spinal level for insertion of a surgical electrode. (C) Following partial T9 and T10 laminectomies, retrograde placement of a 16-contact epidural electrode array, 65 cm in length (Specify 5-6-5; Medtronic, Fridley, Minnesota, United States) (arrow), at T10-T12 vertebral levels in rostrocaudal direction was achieved. The electrode was centered at the T11 spinal level. (D) After creating strain relief loops (white arrowhead), the electrode wires (black arrowhead) were implanted in subcutaneous tissue and then connected to a pulse generator (The Intellis, Medtronic), which was implanted in a subcutaneous pocket at the right lumbar region. L, left; R, right.

The retrograde technique presents certain technical challenges compared to the standard approach, and it comes with potential drawbacks, including the theoretical risk of electrode migration upwards and the need for reversed rearrangement of electrode contact mapping, both of intraoperatively and postoperatively. A review of existing literature revealed case reports or case series concerning retrograde placement of SCS electrodes (–Table 1). The primary reasons for opting for this method include the need for high cervical SCS, desire to avoid neural injury, adhesions resulting from previous spinal surgery, the need for optimal pain distribution coverage, and the placement of the electrode in an extremely caudal location.^{19–26} Most rationales for using the retrograde technique were either extremely cephalad or caudal location of lead placement.^{19,21,23,25} Case reports, including our case that used

the retrograde technique due to postsurgical adhesions or fibrosis, were rare.^{20,24} Our case was unique in terms of retrograde placement of surgical electrode while the remaining single case report used percutaneous leads for pain treatment.^{20,24} Selection of electrode types should be tailored for an individual patient and mainly depend on spinal pathology and variation.

Conclusion

Retrograde epidural SCS can be a viable option in cases where the conventional anterograde technique for electrode placement is unfeasible due to anatomical limitations. It should be considered in patients with extensive epidural fibrosis at the sites of electrode insertion due to prior spinal surgery or those with anomalous spinal anatomy that

Table 1 Literature review of spinal cord stimulation using the retrograde electrode placement technique

Author ^{reference} (year)	Article type	Diagnosis	Electrode type	Entry point to level of electrode placement	Reason for using retrograde technique
Moen et al ¹⁹ (2011)	Case series (n = 7)	FNSS	Surgical (5-6-5)	From C0-1 (atlanto-occipital) space to C1-2 vertebral levels	High cervical SCS
Perper ²⁰ (2012)	Case report (letter to editor)	Refractory L5 radiculopathy	Percutaneous	From C7-T1 space to lower border of T8 vertebral level	Adhesions from previous surgery Failed to anterograde approach
De Andres et al ²¹ (2013)	Case series (n = 10)	Perineal neuralgia, coccygodynia, stump pain, interstitial cystitis, FBSS, sciatic neuropathy, lumbar or sacral radiculopathy	Percutaneous	From L2-3, L3-4, L4-5 spaces to sacral levels	Caudal placement of electrode close to the neural structures Obtain better paresthesia in a selected dermatome and prevent patient discomfort
Taghva ²² (2014)	Case series (n = 3)	Case 1 FBSS Case 2 CRPS with FBSS Case 3 CRPS	Surgical (2 × 8) (combined anterograde and retrograde)	Case 1: From previous T9 laminotomy to T11-12 vertebral levels Case 2: From T7-8 laminotomy with anterograde to T5-6 and retrograde to T8-10 vertebral levels Case 3: From T10-11 laminotomy with anterograde to T9 and retrograde to L1 vertebral levels	Case 1: Failed to previous T7-8 paddle SCS via T9 laminotomy Case 2: Extensive pain distribution which required two paddle electrodes Case 3: Extensive pain distribution which required two paddle electrodes
Abd-Elseyed et al ²³ (2017)	Case report (letter to editor)	Intractable pelvic pain	Percutaneous	From L3-4 space to S3 level	Caudal placement of electrode
van Helmond et al ²⁴ (2017)	Case report	FBSS	Percutaneous	From C7-T1 space to lower border of T8 vertebral level	Postsurgical changes
Oosterbos et al ²⁵ (2018)	Case series (n = 28)	FNSS, neuropathic pain, CRPS, amputation pain, fibromyalgia	Surgical various types (1 × 4, 1 × 8, 2 × 8, 5-6-5)	From C0-1 (atlanto-occipital) space to C1-2 vertebral levels	High cervical SCS
Haddad et al ²⁶ (2021)	Case report	Refractory coccygodynia	Percutaneous	From L4-5 space to S2-4 levels	Caudal placement of electrode Reduced risk of wound infection
The current case	Case report	Intractable neuropathic pain after conus medullaris and cauda equina injuries	Surgical (5-6-5)	From partial T9-10 laminectomy to T10-12 vertebral levels	Failed to anterograde approach due to extensive epidural fibrosis following previous spinal surgery

Abbreviations: C, cervical; CRPS, complex regional pain syndrome; FBSS, failed back surgery syndrome; FNSS, failed neck surgery syndrome; L, lumbar; S, sacral; SCS, spinal cord stimulation; T, thoracic.

impedes the conventional electrode placement approach. Nevertheless, rearrangement of electrode contacts must be reversed during the mapping of the stimulator.

Ethical Approval

For only a single case report, ethical approval was not required by the Ethics Committee of the Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand. The patient's data in this case report retained full confidentiality in compliance with the Declaration of Helsinki.

Authors' Contributions

L.C.L. contributed in writing, reviewing, editing, and approval of the final manuscript. S.S. helped in reviewing and approval of the final manuscript. B.S. has contributed in conceptualization, supervision, editing, and approval of the final manuscript. S.J. and P.S. reviewed and approved the final manuscript.

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Conflict of Interest

None declared.

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