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Placement of spinal cord stimulation paddle leads in the thoracic spine using en bloc laminoplasty: A technical note

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ABSTRACT

Objective: Spinal cord stimulation (SCS) has become a successful treatment option for managing chronic pain syndromes. Conventional methods for placing SCS leads include percutaneous insertion or open laminectomy in cases requiring better visualization. However, achieving accurate placement of paddle leads while minimizing surgical invasiveness remains a challenge in cases with anatomic constraints such as dural scarring.

Methods: We present a novel surgical technique for the placement of SCS paddle leads in the thoracic spine using en bloc laminoplasty, which is currently employed at our institution for patients with chronic pain syndromes.

Conclusions: This technique can provide accurate placement of paddle leads in patients with anatomic constraints or dural scarring that impede percutaneous implantation. Additionally, it offers potential structural advantages over laminectomy by reconstituting posterior stabilization and protection of the paddle leads.

1. Introduction

Spinal cord stimulation (SCS) has become a popular treatment modality for chronic pain syndromes since it was first introduced in 1967.[1,2] It has been shown to be an efficacious and cost-effective option for many neuropathic and radicular pain syndromes,[3,4] in addition to several other accepted indications.[5] Despite its established clinical benefits, complication rates may be as high as 30–40 %,[6,7] around 75 % of which are hardware-related complications.[6] Perhaps the most common hardware-related complication is lead migration, which has been documented at a rate of 8.5–22.6 %.[6,8] Despite over 50 years of research and development, hardware-related complications still remain a major cause of morbidity and a financial burden to our healthcare system.[7]

SCS leads may be inserted percutaneously or in a surgically open technique utilizing a laminectomy, which involves removal of the vertebral lamina to place the electrode leads directly over the dorsal column of the spinal cord.[9] For chronic pain conditions, conventional spinal levels for lead placement are between T8 and T10. Percutaneous implantation has gained popularity due to the reduced risk of surgical complications and shorter hospital stay,[10] yet it may result in a higher incidence of implant migration and reduced efficacy compared to laminectomy.[11] This is due in part to the less extensive surgical exposure and the use of more remote anchoring techniques.[5] Additionally, certain anatomic constraints such as fibrous scar tissue attached to the dura pose challenges during the placement of percutaneous electrodes.[12]

Various techniques and anchoring materials have been described for open placement of SCS leads,[5] but the fundamental procedure of laminectomy has remained largely unchanged over time. En bloc laminoplasty is an alternative technique that preserves the vertebral lamina, which may provide stability and a protective barrier to the paddle leads. While a laminoplasty technique has been described in cervical SCS cases,[13] no such literature has documented laminoplasty for SCS implantation in the thoracic spine. For this reason, we present an en bloc laminoplasty technique currently employed at our institution, with a discussion regarding its potential benefits and shortcomings.

Abbreviations: Spinal cord stimulation, (SCS); magnetic resonance imaging, (MRI); implantable pulse generator, (IPG).

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Fig. 1. Intraoperative image showing adequate exposure with the use of two Weitlaner retractors.

2. Technique

Patients referred to a neurosurgery clinic for chronic pain that have failed to respond to conservative therapy are evaluated for surgical candidacy. Preoperative patient evaluation begins with a SCS trial and imaging prior to operative implantation. For patients with radicular pain symptoms, magnetic resonance imaging (MRI) is performed to rule out more compressive pathology or other contraindications to operate. Appropriate surgical candidates first undergo a percutaneous SCS trial, where leads are placed subcutaneously into the extradural space to identify the spinal cord levels at which an adequate response to pain is achieved. Trials proceed for a minimum of 5–7 days and are considered successful if the patient experiences at least a 50 % reduction of pain. At our institution, these patients are then referred to a neurosurgeon for implantation of permanent electrodes utilizing paddle leads based on surgeon preference and experience. This is performed around 6 weeks after the trial procedure. The paddle leads are typically placed between T7-T9, which are the levels that will be referenced in this technique.

Surgery is performed under general anesthesia with neurophysiologic monitoring. The patient is positioned prone on a Jackson table with all pressure points padded and the arms placed on arm boards. The midline is marked by referencing the spinous processes and a flank incision site is also marked for implantation of the implantable pulse generator (IPG). Following sterile prepping, draping, and a formal timeout, fluoroscopy is used to mark the inferior lamina of the T9 vertebrae, which will be removed to guide dissection.

Subperiosteal dissection of the paraspinal muscles is performed to the level of the medial facet, with a Weitlaner retractor positioned to expose the width of the vertebrae (Fig. 1). Dissection is continued laterally to ensure adequate visualization while preserving the facet capsules. The inferior lamina of T9 is confirmed again with fluoroscopy, which is then removed using standard laminectomy technique (Fig. 2). At this point, attempts should be made to place the paddle beneath the T8 lamina prior to laminoplasty with the goal of being midline and at the correct caudal level. Using a Woodson to clear the epidural space can help facilitate this process. If the lead cannot be passed due to a tactile obstruction, partial window laminotomies may be performed depending on the location of obstruction. For instance, if the lead continues to pass laterally, a lateral window laminotomy can enable clearance of local dural scarring in that area.

If correct positioning cannot be attained using these measures, laminoplasty is carried out. Using an ultrasonic bone scalpel (Misonix, Farmingdale, NY), bilateral cuts are made in the T8 lamina medial to the facet line. En block removal of the T8 lamina is performed using an upgoing curette and rongeur (Fig. 3). The T8 lamina is then preserved in normal saline. Additionally, the inferior lamina of T7 can be undercut to provide more space for paddle lead placement. Any residual scarring tracts visualized on the exposed dura can be gently peeled off using microsurgical technique with pickups and a small upgoing curette.

A 16-channel paddle electrode (Penta™, St. Jude Medical, Plano, TX) is then placed directly on the dura at the T8 level (Fig. 4). Correct positioning is confirmed once again with fluoroscopy (Fig. 5) before anchoring the lead wire at the base of the paddle to the dura using 6-0 prolene suture, which should be anchored using with a partial thickness bite to avoid the risk of dural tear and cerebrospinal fluid leak. This suture is a provisional step to maintain paddle electrode positioning during the process of repositioning the removed lamina.

At this point, attention is turned to reattaching the removed lamina. Craniotomy-type titanium plates and screws (Stryker Craniomaxillofacial, Portage, MI) are secured to the disconnected lamina (Fig. 5). This piece is placed back in its anatomic position and secured with two more screws laterally (Figs. 6 and 7). The wire is further secured to fascia to provide additional stability. Lastly, a subcutaneous pocket is made in the patient's flank to fit the IPG and a subcutaneous tunneling device is used to pass the wire from the IPG to the paddle leads. IPG impedances are tested prior to closure. Motor and sensory evoked potentials are monitored throughout the procedure.

3. Discussion

Achieving proper epidural placement of SCS paddle leads can be challenging in patients with anatomic constraints, such as dural scarring from a previous SCS trial. This study outlines a technique for thoracic en bloc laminoplasty that is currently performed at our institution with dependable accuracy. This technique provides a viable alternative to the traditional laminectomy approach and, in our opinion, offers a similar safety profile while providing several advantages.

This "recapping laminoplasty" technique involves en bloc removal of the lamina and reattachment with craniotomy-type plates and screws after placement of paddle leads. Several laminoplasty variations have been described, which we believe could be similarly effective as long as they don't compromise the visualization or accuracy of paddle lead placement. Our technique utilizes an ultrasonic bone scalpel, which may help mitigate the laminar bone loss associated with cutting, ideally to expedite union of the affected lamina.[14]

Compared to laminectomy, en bloc laminoplasty preserves the posterior vertebral lamina instead of discarding it. This provides a potential

Fig. 2. Posterior view of the operative field following T9 laminectomy.

Fig. 3. Posterior view showing the exposed dura mater over the T8-T9 vertebral levels.

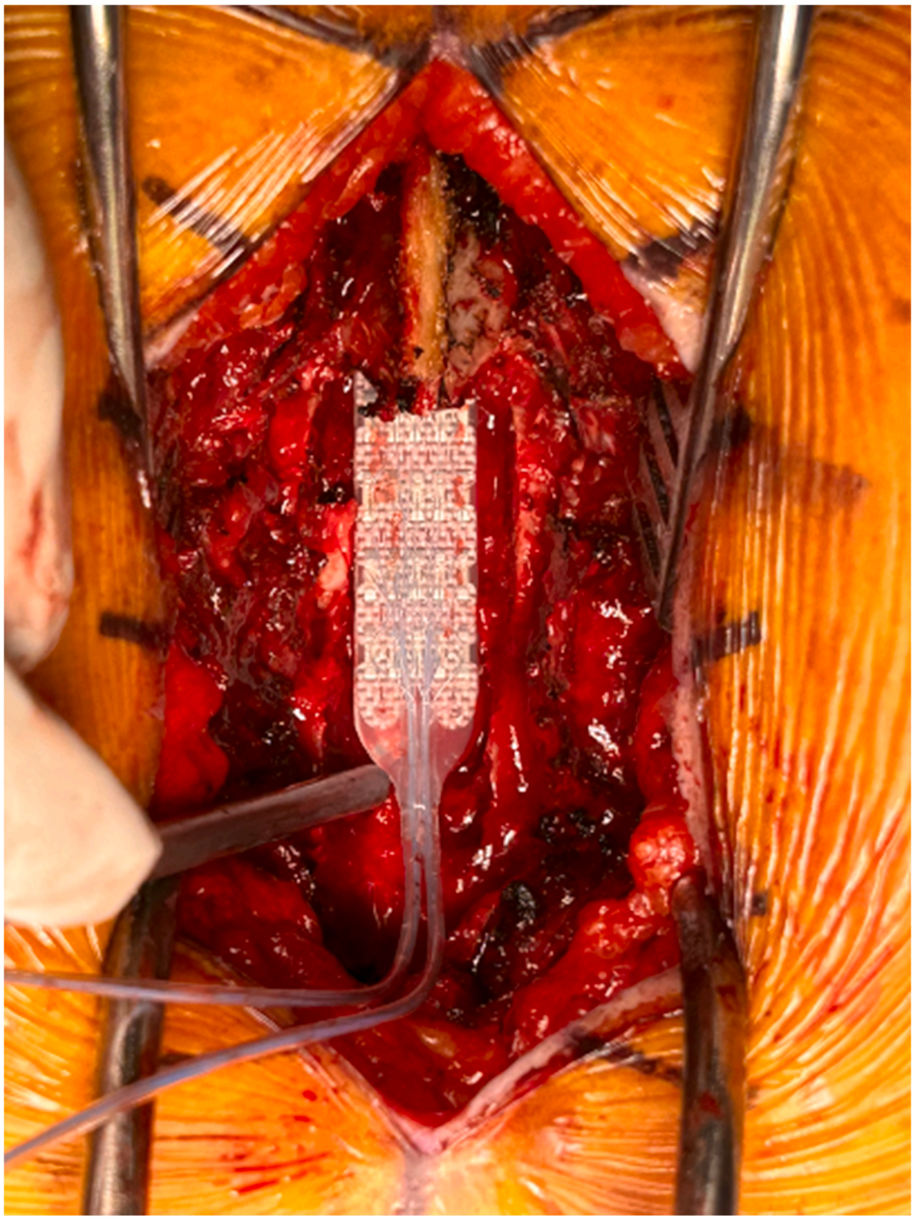

Fig. 4. Intraoperative image of the paddle lead placed on the dura after the T8 and T9 laminae have been removed.

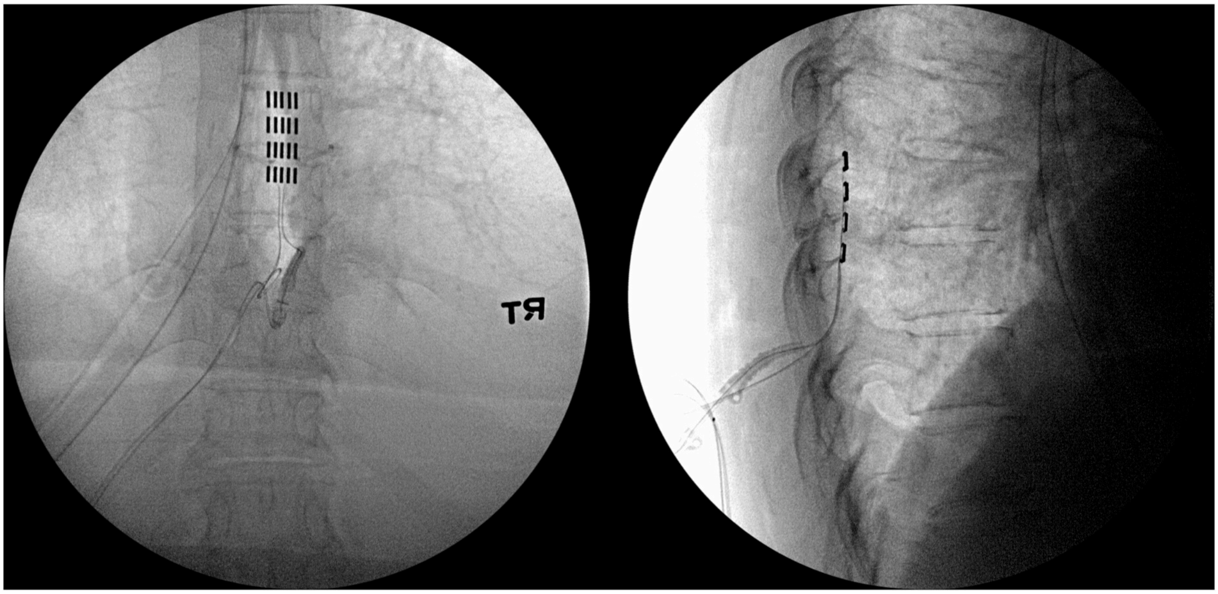

Fig. 5. Anteroposterior and lateral fluoroscopic images showing a paddle lead at the T8-T9 level, with appropriate midline positioning.

advantage of maintaining lead positioning, as the posterior vertebral lamina can help stabilize the paddle lead in the epidural space by acting as a posterior buttress and protective barrier. Laminoplasty has also been shown to create less dural scarring than laminotomy,[15] which is clinically important because scar tissue after laminotomy has been associated with decreased IPG efficacy and early lead migration.[16,17] We have noticed instances of dural scarring that seem to be caused by the SCS trial, given that the scar tissue has appeared along the original direction of the percutaneous trial electrodes. We recommend gently resecting this scar tissue, as neglecting to remove it may interfere with paddle lead placement or cause increased impedance. It remains uncertain why this develops in certain patients and whether patient factors are associated with an increased incidence. Furthermore, there is uncertainty on whether dural scarring prior to laminoplasty affects subsequent lead migration or IPG efficacy to a similar degree as what has been described with laminectomy.

It is important to emphasize that the decision to perform laminoplasty should be made intraoperatively only when the paddle lead cannot be correctly positioned without removal of the lamina. For instance, caudal hemi-laminotomy can help facilitate the initial pass of the paddle lead, and partial window laminotomies can be utilized to decompress a focal obstruction, if encountered. Only when optimal positioning cannot be achieved through less invasive methods should this recapping laminoplasty be performed. Additionally, this technique is described for primary implantation, but it can also be useful for revision cases where dural scarring is more likely to necessitate lamina removal for proper positioning of paddle leads.

It should be noted that the general protocol of operative decision-making has been effectively utilized at this institution, but other workflows may exist for successful placement of SCS. Therefore, this approach was developed as methodological progression of operative steps for complex cases, which has been effective in overcoming challenges we have encountered. We utilize two-hole craniotomy-type miniplates for fixation of the lamina segment, but a variety of miniplate options are available that may also yield satisfactory outcomes. The description of this institution's workflow is not meant to draw comparative conclusions relative to established processes at other institutions.

Drawbacks to this technique include increased operative time and a more invasive procedure compared to a percutaneous approach. There exists a risk of durotomy and cerebrospinal fluid leak by anchoring the lead wire at the base of the paddle to the dura, which should be respected and avoided with careful suture technique and a partial-thickness bite in the dura. There is also a theoretical risk of instability with manipulation of the posterior spinal column, but this is mitigated by the rigidity of the thoracic spine and presumed union of the reattached lamina. Compared to laminectomy, these risks are believed to be marginal.

4. Conclusion

In conclusion, en bloc laminoplasty offers a reliable solution to ensure accurate placement of SCS paddle leads in patients with anatomic constraints or dural scarring that hinder accurate placement through previously described methods. We believe this technique to be a safe and efficacious alternative to laminectomy with little to no added surgical risk. Further investigation to evaluate the clinical outcomes of this technique is warranted and currently underway.

CRediT authorship contribution statement

Samuel D. Stegelmann: Writing – original draft, Visualization, Data curation. **Roman Rahmani:** Writing – review & editing, Conceptualization. **Jae Min Yim:** Writing – review & editing, Conceptualization. **Zubair Ahammad:** Validation, Supervision, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

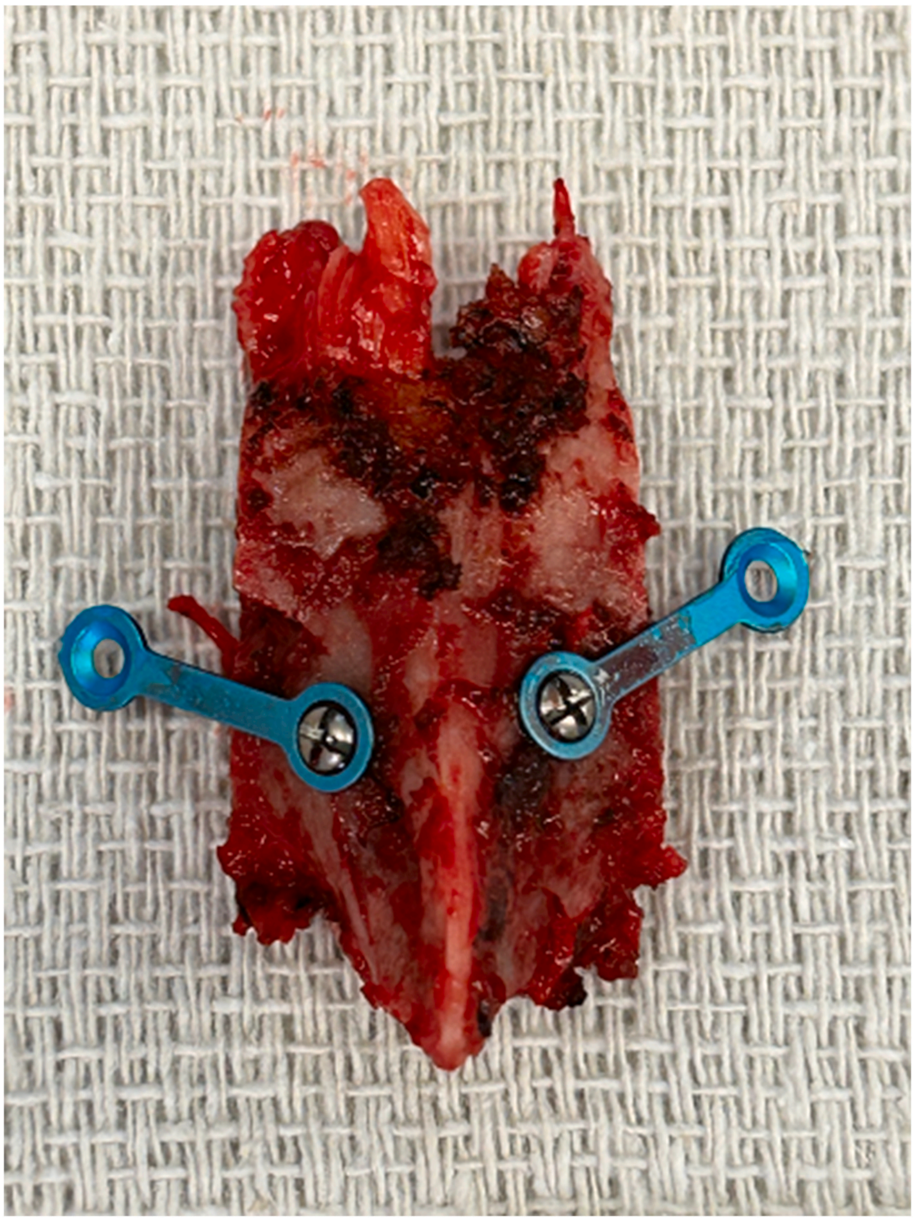

Fig. 6. Intraoperative image from a sterile back table showing the removed portion of the lamina fixed with two titanium plates and screws.

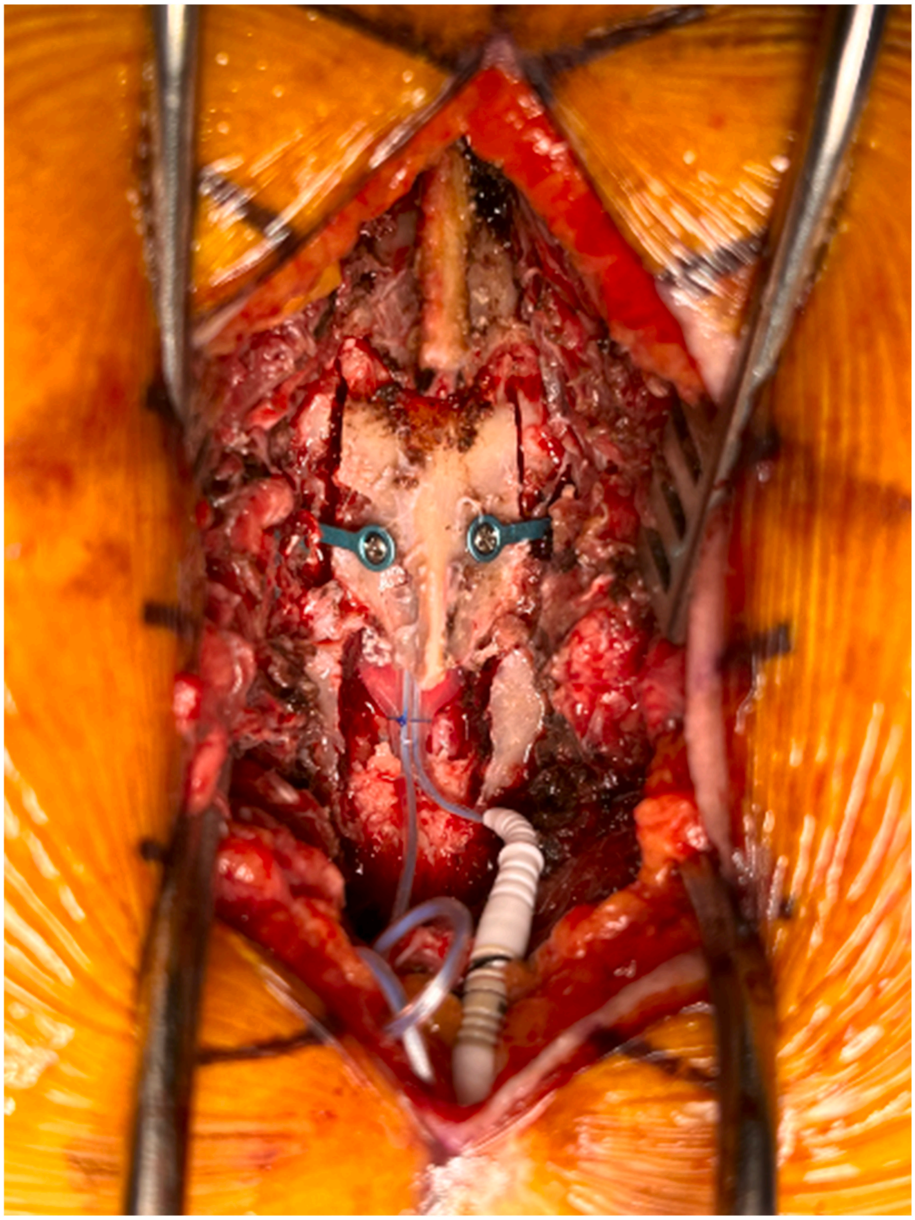

Fig. 7. Intraoperative image following laminoplasty, demonstrating the final placement of the T8 lamina over the paddle lead.

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