A Novel Technique for the Implantation of Paddle Leads in the Cervical Spine

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Objectives: Electrical spinal cord stimulators are routinely used in the thoracic spine for back and lower extremity pain. The anatomy of the cervical spine differs significantly from that of the thoracic spine and deserves special considerations if these implants are to be inserted safely in the neck. This paper explores the technical challenges of implanting paddle leads in the cervical spine and offers a novel technique for implantation.

Materials and Methods: Thirty-four patients underwent implantation of permanent spinal cord stimulators in the cervical spine by the same surgeon. The ages ranged from 26 to 59 with an average age of 45 years. Fifty-three percent of the patients were female, and 47% were male. Nineteen patients received St. Jude Exclaim leads; 15 patients received Boston Scientific Artisan leads. Mechanical failure of the device was the end point.

Results: Eleven of the 34 patients (32%) required removal or revision of the device for mechanical failure. Forty percent of the Boston Scientific patients had mechanical failures compared with 25% of the St. Jude patients (p = 0.73). When the Boston Scientific patients were compared with the St. Jude patients with the newer technique of implantation (mechanical failure = 0), the p value was 0.06.

Conclusion: A new technique is presented that allows easy and reliable implantation of cervical paddle leads in the neck with a low risk of iatrogenic complications.

Keywords: Cervical spine, neuromodulation, paddle leads

Conflict of Interest: Dr. Jacob Amrani has a provisional patent for a lead related to this work. There was no funding source for this work.

INTRODUCTION

Neuromodulation has been used successfully to treat many chronically painful conditions, such as failed back surgery syndrome (1), chronic regional pain syndrome (2), and ischemic limb pain (3). The technique for introducing permanent spinal cord paddle stimulator leads in the thoracic spine is well established (4). With the success of neuromodulation for painful conditions of the back and lower extremities has come interest in using these devices for similar conditions in the neck and upper extremities. However, the anatomy of the cervical spine is unlike that of the thoracic spine. Different considerations exist that require a reevaluation of the standard techniques that have been applied to date. The following is a review of the author’s experience with the implantation of paddle leads in the cervical spine and the evolution of a technique that is easy and reliable and has a low incidence of iatrogenic complications.

MATERIALS AND METHODS

This is a case series review of the author’s experience with the implantation of permanent spinal cord stimulator paddle leads in the cervical spine specifically looking at mechanical failures. From January 2009 to January 2012, 545 spinal cord stimulator paddle leads were either inserted or revised by the author. Of these, 513 were implanted in the thoracic spine, and 34 were implanted in the cervical spine.

Subjects

During the study period, 34 patients underwent implantation of permanent spinal cord stimulator leads in the cervical spine. Thirteen patients had chronic neck and radicular pain, 11 patients had cervical post-laminectomy syndrome (defined as persistent neck and arm pain following cervical laminectomy and/or fusion despite a solid fusion on x-ray or computed tomography [CT]), and 10 patients had reflex sympathetic dystrophy of the upper limb. Their ages ranged from 26 to 59. The mean age was 45. Nineteen patients were implanted with a St. Jude Exclaim lead (St. Jude Medical, Plano, TX, USA), and 15 patients were implanted with a Boston Scientific Artisan lead (Boston Scientific, Valencia, CA, USA). The choice of the lead was determined by the referring pain management physician, who performed the stimulator trial. Eighteen (53%) of the patients were female, and 16 (47%) were male. Of the 19 patients receiving St. Jude implants, 10 (53%) were female and 9 (47%) were male. Of the 15 patients receiving Boston Scientific implants, 8 (53%) were female and 7 (47%) were male. Thirteen St. Jude leads were placed over the ring of C1, and six were placed antegrade under C4 and C3. The 15 Boston Scientific leads were inserted antegrade following a laminectomy at C5. All patients were referred back to the author by the pain management physicians and/or the company representatives for insertion.
any device-related problems. The follow-up therefore ranged from four months to three years. All device-related complications manifested within the first postoperative month.

Procedure

All procedures were performed under general anesthesia. The patient is positioned prone on a radiolucent operating table with the head in a Mayfield horseshoe. The arms are tucked to the sides. A standard posterior approach to the cervical spine is made. The spinous process of C2 is used as a landmark. For implantation over the ring of C1, the spine is exposed subperiosteally from the occiput to C3. For subaxial implantation of a St. Jude Exclaim lead, the spine is exposed from C2 to C5. For implantation of a Boston Scientific Artisan lead, the spine is exposed from C2 to C6.

The Boston Scientific lead covers three cervical levels. It cannot be inserted over the ring of C1. This lead is inserted antegrade after a laminectomy at C5. A laminotomy at C3-4 is almost universally required to pass the lead cephalad and keep the lead in the midline. This lead is stabilized at its tail end to the spinous process of C6 with silastic sleeves around the tails of the implant.

The St. Jude Exclaim lead covers 1.5 cervical levels. For patients with neck and arm pain, the lead is inserted antegrade under C4 and C3. After exposing the spine from C2 to C5, the inferior 2–3 mm of the spinous processes of C2, C3, and C4 are removed with a Leksell rongeur. A 1- or 2-mm Kerrison rongeur is then used to remove the ligamentum flavum at C2-3, C3-4, and C4-5. A 2-0 Ethibond suture on a CT-2 needle is passed backhand beneath the lamina of C4 from C4-5 to C3-4, and then beneath C3 from C3-4 to C2-3. The St. Jude Exclaim lead has four dimples from the manufacturing process, two at the leading edge and two at the tail edge. An 18-gauge needle can be passed through these dimples without damaging the stimulator wires. After pushing the needle through the lead, a suture of 0 Ethibond is fed into the sharp end of the needle (Fig. 1). When the needle is removed, the suture is left passing through the lead. This process is repeated at each dimple until the 0 Ethibond forms a lasso through the lead with the two free ends acting as a tether or lanyard and exiting the leading edge of the paddle (Fig. 2). The 2-0 Ethibond suture is used to pull the 0 Ethibond tethers under C4 and C3. The tethers are then used to guide the paddle under C4 and C3. A towel clip is used to create a hole in the spinous process of C2 or C3. A free needle is used to pass one limb of the 0 Ethibond through the spinous process hole, which is then tied to the other limb (Fig. 3). No other anchoring is used; i.e., the silastic sleeves are not used at all with the tethering technique.

For patients who have occipital or temporal pain, in addition to neck and arm pain, the St. Jude Exclaim lead can be passed over the ring of C1. After exposing the spine from the occiput to C3, the ligamentum is removed from C1-C2 and occiput-C1. Different sized needles are used to pass sutures beneath the ring of C1 and the lamina of C2. These are used to pull a suture of 0 Ethibond from the top of C1 to the bottom of C2. Another suture of 0 Ethibond is...
passed through the lead as described above. The sublaminar suture is used to pull the Ethibond tethers first beneath C1, then beneath C2. The tethers are used to guide the paddle beneath C1 and C2. The tethers can then be tied around or through the spinous process of C2 (Fig. 4).

After implantation of the lead, the C-arm is used to verify its position in the AP and lateral planes (Fig. 5). Two tunnelers are then used to pass the tail of the lead from the cervical incision to a subcutaneous pocket above the left hip. A large loop of the tail is left in the cervical wound as a strain relief. The implanted pulse generator is inserted in a standard fashion above the left hip. The wounds are closed in a standard fashion without drains. Soft collars are applied for comfort but have been found to be unnecessary for the St. Jude Exclaim lead when the tethers are passed through all four corners of the implant. Lateral flexion and extension x-rays are obtained six weeks postoperatively, at which time the collar is discontinued.

Statistics

The Fisher’s exact test was used to compare the mechanical failure rate of the Boston Scientific Artisan lead with that of the St. Jude Exclaim lead.

RESULTS

There were no dural tears, cerebrospinal fluid (CSF) leaks or neurologic complications in this series. All wounds, except one (an infection), healed primarily without incident. Eleven (32%) of the 34 patients required removal or revision of their cervical spinal cord stimulators within one month of insertion. Six (40%) of the 15 patients with a Boston Scientific lead required removal or revision. One was removed for infection. This was an unusually long procedure due to difficulty positioning the lead in the midline, which is not uncommon with this lead. Two others displaced into the lateral gutter postoperatively in a “windshield wiper” manner. The other three displaced out of the spinal canal from under the lamina, presumably from neck flexion, despite use of a soft collar post-op. Five (26%) of the 19 St. Jude patients required removal or revision. All five St. Jude lead failures occurred when the tethers were passed only through the two dimples in the leading edge of the paddle. At revision, it was found that the tether suture pulled through the silastic between the suture holes. The suture and the spinous process to which the lead had been anchored were intact in each case. There have been no failures with the St. Jude lead since incorporating the two dimples in the tail edge of the paddle producing a rectangular configuration.

Fisher’s exact test comparing the failure rate between the Boston Scientific Artisan lead and all the St. Jude Exclaim leads revealed a p value of 0.73, or no significant difference. However, when the Boston Scientific lead is compared with the St. Jude leads that were implanted with the tethers inserted through all four dimples in a rectangular fashion, the p value drops to 0.06.

An interesting incidental finding in this study was the bending of the Boston Scientific Artisan lead on the six-week post-op lateral flexion and extension x-rays. With cervical flexion, the implant remained smooth. With extension, the lead buckled. The Exclaim leads always moved in unison with the vertebrae to which they were attached.

DISCUSSION

There is not much literature devoted to cervical spinal cord stimulation. The majority that does exist deals with the implantation of percutaneous leads. Most of the remaining papers lump thoracic and cervical implants together. Details of the surgical technique used and the complications are not distinguished between the thoracic groups and the cervical groups.

Displacement of the stimulator leads is not an uncommon cause of failure of cervical spinal cord stimulation. Robaina et al. (5) reported on 11 patients and stated the morbidity was “centered around local infection and displacement of the electrodes.” Falowski et al. (6) reported a 15% mechanical failure rate when thoracic leads were inserted with patients under general anesthesia compared

![Figure 4. Lead implanted retrograde under C1 and C2, sutured to the spinous process of C3.](image)

![Figure 5. AP and lateral views of a St. Jude Exclaim lead inserted over the ring of C1.](image)
with a 30% failure rate when the leads were inserted with the patients awake. The current author found a 32% failure rate overall when permanent paddle leads were inserted in the cervical spine with all patients under general anesthesia. A failure rate of one in three is unacceptable as correction requires a second surgical procedure on the mid or upper cervical spine with the attendant risks of infection, spinal fluid leak, and/or neurologic injury. There is also the issue of how to anchor the lead the second time around that will be more secure than the first time.

The anatomy of the cervical spine offers challenges not found in the thoracic spine. The cervical spinal canal is widest at occiput-C1 and narrows considerably at C5 through C7 (7). Due to the conical shape of the cervical spinal canal and the potential for subsequent disc herniations, most commonly at C5-6 and C6-7, it was the author’s custom to perform a laminectomy when implanting distal to C4. The extensive overlap of the thoracic laminae and the limited motion in that portion of the spine provide a stable environment for a thoracic lead. The cervical spine is much more mobile and offers little overlap of the cervical laminae. Both conditions encourage a lead to displace out of the canal with flexion, especially if the device is anchored at its tail end. Anchoring the device at its leading edge allows the lead to move with the spine, as noted in the flexion-extension views presented here (Figs. 6 and 7).

The thoracic spinal canal is larger and rounder than the cervical spinal canal, and the segments are longer. This allows one to push a lead antegrade into place in this region of the spine. The cervical canal is smaller, more trefoil shaped, and the segments are much shorter. The Boston Scientific Artisan lead, which covers 1.5 segments in the thoracic region, covers three segments in the cervical spine (Fig. 8). These factors combine to make it difficult to push this lead antegrade into the cervical spine while keeping it in the midline. There are no dimples, and there is little excess silastic between the contacts and the edge of the lead, making it impossible to place sutures through the lead. Therefore, this lead cannot be pulled into place, and it must be anchored at its tail end. When this is done, the lead can act like a large windshield wiper with the tip displacing laterally when the patient turns his or her head. Even when it stays in the midline, x-rays (Fig. 8) reveal that the lead buckles with neck extension. This could be a source of positional coverage experienced by the patients with this lead. It is unknown whether a larger, stiffer lead, such as the tripole or penta, would displace or buckle as the Artisan lead did. However, Levy et al. (8) warned that “the risk of neurologic injury is related to the volume (thickness $\times$ width $\times$ length) and stiffness of the electrode” and that “if acute blunt trauma to the cord occurs, the cord will react by swelling. The presence of a large-volume electrode will then contribute to further ischemia and subsequent spinal cord damage.” Falowski et al. (9) reported a woman, who fell and sustained a central cord injury beneath a previously placed cervical stimulator. They stated that the “cervical cord injury (was) induced by the electrodes of her spinal cord stimulator working as a space occupying mass. This case presentation should raise awareness to the risks involved in placing a space occupying mass in the epidural space.” This makes the buckling of the Artisan lead noted in this paper all the more disconcerting.

Placement of a stimulator lead over the ring of C1 allows coverage of the occiput and ear, in addition to the neck and upper extremities. The presence of the occiput and the curvature of the ring of C1 mandate that any lead placed in this area negotiate a 90-degree curve to get into the canal. Feler (7) first described the implantation of paddles leads retrograde under the ring of C1 and the lamina of C2 in 2003, and introduced the current author to the technique in 2009. However, the current author found it difficult to push a lead into position here. Anyone familiar with passing Luque wires or performing Brooks fusions should be comfortable passing sutures beneath the cervical laminae. Such sutures can be used to drag a lead into the spinal canal. Applying an upwardly directed force to the tethers at the leading end of the paddle and to the lead at the tail end as the paddle is being placed helps keep the lead against the ventral surface of the laminae and away from the spinal cord. Since the tethers are passed in the midline, the lead cannot deviate.
latterly. Anchoring at the leading edge forces the paddle to move with the spine in flexion and extension. Feler’s technique involved suturing the implant directly to the dura. He, also, reported no lead migration. The current author believes that Feler’s success was due to his anchoring the lead at its distal, leading edge. The current technique offers the alternative of anchoring the lead to the spinous process. No CSF leaks or neurologic injuries were noted in either series.

Initially, the tether suture was placed through the dimples in the very distal tip of the St. Jude Exclaim lead (a simple stitch in on one side, then out on the other). This left only 4–5 mm of silastic between the suture holes. The first five implants failed because the suture cut through this insufficient amount of material postoperatively as the patients began moving their necks. The technique was then modified to include all four corners of the implant. There have been no mechanical failures to date with the current technique.

The technique described is relatively simple when compared with other posterior cervical procedures commonly performed by spine surgeons today, such as the implantation of C1–C2 transarticular screws, inserting screws into the lateral masses of C1 and the placement of intralaminar screws. There were no neurologic complications in this series despite the absence of spinal cord monitoring. There were no infections in the tethered group. Using the spinous process of C2 as a landmark eliminated the need for a localizing radiograph, and, since the implants are always positioned midline by the stereotactic process. No CSF leaks or neurologic injuries were noted in either series. Feler’s technique involved suturing the implant directly to the dura. He, also, reported no lead migration. The current author believes that Feler’s success was due to his anchoring the lead at its distal, leading edge. The current technique offers the alternative of anchoring the lead to the spinous process. No CSF leaks or neurologic injuries were noted in either series.

In conclusion, the described technique is easy and reliable. The key is to include all four corners of the implant and to anchor the implant at its leading edge. Caution should be used with any lead implanted in the cervical spine that can only be anchored at its tail end. These same concepts apply to implantation of spinal cord stimulator leads below T10, another area of the spine with high mobility and limited laminar overlap.

Authorship Statement

Dr. Amrani was the sole author of this submission and responsible for the manuscript and data presented.

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REFERENCE


COMMENT

In this paper the author describes a method for placing paddle electrodes into the epidural space within the cervical spine. Cervical implants have a higher risk of injury using paddle lead implants as compared to coaxial leads because of the smaller available space of the spinal canal to accept a lead. While this paper represents his anecdotal impressions regarding the potential benefits of such a procedure and while I disagree with some of his perspectives on the specific location of electrodes, this paper serves as a reminder to consider the technique that we each use to achieve paddle lead implants. This method offers a potential advantage of reducing the lead to spinal cord insertion angle. Its application in clinical practice by other hands may limit its acceptability and performance.

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Comments not included in the Early View version of this paper.