Original Article

Minimally invasive cervical laminoforaminotomy – Technique and outcomes

ABSTRACT

Background: Cervical radiculopathy is a common pathological entity encountered by spine surgeons. Many surgical options have been described including anterior cervical discectomy with or without fusion to arthroplasty and posterior cervical laminoforaminotomy. Being a motion-preserving procedure, posterior cervical laminoforaminotomy is an excellent treatment for patients with unilateral radiculopathy secondary to a laterally located herniated disc or foraminal stenosis. With the advent of minimally invasive techniques, this procedure has regained popularity.

Objectives: Although there is enough evidence in the literature highlighting the benefits, safety, and efficacy of minimally invasive versus conventional techniques, a detailed technical report along with long-term surgical outcomes is lacking.

Methods: The authors present their experience in minimally invasive cervical laminoforaminotomy (MIS-CLF) over a 7-year period (2013–2020) along with a technical note. Clinical evaluation was performed both before and after surgery, using the Visual Analog Scale (VAS) pain scores. Patient functional outcome was measured using the modified Odom's criteria.

Results: There were no major perioperative complications. No patient required surgery for the same level during the follow-up period which ranged from 1 to 3 years. Statistically significant results were obtained in all cases, reflected by an improvement in VAS for neck/arm pain.

Conclusion: MIS-CLF is an effective technique for treatment of radiculopathy due to cervical disc herniation in a carefully selected subgroup of patients with good medium- to long-term outcomes. A larger study would possibly highlight the effectiveness of this procedure.

Keywords: Cervical disc prolapse, cervical laminoforaminotomy, cervical spine, keyhole foraminotomy, minimally invasive, neck pain, radiculopathy

INTRODUCTION

Cervical radiculopathy is a common condition in clinical practice managed by the neurosurgeon. Symptoms have been excellently managed with anterior cervical discectomy and fusion (ACDF), which has been accepted as the "gold standard" management for the last 50 years.[1,2] However, reports have revealed that it is fraught with numerous approach and procedure-related morbidities.[3] Over the past few decades, clinical and cadaveric studies also provide evidence to suggest that spinal fusion leads to inherent kinematic and biomechanical issues leading to adjacent segment disease.[4,5] Recently, much debate has sparked as to the role of motion-preserving techniques, whenever possible, in contrast to fusion where motion is lost, as an alternative albeit controversial solution.[6]

Posterior cervical laminoforaminotomy (PCF) is a relatively well-accepted motion-preserving technique among spinal surgeries standing the test of time for more than 60 years.[7] It is an excellent treatment for patients with unilateral radiculopathy secondary to a laterally located

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herniated disc or foraminal stenosis.[8] This technique may be a popular alternative to ACDF, when nonoperative measures have failed to provide adequate relief.[9] However, various reasons including need for morbid open surgery had led to its decline. With the advent of minimally invasive surgical (MIS) techniques that result in a reduction in blood loss, a shorter hospital stay, and a decreased need for the use of medication postoperatively, this procedure has once again gained popularity.

METHODS

During a 7-year period, from 2013 to 2020, 50 consecutive patients, who had undergone minimally invasive cervical laminoforaminotomy (MIS-CLF), were included in the study. A retrospective analysis of a prospective cohort of patients was performed.

The inclusion criteria were the presence of unilateral radicular symptoms, evidence of foraminal stenosis on the preoperative magnetic resonance imaging corresponding to the side and severity of symptoms, and failure of conservative management for a minimum of 4–6 weeks. Etiologies considered were degenerative foraminal stenosis, due to facet hypertrophy or osteophyte, and disc herniation. Patients were excluded if they presented with significant mechanical neck pain. Etiologies such as tumor, trauma, as well as significant instability due to spondylolisthesis were also excluded. Demographic and perioperative data collected were age, gender, number and level of surgery, estimated blood loss, operative time, and length of hospital stay. A detailed neurological examination was preoperatively performed in all cases. Clinical evaluation was performed both before and after surgery, using the Visual Analog Scale (VAS) pain scores for both neck and arm pain. Score improvements were then calculated and statistically analyzed. Functional outcome was evaluated using the modified Odom's criteria [Table 1].[10,11]

Statistical analysis was performed using paired *t*-tests. A probability value <0.01 was regarded as significant.

Case illustration and surgical procedure

The surgery was performed in prone position with the head fixed on a radiolucent head frame [Figure 1]. Intraoperative neuromonitoring was connected and utilized throughout the surgery. The appropriate level was identified with a C-arm [Figure 2]. A small skin incision (18–20 mm) was marked overlying the desired level approximately 1 cm lateral to the midline on the ipsilateral side [Figure 2]. After painting and draping, incision was then made and carried deep through to the fascia. Dissection of the crisscross muscle fibers was done using monopolar cautery until lamina was identified.

The next steps involved the use MetRx tissue dilator system (MetRx; Medtronic Sofamor Danek, Memphis, TN, USA) [Figure 3].

Figure 1: Patient positioned prone on radiolucent head fixation frame in neutral position and intraoperative neuromonitoring connected

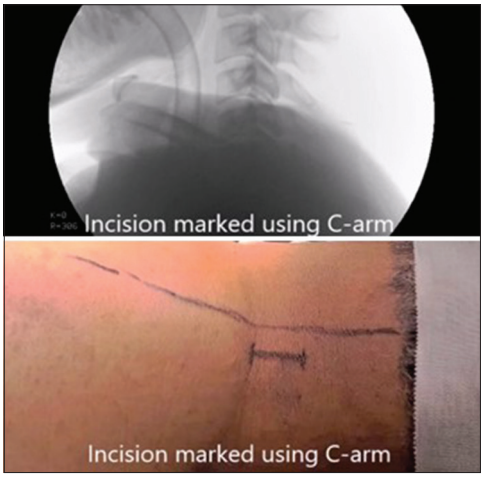

Figure 2: Appropriate level is confirmed with C-arm fluoroscopy and paramedian incision of 2 cm is marked approximately 1 cm from midline

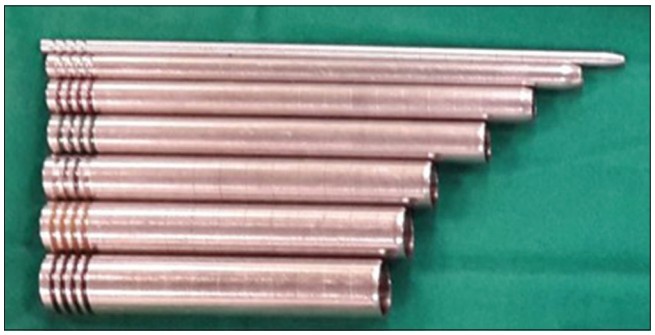

Figure 3: Sequential tissue dilator system (MetRx; Medtronic Sofamor Danek, Memphis, TN, USA)

Using fluoroscopic guidance, the first (smallest) tubular dilator was inserted and docked to the bone at the junction of the lamina and facet joint. It was then manipulated to dissect the soft tissue of the bone. The subsequent dilators with increasing diameter were sequentially inserted between the paraspinal muscles and used to dissect the muscles of the underlying bone surfaces [Figure 4].

An 18-mm diameter working port was introduced and secured to the operative table with a flexible arm. The dilators are then removed and fluoroscopy is repeated to confirm the positioning and level [Figure 5].

The next steps were performed under the surgical microscope. Monopolar cautery was used to remove the remaining soft tissue overlying the lamina and the base of the spinous process. The ipsilateral facet joint, base of spinous process, and lamina were identified [Figure 6].

The inferior part of the superior lamina and the superior part of the inferior lamina were then drilled, and the ligamentum flavum was exposed up to its attachment with the lamina. During the drilling, the ligamentum flavum was preserved in order to protect the dura. Next, the ligamentum flavum was carefully removed using Kerrison rongeurs. These techniques minimized the risk of injury to the dura [Figure 7].

If required, rarely, further lateral exposure was achieved by partial drilling of the medial aspect of the facet joint. After the ligamentum flavum was gently resected, the dura along with the nerve root were exposed [Figure 8].

The extruded disc and the extraspinal migrated fragments, if any, were identified by gently separating the nerve root medially and away from the disc herniation [Figure 9].

Once the anatomical relationship between the nerve root and the disc herniation was clarified, the discectomy was carried out. At times, if only an extruded and migrated disc fragment was found, the annulus was not incised and only fragmentectomy was performed [Figure 10].

In most other cases where a large annular tear was noted, it was further incised and the disc space was entered with a pituitary rongeur. Only the loose fragments were removed and no attempt was made to remove more disc material than deemed necessary [Figure 11].

Hemostasis was then secured, the surgical site was irrigated, and the working port was removed [Figure 12]. Wound closure was achieved with a subcutaneous stitch and the skin was closed with intradermal suture [Figure 13 and Video 1].

Post procedure, he improved significantly in terms of pain (immediate recovery) as well as neurological deficit (power in deltoid and biceps – grade 5) at the end of 3 months.

Table 1: Modified Odom's criteria

Grading	Definition
Excellent	All preoperative symptoms and abnormal findings improved
Good	Minimal persistence of preoperative symptoms (neck tenderness only, otherwise no symptoms). Abnormal findings improved
Fair	Definite relief of some preoperative symptoms. Other symptoms slightly improved (residual root irritation with transient pain)
Poor	Symptoms and signs unchanged or worse

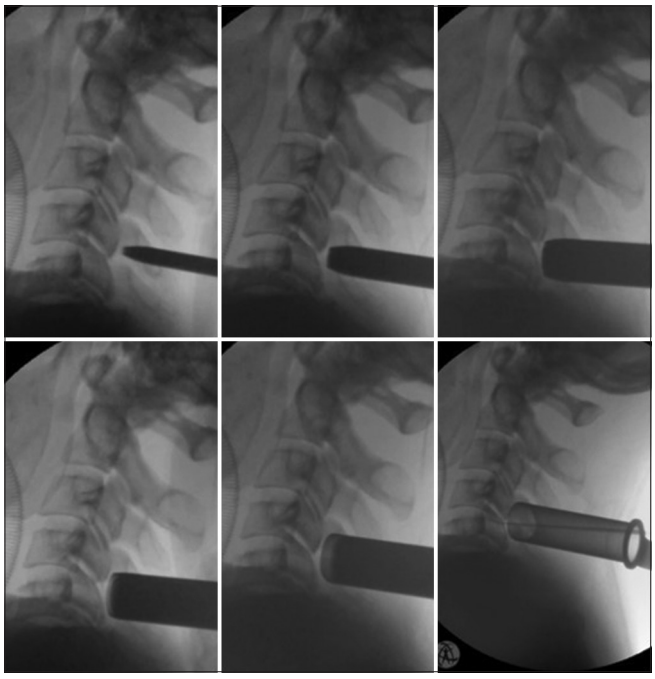

Figure 4: Fluoroscopy showing technique of inserting the sequential dilators – docking onto the lamina-facet junction

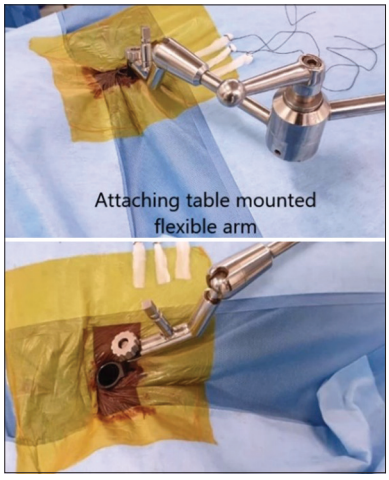

Figure 5: Attaching the final working port (18-mm tube) to the table-mounted flexible arm

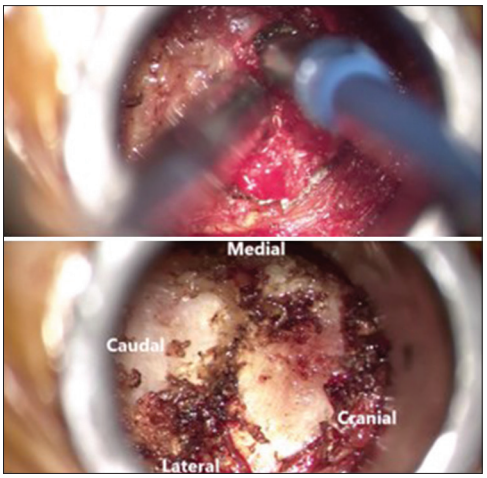

Figure 6: Under microscope, dissecting soft tissue with monopolar cautery (above); final identification of anatomical landmarks (lamina-facet junction)

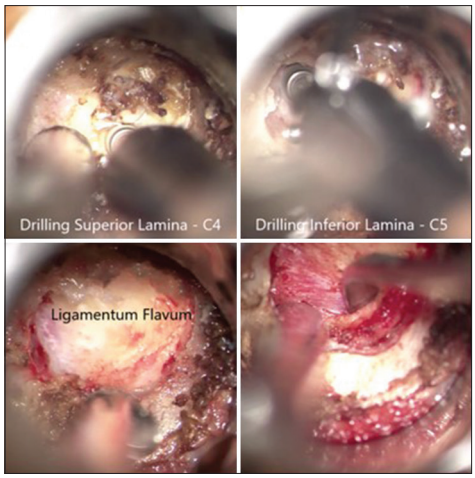

Figure 7: Laminotomy – drilling of the inferior part of the superior lamina and the superior part of the inferior lamina to expose the ligamentum flavum which is carefully removed to expose the dura

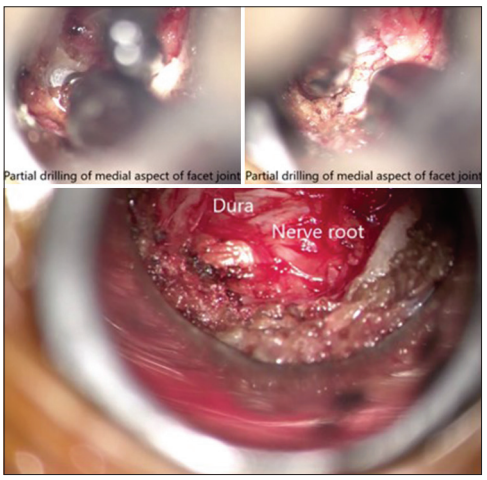

Figure 8: Further partial medial facet drilling to expose the origin of the nerve root from the dura

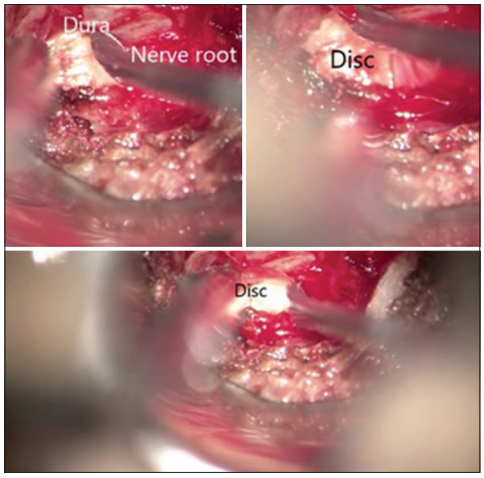

Figure 9: Identification of the disc fragment by gently retracting the nerve root medially and superiorly

RESULTS

Totally, 50 consecutive patients were operated upon, of which 31 (62%) were men and 19 (38%) women. The average age was 43 years (standard deviation [SD]: 8.0). Two patients had previous surgery (ACDF at the adjacent level). Baseline VAS (neck) and VAS (arm) scores were 8 (SD: 1.3) and 7 (SD: 0.6), respectively. Table 2 highlights the demographic data.

The operative data are summarized in Table 3. There were 51 total operated levels on 50 patients, of which single-level and two-level surgeries were performed in 96% and 4% of the patients, respectively. There were significant improvements in the VAS neck pain (8 vs. 2.5, $P < 0.001$) and VAS arm pain (7 vs. 1.5, $P < 0.001$). No statistically significant differences were found between the extent of improvement in the VAS between the first postoperative follow-up and the latest follow-up. The functional outcome assessed by Odom's criteria was excellent and good in 94% of the patients [Table 3].

The follow-up data are summarized in Table 4.

The mean follow-up was 31.4 (median: 26.0) months. No major complications were noted and none of the patients required reoperation.

DISCUSSION

Open posterior cervical foraminotomy (PCF) has been a well-described technique since the 1940s for the treatment of foraminal stenosis.[7] Where ACDF might have been considered the "gold standard" for treatment of cervical radiculopathy due to herniated disc, PCF seemed to have an edge in certain aspects. In selected subgroup of patients,

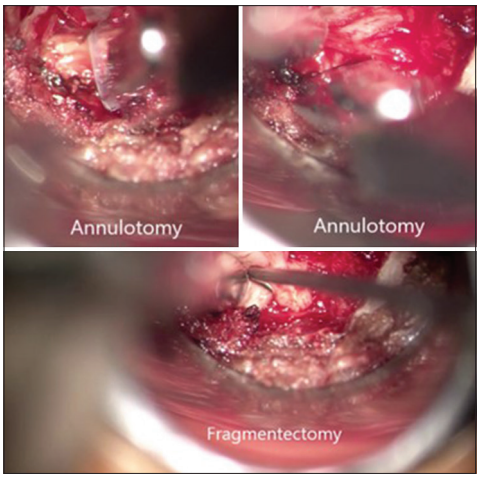

Figure 10: Annulotomy performed and fragmentectomy done using a right-angled nerve hook

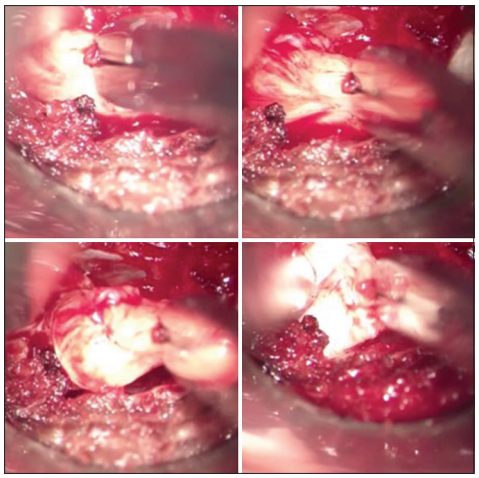

Figure 11: Discectomy – disc entered with rongeurs and loose fragments removed

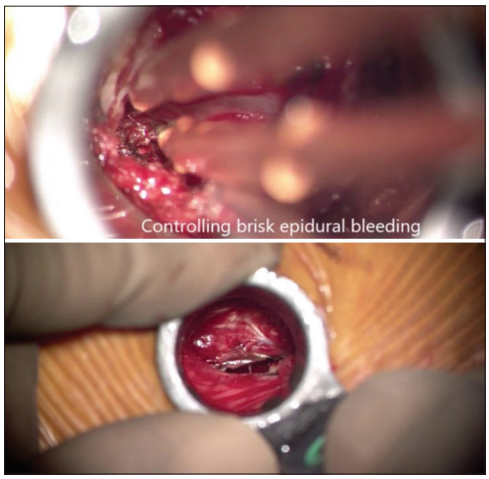

Figure 12: Hemostasis – brisk epidural bleeding controlled (above); working port removed and separated muscle fibers fall back– occluding dead space (below)

Table 2: Summary of patient demographics

Patient demographics	Results
Total number of patients (*n*)	50
Mean age (years)	43
Sex	
Male	31
Female	19
Baseline pain scores	
Mean preoperative VAS (neck pain)	8 (+/−1.3)
Mean preoperative VAS (arm pain)	7 (+/−0.6)

VAS: Visual Analog Scale

there were several advantages such as (1) direct and targeted decompression of the involved nerve root, (2) no disruption of the disc space, (3) avoidance of fusion, and (4) avoidance of possible anterior approach-related problems.[8]

However, open PCF had its downfall due to inherent technical drawbacks including (1) long midline incision, (2) extensive

Figure 13: Final skin closure (continuous subcuticular absorbable suture)

subperiosteal dissection to detach deep muscles such as semispinalis and multifidus that are dynamic stabilizers of the lamina and facet joint, (3) long-lasting postoperative neck spasm and pain, (4) postoperative instability at the surgical level, and (5) loss of lordosis (or development of kyphosis) which may accelerate disc degeneration due to the wide detachment of muscle and ligament surrounding the facet and excessive facet joint resection.[12,13]

Minimally invasive access to posterior spine using tubular retractors was popularized by Foley *et al*. in 1997.[14] There were several reported advantages including less tissue dissection, decreased blood loss, decreased postoperative pain, shorter hospital stay, and earlier ambulation. Applying the same principles to the cervical spine, the tubular techniques were extrapolated to develop MIS-CLF. Adamson, in 2001, described the microendoscopic technique as an alternative to traditional methods, while Fessler and Khoo presented their initial experience with tubular retractors in 2002.[12,15] This provided significant benefits including safe, rapid, and direct localization of the intervertebral foramen

Table 3: Operative data

Operative data	Results
Total operated levels	51
Surgical approach	
Left	27
Right	23
Levels operated	
C4-5	8
C5-6	19
C6-7	22
C7-T1	2
Number of levels	
Single level	49
Two levels	1
Mean operative time (h)	1.6
Mean blood loss (mL)	33.4

Table 4: Follow-up data

Follow-up data	Results
Follow-up duration (months)	24
Mean postoperative stay (days)	2.3
Mean postoperative VAS (neck pain)	2.5 (+/−1.5)
Mean postoperative VAS (arm pain)	1.5 (+/−0.7)
Odom's criteria	
Excellent	37
Good	10
Fair	3
Poor	0

VAS: Visual Analog Scale

with excellent visualization of lateral spinal structures without significant muscle retraction or potentially destabilizing bony resection.

As such, primary complications related to MIS-CLF are rare. Among these, cerebrospinal fluid leaks, infections, wound hematoma, and nerve manipulation leading to radicular numbness were the ones reported ranging from 2% to 9%.[16] These may be avoided by limiting nerve root handling or spinal cord manipulation. Risk of inducing segmental instability also remains minimal as long as <50% of the facet is disrupted.[17,18]

A brief review of the literature reveals multiple studies highlighting the superiority of MIS-CLF over PCF. Lawton *et al*. found excellent clinical outcomes, in terms of clinically significant improvement in pain scores, in their series of 38 patients followed up for 24 months, with minimal complications consisting of one durotomy.[19] Young-Joon Kwon analyzed the long-term outcomes of MIS-CLF in 33 patients, followed up for 32 months, and found that pain relief was sustained, with functional restoration, accompanied by good long-term radiological outcome.[20] In another series of 35 patients, Terai *et al*. found MIS-CLF to be highly effective and safe for even two-level pathologies with tandem "keyhole" foraminotomies.[21]

Comparative studies directly evaluating open PCF and MIS-CLF are fewer but still highlight the approach-related benefits of MIS. One meta-analysis by McAnany *et al*. found slightly better success rates (92.7% – open PCF vs. 94.9% – MIS-CLF), though not clinically significant.[22] Summative results from a systematic review by Clark *et al*. indicated that patients who underwent MIS-CLF had lower blood loss (by 120.7 mL), a shorter surgical time (by 50.0 min), less inpatient analgesic use, and a shorter hospital stay (by 2.2 days) as compared with open PCF.[23]

A small yet particularly important randomized clinical trial of 41 patients by Kim and Kim reported a significant decrease in hospital stay and postoperative pain medication use in the MIS group.[24] They acknowledged that a statistically significant shorter surgical incision and less extensive periosteal dissection is probably clinically relevant in delivering the better outcomes in MIS.

A more recent literature review by Platt *et al*. also revealed a trend toward decreased hospital length of stay and postoperative analgesic usage in the MIS cohort, despite there being significant heterogeneity in the studies comparing open and MIS foraminotomy.[25]

In the present study, the authors present the technique of MIS-CLF for cervical radiculopathy along with clinical outcomes in their series of 50 consecutive patients. VAS scores improved significantly from baseline in the immediate postoperative period and were maintained with time. The results were concurrent with similar series of MIS-CLF.[12,15,19] No patient required reoperation for the index or adjacent level during the follow-up period. By performing only a partial undercutting (<30%) of facet wherever needed, and tilting the tubular retractor medially, from a slightly lateral surgical approach, adequate decompression of the nerve root was achieved. This way, majority of the facet was left intact, thereby retaining stability with maximal root decompression, which probably resulted in good clinical outcomes with minimal complications. Since a "muscle-splitting" window is utilized, muscle fibers tend to fall back and occlude any dead space at the end of the procedure.

However, this study has its own limitations. The relatively small number of cases and lack of comparable control group within the same study may need to be investigated in future studies. Longer duration of follow-up with radiological

analysis may be required for assessment of iatrogenic instability. Nevertheless, this study seems to be the only series from India highlighting the effectiveness of this technique in a selected cohort of patients.

CONCLUSION

MIS-CLF is a safe and effective technique to treat patients with radicular pain from foraminal compression. It provides a good alternative option to conventional treatments for a distinct subset of patients in whom this procedure may be warranted. It may be reserved for a select cohort of patients who have debilitating unilateral cervical radicular pain, with nerve root compression demonstrated on imaging, who have failed trials of conservative treatment, associated with or without neurological deficit. The procedure has its own inherent, proven clinical benefits compared with accepted conventional and "gold standard" treatments.

Further studies with longer follow-up and larger sample size with radiological correlation, to possibly highlight its effectiveness, may be required to determine whether such results are sustained.

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Conflicts of interest
There are no conflicts of interest.

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