

Endoscopic Posterior Cervical Craniolateral Inclinator Foraminotomy

A Novel Approach for Lamina Preservation During Tandem Decompression of Cervical Spondylotic Radiculopathy via Unilateral Biportal Endoscopic Spinal Surgery

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Study Design: Case series.

Objective: Endoscopic posterior cervical foraminotomy gains attention for cervical radiculopathy due to its feasibility, better outcomes, and lower complications than traditional approaches, enabling efficient multilevel decompression in a single operation while avoiding anterior cervical discectomy and fusion-related issues. However, with multilevel decompression, the remnant lamina becomes thin and fragile. We propose craniolateral inclinator foraminotomy to minimize bone removal during laminotomy, reducing the risk of iatrogenic or postoperative lamina fractures in tandem decompression.

Materials and Methods: From 2021 to 2022, 8 consecutive patients underwent the procedure and were followed up for at least 6 months. The VAS, NDI, and MacNab scores were recorded for clinical recovery and patient satisfaction evaluations. Preoperative and postoperative CT scans were utilized to measure the lamina preservation percentage at each level.

Results: The clinical outcomes improved significantly in every patient. No postoperative neck pain, segmental instability, or lamina fracture were observed. The mean lamina preservation percentages of C5, C6, C7, and all vertebrae were 68.8%, 73.22%, 71.86%, and 72.18%, respectively.

Conclusions: Ongoing technical adjustments will accompany endoscopic technique development to decrease complications and enhance benefits. Our reported technique avoids extensive laminotomy in multilevel tandem decompression, aiming to prevent lamina fractures and anticipate a reduction in postoperative neck pain.

Level of Evidence: Level IV.

Key Words: cervical, decompression, endoscopic spine surgery, foraminal stenosis, laminar fracture

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the Himnaera Hospital Institutional Review Board of Human Study Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Written informed consent for publication of the patient's clinical details and images was obtained from all of the patients.

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The authors declare no conflict of interest.

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Societal aging has led to an increase in the prevalence of degenerative spondylosis and its associated neuro-pathology. Cervical spondylotic radiculopathy caused by disc herniation or foraminal stenosis is a common condition, and anterior cervical discectomy and fusion (ACDF) has been considered the gold standard therapeutic procedure due to its simplicity, practicality, and consistent outcome; however, it sacrifices the mobility of the vertebral joint and predisposes the patient to the development of adjacent segment disease in the future. An alternative treatment for cervical radiculopathy is posterior cervical foraminotomy (PCF). Along with the improvement of surgical instrument, PCF has evolved from traditional open approach through deep-and-thick neck muscles, to microtubular cervical foraminotomy, to micro-endoscopic PCF, and then to full-endoscopic PCF, decreasing the peripheral soft tissue damages.^{1–4} Recently, with the use of an inclinator stance in endoscopic foraminotomy, more of the facet joint and its capsule can also be preserved, potentially avoiding postoperative neck pain and even hypermobility.^{5,6}

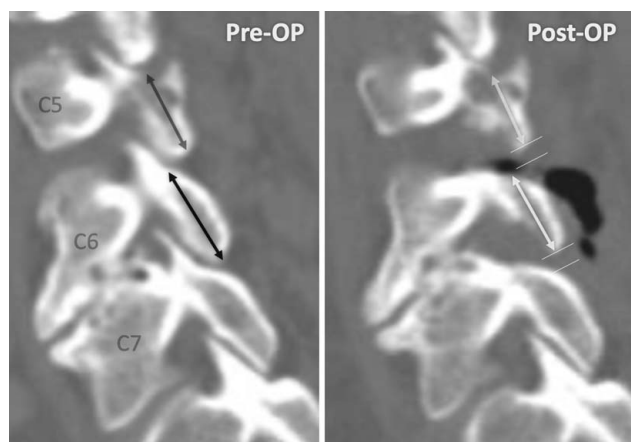


FIGURE 1. The measured preoperative total lamina height and postoperative remnant lamina height.

One of the upsides of this technique is that multilevel decompression can be done rapidly and in one operation. However, the extent of decompression required during PCF has been a topic of debate since its introduction. Keyhole decompression targets the V-point as the central reference and performing decompression of the surrounding bony structures within a specified radius.^{7–9} Landmark identification is also a common method in which the laminotomy is done until the pedicles are exposed to an extent. Some articles have even encouraged circumferential decompression of the root, which involves addressing the superior articular process (SAP), pedicle, disc, and uncinata process to achieve thorough decompression.^{10–13} However, different from the typical lumbar vertebra, the typical cervical vertebra is much smaller and has a thin and fragile lamina. The lumbar lamina can withstand multiple unilateral laminotomy bilateral decompressions still with a solid lamina left. However, in the cervical spine, with multilevel decom-

pression, especially at consecutive levels, the remnant lamina becomes fragile. There is evidence to suggest that iatrogenic or postoperative fractures can occur after multilevel tandem PCF, even with a full endoscopic approach.^{14,15}

In adapting the concept from the cervical inclinatory approach to decrease facet joint violation, we came up with the craniolateral inclinatory foraminotomy. By moving the portal caudally and aiming in a craniolateral direction, decompression was done solely by SAP tip resection. The cervical facet and lamina integrity can both be preserved more at the same time, which decreases the risk of postoperative lamina fracture (theoretically). In this article, we reported the approach in step-by-step detail and short-term outcome of a case series underwent this procedure.

MATERIAL AND METHODS

Patient Evaluation

This study was carried out after we obtained approval from the institutional review board and informed consent from the patients. All procedures were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

From 2021 to 2022, 8 consecutive patients with cervical spondylotic radiculopathy underwent endoscopic posterior cervical craniolateral inclinatory foraminotomy. All patients had undergone a minimum of 2 months of conservative treatment, which encompassed medication, rehabilitation, and epidural steroid injection, before their participation in the study. Patients who had definitive segmental instability, cervical deformities, central localization of the disc herniation, myelopathy, past cervical surgery, and follow-up of less than 6 months were excluded. The medical records including the diagnosis, du-

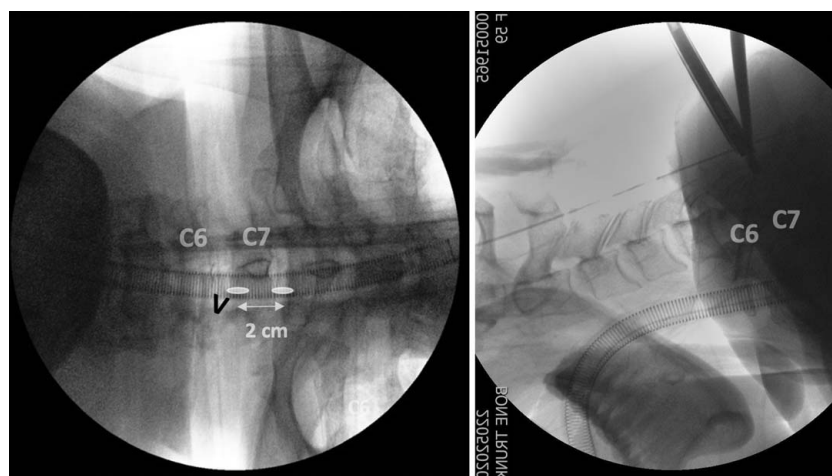


FIGURE 2. The scope portal is located on the lower border of the interlaminar space and the instrument portal is located 2 cm distally from the scope portal.

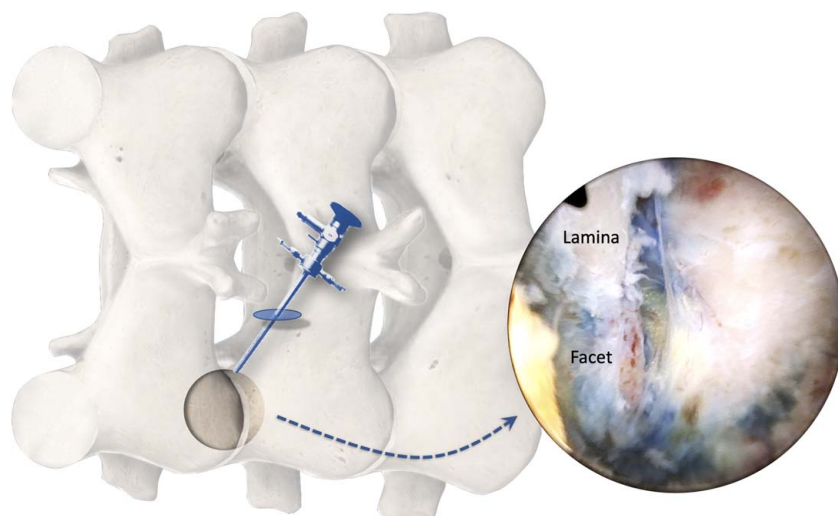


FIGURE 3. The sublaminar access made the lamino-facet junction appear to be like a cleft instead of a V-shaped configuration. [full color online](#)

ration of symptoms, age, sex, neurological findings, primary cervical level involved, operated levels, operative duration, complications, and time to pain relief were obtained for this study. All procedures were performed using an endoscope system by the same experienced surgeon.

The visual analog score (VAS), neck disability index (NDI), and MacNab score were evaluated for clinical recovery and patient satisfaction. Statistical assessments were performed to compare the preoperative, postoperative (within 1 wk), and 8-month follow-up outcomes. Preoperative and postoperative x-ray and CT scans were performed for clinical evaluation and lamina preservation assessments. For the lamina preservation assessment at each level, the CT sagittal cuts, which change with the height of most laminae after surgery, were chosen for the assessments. The lamina height in that cut was extracted preoperatively and postoperatively to calculate the lamina preservation percentage (Fig. 1).

Statistical Analysis

Statistical analysis was performed between the pre-

operative and postoperative clinical results using the Wilcoxon signed-rank test and paired *t* test on SPSS version 20 (IBM). Statistical significance was defined at $P < 0.05$.

Surgical Approaches

The patient was placed in the reverse Trendelenburg position on a radiolucent table with a soft cushion that was well-padded at bony prominences of the body after the general anesthesia. A soft head holder was used to maintain the neck in a slight flexion position. Both shoulders were depressed caudally via taping to the surgical table. Level confirmation and marking were conducted under fluoroscopic guidance before the incision. When performing craniolateral inclinatory foraminotomy, the incision for the scope portal is located on the lower border of the interlaminar space; that is, the upper border of the lower lamina. The incision for the instrument portal is located 2 cm distally from the scope portal (Fig. 2). The muscle fascia perpendicular to the skin is incised to prevent the obstruction of water flow during surgery. A

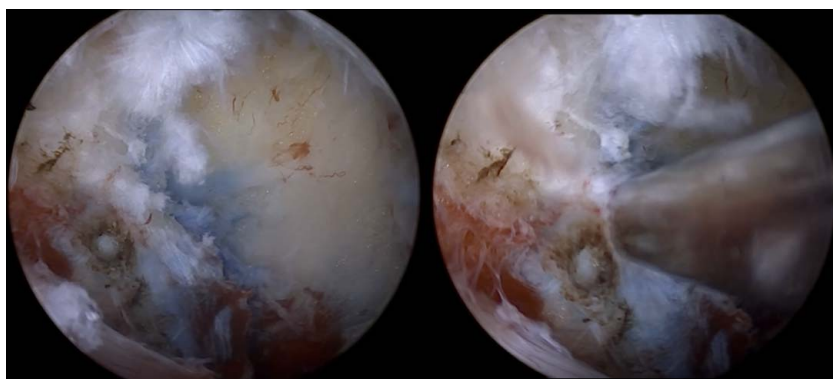


FIGURE 4. Distal laminotomy of about 2 mm was performed to widen the working space. [full color online](#)

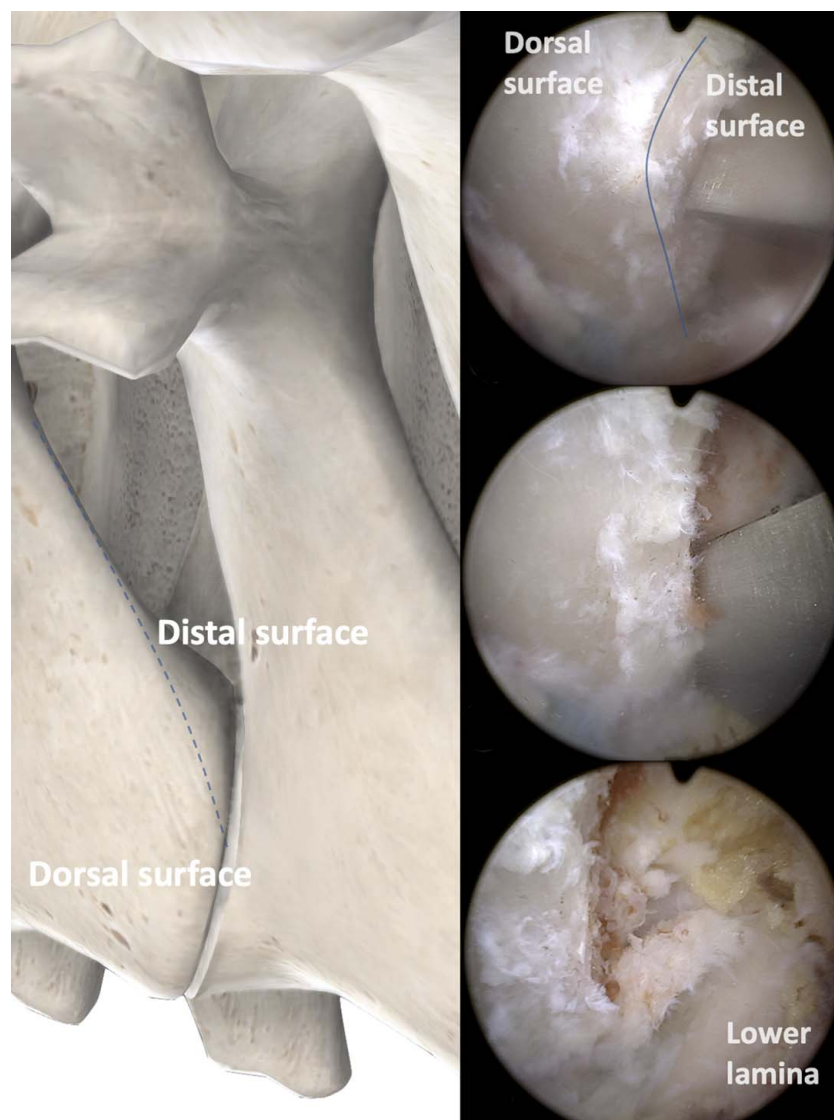


FIGURE 5. A pedicle chisel was used to extend the distal laminotomy of the upper lamina deeper into the anteromedial part of the inferior articular process. full color online

smooth periosteal elevator is used to detach and shift the paraspinal muscle and other soft tissues from the dorsal lamina to the lateral side.

After successfully introducing the endoscope to the lamino-facet junction, shavers, and radiofrequency wands are used to clear the rugged muscle and debris around it. A major difference in endoscopic view between the cranio-lateral inclinatory approach and the conventional approach is that there is no V-point. From the caudocranial point of view, the lamino-facet junction between the 2 levels appears to be like a cleft instead of a V-shaped configuration (Fig. 3). After identifying the interlaminar cleft, a distal laminotomy of about 2 mm was performed to widen the working space (Fig. 4). The sublaminar space required for the instrument to reach deeper is at least 8 mm. Proximal laminotomy of the lower lamina should be performed if the trajectory of the instrumental portal is obstructed.

After creating enough space for instrument manipulation, the pedicle chisel was used to extend the distal laminotomy of the upper lamina deeper into the inferomedial part of the inferior articular process (IAP), revealing the superior articular process (SAP) underneath (Fig. 5). Instead of performing wider proximal laminectomy, <25% of inferomedial IAP removal is sufficient to reveal the medial SAP tip from the caudocranial point of view. Proximal laminotomy of the lower lamina was performed using a Kerrison punch laterally to reach the pedicle margin and create an anchoring point for a 5-mm Hockey chisel to resect the cranial tip of the SAP (Fig. 6). Instead of exposing the entire nerve root, decompression was accomplished by removing the SAP tip (Fig. 7). In severe cases with narrowed spinal canals due to disc space collapse and lateral recess stenosis, the safe working space between the dura and pedicle can be narrow. To achieve a

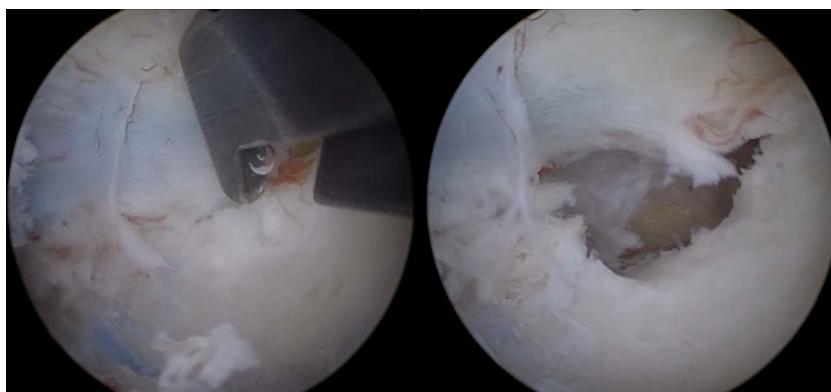


FIGURE 6. Proximal laminotomy of the lower lamina was performed using a Kerrison punch to create an anchoring point for a chisel to resect the cranial tip of the superior articular process. full color online

safe and sufficient working space while minimizing the risk of dura injury, partial craniomedial pediculotomy can be performed to create more room at the root axilla region, thereby relieving the root from suprapedicular kinking. (Fig. 8). After the end of the bony procedure, the perineural membrane is to be removed piece by piece using a small pair of pituitary forceps or a hook radiofrequency probe. The ligamentum flavum was mostly left untouched to protect the dura mater and the venous plexus. Piece-meal removal of the lateral border of the ligamentum flavum was done for better visualization of the nerve root in more severe degenerative cases. A drain is placed at the epidural space, and the wound is closed using 4-0 nylon sutures (the procedure is well demonstrated in the Supplemental Video, Supplemental Digital Content 1, <http://links.lww.com/CLINSPINE/A364>).

RESULTS

The mean age of the 8 included patients (6 males and 2 females) were 62.8 ± 4.2 (56–70). There were 4 single level (C45:1; C56: 1; C67: 2) and 4 multilevel cases (C567: 3; C456:1), and a total of 12 foraminotomies (C45: 1; C56: 5; C67: 6) were performed.

Surgical Outcome

Preoperative VAS and NDI scores were improved significantly after the surgical procedures: the average VAS score changed from 7.37 preoperatively to 1.62 at the last follow-up visit (sixth month), while the average NDI score changed from 29.12 to 10.12. The MacNab criteria revealed excellent results in 5 patients, good in 2 patients, and fair in a patient (Table 1). All patients showed significant improvement in neurological pain. One patient experienced residual discomfort in the scapular area, and another patient reported persistent hand paresthesia. The patient demonstrated fair MacNab sustained a prolonged C456 radiculopathy with significant thenar muscle atrophy. The decompression successfully relieved the pain and soreness, but the patient continued to suffer from hand weakness. No complaint of postoperative neck pain was mentioned.

Radiologic Assessment

No postoperative segmental instability was noted. The mean preoperative lamina heights of C5, C6, and C7 were 12.5 , 15.0 ± 2.0 , and 14.6 ± 2.9 mm, respectively, and the mean postoperative lamina remnant heights were 8.6 , 11.2 ± 2.2 , and 10.0 ± 2.7 mm, respectively. Lamina preservation percentages were calculated at each level, and the



FIGURE 7. The decompression is accomplished by resecting the cranial tip of SAP. SAP indicates superior articular process. full color online

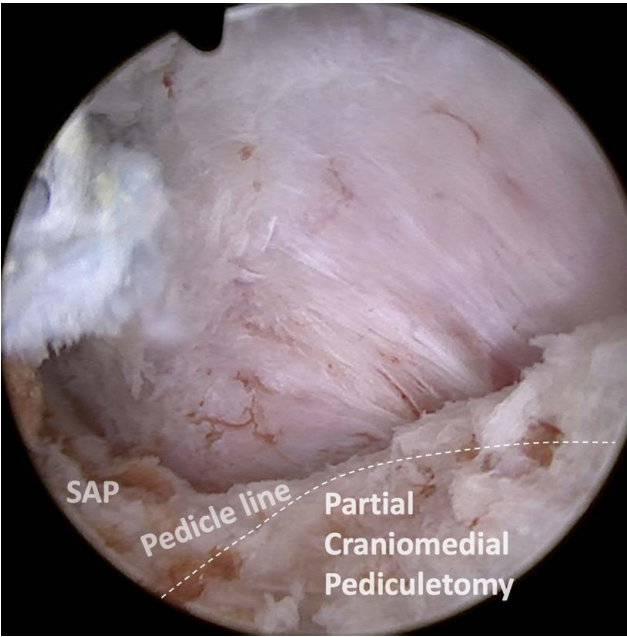


FIGURE 8. Partial craniomedial pediculetomy could be performed to create more space at the root axilla region. SAP indicates superior articular process.

mean preservation percentage was 68.8%, 73.22%, and 71.86% at C5, C6, and C7. The average preservation percentage of all levels was 72.18% (Table 2).

DISCUSSION

Although intraoperative observation of root pulsation and perineural vascular circulation can be the most direct and comprehensive method to evaluate the decompression sufficiency of nerve root, it lacks a standard guideline to reach enough interobserver consistency and may vary a lot according to experience. Keyhole decompression utilizes the V-point as a guide for understanding the extent of laminoforaminotomy. However, the V-point is an imaginary target, which is the crossover point of the upper and lower lamina, and its location can differ based on the patient’s position, laminar slope, and height. In cases of advanced disc height collapse, the V-point can be

significantly medially shifted (Fig. 9), and the decompression radius needs to be increased to avoid incomplete decompression at the cost of more lamina removal. The average cervical lamina height is around 10–15 mm, and the suggested laminoforaminotomy radius is around 3–6 mm; so, the lamina in the middle of consecutive decompression can easily be removed for 6–12 mm, which is more than 50% of the lamina, resulting in near-total hemilaminectomy after the upper and lower laminotomy.^{7–9,16,17} It is crucial to acknowledge that the extent of lamina removal can be even greater when aiming to identify both the upper and lower pedicles in the context of circumferential decompression methods. An original article by Ohmori et al¹⁴ describes a patient who suffered a lamina fracture following a full endoscopic foraminotomy procedure. The incidence of lamina fracture as a complication of foraminotomy is not well-established, as the minimal fractures may only be identifiable by CT or significant fragment displacement. However, this case report provides evidence that this complication can occur, despite undergoing a full endoscopic approach. Neglected postoperative lamina fractures might as well constitute one of the causes of postoperative neck pain.

The cervical intervertebral foramen is an oval bony ring consisting of the upper and lower vertebral notch. The vertical diameter of the foramen has been reported to be approximately twice the horizontal diameter; so, in cervical radiculopathy, clinical results can be dependent on sufficient decompression of the horizontal plane. In our opinion, when using a posterior approach, instead of attempting to expose all the pedicle margins, targeting a well-executed resection of the hypertrophied SAP tip is a more effective strategy, and may be the key to achieving successful decompression. As we have learned from the inclinatory micro-tubular-PCF and full-endoscopic-PCF techniques to preserve at least 50% of the facet and prevent hypermobility,^{5,18} we try to adapt the same concept to target only the SAP tip, preserving the lamina. Before the utilization of endoscopy in PCF, this idea had been considered impossible because the SAP is hidden too deep under the IAP. Only with the aid of endoscopic techniques can this idea be rendered feasible by putting the lens directly into the interlaminar space and locating the SAP tip without excessive lamina removal.

TABLE 1. Patient’s Demographic Data and Clinical Outcome

Patient no.	Sex	Age	Diagnosis	Level	Preoperative		Postoperative		MacNab
					VAS	NDI	VAS	NDI	
1	F	60	Cervical spondylosis	C5/6 left	8	29	2	11	Good
2	M	70	Cervical spondylosis	C5/6 left	7	34	2	12	Excellent
3	M	56	Cervical spondylosis	C6/7 right	6	24	3	15	Good
4	M	61	Cervical spondylosis	C4/5 right	7	29	1	13	Fair
5	M	67	Cervical spondylosis with hard disc extrusion	C6/7 left	8	37	1	6	Excellent
6	M	59		C6/7 right	8	28	1	8	Excellent
7	F	62	Cervical spondylosis	C5/6 rightC6/7 left	7	24	2	10	Excellent
8	M	68	Cervical HIVD	C5/6 left	8	28	1	6	Excellent
Mean		62.8			7.37	29.12	1.62	10.12	

F indicates female; M, male; NDI, neck disability index; VAS, visual analog score.

TABLE 2. Radiologic Analysis and the Lamina Preservation Percentage

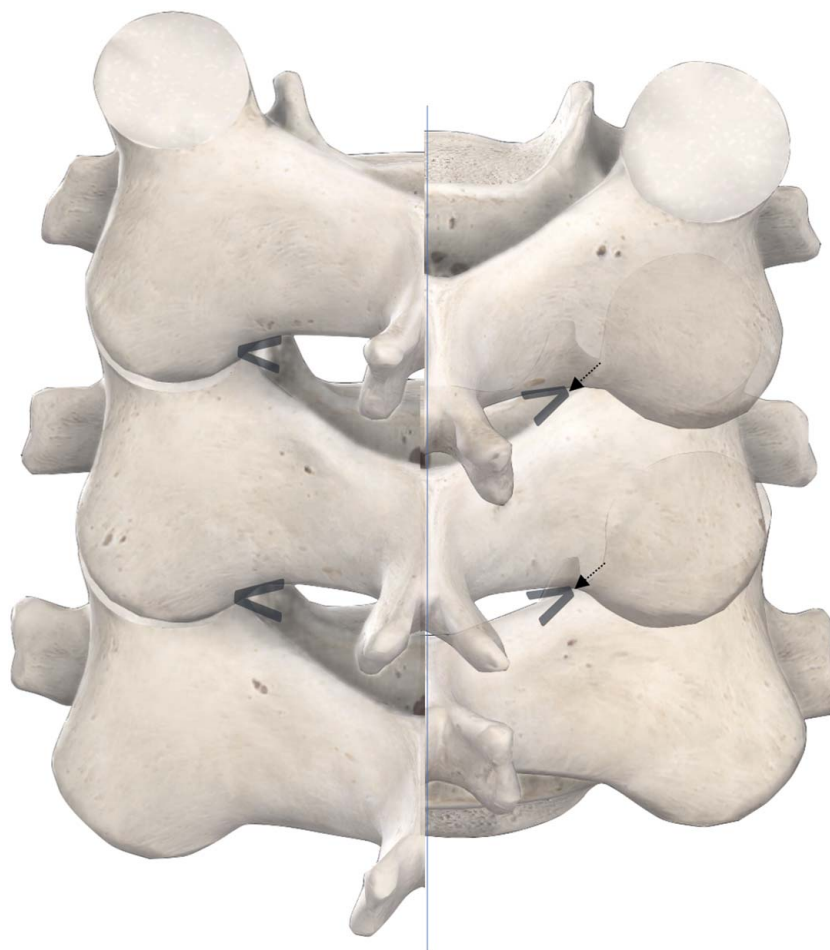

Patient no.	Level	Preoperative total lamina height (mm)	Postoperative remnant lamina height (mm)	Preservation percentage (%)
1	C5/6 left	16.5	13.3	80.6
	C6/7 left	11.9	7.1	59.7
2	C5/6 left	12.3	8.5	69.1
	C6/7 left	11.5	7.2	62.6
3	C6/7 right	14.6	10.6	72.6
4	C4/5 right	12.5	8.6	68.8
	C5/6 right	14.3	10.9	76.2
5	C6/7 left	16.8	13.2	78.6
6	C6/7 right	17.6	12.7	72.2
7	C5/6 right	12.8	7.6	59.4
	C6/7 left	13.1	11.2	85.5
8	C5/6 left	12.5	10.1	80.8
Mean		13.87	10.08	72.18

In our series, posterior cervical craniolateral inclinatory foraminotomy successfully achieved lamina preservation up to 70% at almost every level, and the postoperative CT revealed well-decompressed neurofora-

men (Fig. 10). Compared with the postoperative 3D CT reconstruction shown in previous studies, the lamina preservation in our case appears to be much more solid (Fig. 11).^{5,18,19} All patients demonstrated significant improvements in their VAS, NDI, and MacNab scores, and there were no complaints of postoperative neck pain.

Limitations

Although our series yielded excellent clinical and radiologic results, there are still several things to be concerned about. First, in the current literature, a more aggressive circumferential foraminal decompression with partial pediclectomy is suggested to release the nerve root completely from the anterior structures. In our series, most decompressions are done by simple SAP tip resection and perineural membrane adhesiolysis. In our opinion, it is unnecessary to perform partial pediclectomy in cases without advanced disc collapse and severe stenosis resulting in limited working space and suprapedicular kinking. However, if the decompression was insufficient, the outcome might gradually differ as the number of cases increases. Second, measurement errors could have oc-

**FIGURE 9.** The significantly medially shifted V-point in cases of severe degeneration with advanced disc height collapse. 

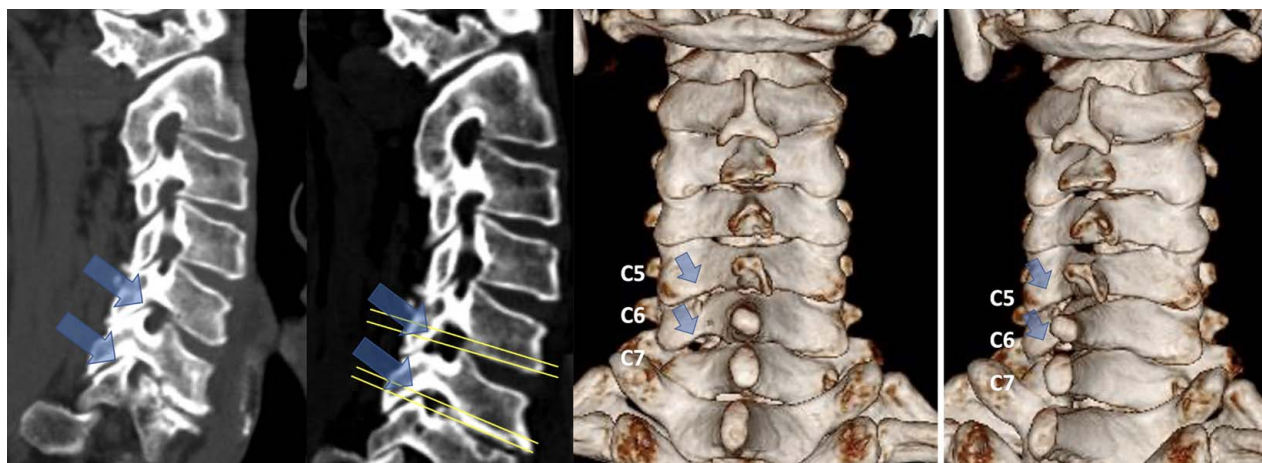


FIGURE 10. Postoperative CT revealed well-decompressed neuroforamen. full color online

curred because the measuring methods were based on only a single sagittal CT cut. The preoperative and postoperative cuts could have differed slightly according to the patient's lying position. Measurement by area with the use of 3D CT reconstruction and a control group with conventional endoscopic PCF should be mandatory in future studies. Third, there are still no rigorous studies on the clinical significance of the preservation of cervical laminae. Even though we successfully preserved the integrity of most laminae, more research still needs to be conducted to prove the relationship between them. Lastly, this preliminary report comprises only a small number of patients with limited follow-up, and no comparisons have been provided with more established surgical approaches to ascertain whether this novel approach reduces complications or yields comparable outcomes to more conventional techniques.

CONCLUSION

Technical adjustments will keep accompanying the development of the endoscopic technique to decrease the incidence of complications and promote its potential benefits. The endoscopic posterior cervical craniolateral inclinatory foraminotomy technique has demonstrated success in circumventing the need for extensive laminotomy in multilevel tandem decompression procedures, effectively alleviating neurological symptoms associated with cervical spondylotic radiculopathy. However, further investigation is necessary to explore the correlation between lamina preservation and the occurrence of postoperative neck pain, establishing conclusive evidence in this regard.

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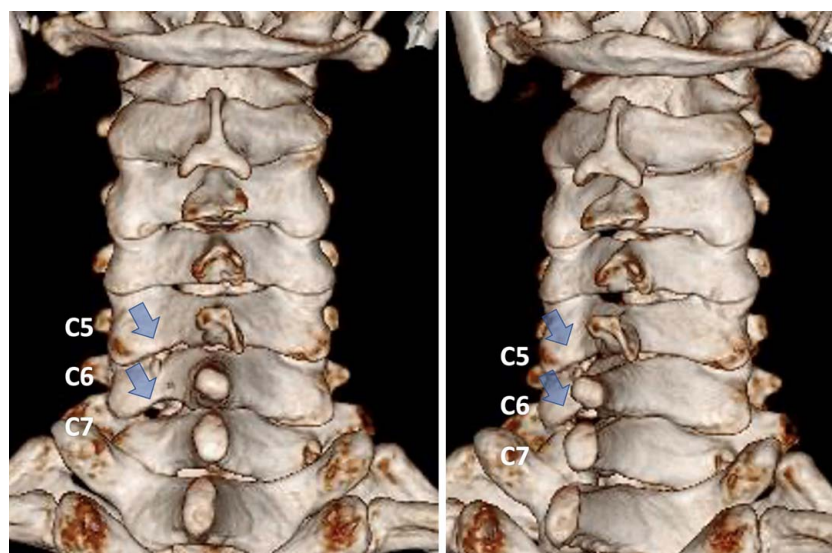


FIGURE 11. The lamina is well preserved after craniolateral inclinatory foraminotomy. full color online

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