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ORIGINAL ARTICLE

Unilateral open-door laminoplasty alone with and without foraminoplasty for the treatment of mixed cervical spondylosis

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ABSTRACT

Objectives: This study aims to compare the clinical outcomes of unilateral open-door laminoplasty with adjunctive foraminoplasty in the management of mixed cervical spondylosis.

Patients and methods: Between January 2016 and January 2024, a total of 60 patients (36 males, 24 females; mean age: 71.8 ± 9.9 years; range, 52 to 92 years) who were diagnosed with mixed cervical spondylosis and underwent unilateral open-door laminoplasty were retrospectively analyzed. The patients were divided into two groups: Group A (n = 30) received laminoplasty alone and Group B (n = 30) underwent laminoplasty combined with foraminoplasty. Demographic data, perioperative outcomes, clinical efficacy, and complication rates were compared between the two groups.

Results: Group A showed significantly shorter operative time and reduced intraoperative blood loss compared to Group B ($p < 0.001$). Both groups exhibited significant improvements over time in Visual Analog Scale (VAS) scores for neck and upper limb pain ($p < 0.05$) and Japanese Orthopaedic Association (JOA) scores ($p < 0.05$). At the final follow-up, Group B demonstrated superior JOA scores and lower VAS scores for both neck and upper limb pain relative to Group A ($p < 0.05$). The incidence of postoperative C5 nerve root palsy and persistent upper limb radicular pain was significantly higher in Group A than in Group B ($p < 0.05$).

Conclusion: For patients with mixed cervical spondylosis, combining unilateral open-door laminoplasty with foraminoplasty provides effective concurrent decompression of the spinal cord and nerve roots, resulting in a significant symptomatic improvement in both myelopathic and radicular manifestations with a reduced risk of certain postoperative neurological complications.

Keywords: C5 nerve root palsy, foraminoplasty, mixed cervical spondylosis, multilevel degenerative cervical myelopathy, unilateral open-door laminoplasty.

Cervical spondylosis refers to a spectrum of degenerative changes within the cervical spine, often resulting from chronic mechanical stress, osteophytic proliferation, and disc herniation.[1] Clinically, it is categorized into five main subtypes: radiculopathy, vertebral artery insufficiency, sympathetic, myelopathy, and a mixed variant. The mixed type is diagnosed when features of two or more subtypes are present, with the coexistence of radiculopathy and myelopathy being particularly frequent.[2] Consequently, treatment goals include adequate decompression of both neural roots and the spinal cord, preservation of cervical alignment, and stabilization of the spinal column.[3]

Unilateral open-door laminoplasty is widely used for multilevel cervical spondylotic myelopathy (CSM), as it reconstructs the posterior arch, enlarges the spinal canal, and helps maintain sagittal alignment.[3] However, in cases complicated

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by foraminal stenosis and nerve root compression, laminoplasty alone may not sufficiently address radicular symptoms[4] and could occasionally intensify them.[5] This phenomenon is often attributed to posterior shifting of the spinal cord after decompression, which may traction and exacerbate compression on nerve roots within already narrowed foramina.[6] Surgical options include anterior, posterior, or combined approaches. While anterior decompression alone has shown satisfactory outcomes in selected CSM cases,[7] it is associated with risks such as adjacent segment degeneration (ASD), possible reoperation, and occasionally inadequate decompression. A combined anterior-posterior strategy, though more comprehensive, involves greater surgical invasiveness.[8]

In light of these considerations, our institution has increasingly employed unilateral open-door laminoplasty supplemented with foraminoplasty for the management of mixed cervical spondylosis. In the present study, we aimed to compare surgical outcomes between those undergoing laminoplasty alone and those receiving additional foraminotomy.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Xi Chang People's Hospital, Department of Orthopaedics between January 2016 and January 2024. Patients diagnosed with mixed cervical spondylosis and treated with unilateral open-door laminoplasty were enrolled in this study. Inclusion criteria were as follows: (1) multisegmental degenerative changes affecting more than three levels, accompanied by clinical manifestations of both myelopathy and radiculopathy; (2) unilateral radicular symptoms correlated with imaging findings; (3) cervical canal stenosis resulting from ossification of the posterior longitudinal ligament, hypertrophic ligamentum flavum, or developmental narrowing; and (4) persistent symptoms despite three to six months of structured conservative management. Exclusion criteria were as follows: (1) previous cervical spine surgery or traumatic injury; (2) presence of cervical kyphosis exceeding 10° or objective cervical instability; (3) diagnoses such as spinal tuberculosis, neoplasms, or active infection; (4) incomplete clinical or follow-up records; and (5) severe cardiocerebrovascular comorbidities, contraindications to surgery, or evidence of upper motor neuron disease. Finally, a total of 60 patients (36 males, 24 females; mean age: 71.8 ± 9.9 years; range, 52 to 92 years) who met the inclusion criteria were recruited. The patients were divided into two groups as Group A (n = 30, unilateral open-door laminoplasty alone) and Group B (n = 30, laminoplasty with concomitant foraminotomy). Cervical alignment was assessed qualitatively via lateral radiographs. We performed routine radiographic evaluations pre- and postoperatively, including lateral and dynamic X-rays, to assess spinal stability and alignment. A written informed consent was obtained from each patient. The study protocol was approved by the Xi Chang People's Hospital Ethics Committee (Date: 11.01.2016, No: 2016-S-109). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical process

All procedures were conducted under general anesthesia by a consistent surgical team. Patients treated between January 2016 and January 2020 were assigned to Group A, while those treated between February 2020 and January 2024 comprised Group B. Each patient was placed in a prone position with the head stabilized in a Mayfield skull clamp. A midline posterior incision was utilized to expose the laminae and facet joints from C2 to C7. We applied the meticulous dissection technique to subperiosteally elevate the paraspinal muscles, thereby minimizing trauma and denervation in order to preserve their dynamic stabilizing function.

In Group A, the side for opening was determined according to the symptomatic upper limb; in cases with bilateral symptoms, the more severely affected side was chosen. Using either a high-speed burr with a diamond tip or an ultrasonic bone curette, gutters were fashioned at the junction of the lamina and facet joint. The hinge side was undercut to preserve the inner cortical continuity, while the opening side was fully decorticated. The ligamentum flavum was meticulously separated from the underlying dura with a neural dissector, and the lamina was elevated. Appropriately sized and contoured titanium miniplates were contoured and secured to maintain the expanded position of the opened lamina. A drain was placed before layered wound closure.

In Group B, following completion of the laminoplasty, foraminotomy was performed at levels corresponding to clinical radiculopathy and radiographic evidence of nerve root compression. The foraminotomy was performed by carefully

undercutting the medial portion of the facet joint using a 2 to 3 mm Kerrison punch to visualize and decompress the nerve root until the nerve root was visually confirmed to be free of compression and the proximal portion of the root was adequately mobilized. To minimize the risk of iatrogenic instability, over 50% of the lateral facet joint was preserved. Further decompression was achieved, when necessary, using a small punch to excise osteophytes or hypertrophic tissue ventral to the nerve root (Figure 1).

Postoperative monitoring included assessment of vital signs and neurological symptoms. All patients wore a cervical collar (semi-rigid Philadelphia collar) for exactly four weeks after surgery. Patients were encouraged to perform light activities of daily living, yet were advised to avoid heavy lifting, forced neck flexion, and high-impact movements during the collar period. The structured rehabilitation protocol initiated after collar removal, including a supervised physical therapy program focusing on active range of motion exercises, isometric strengthening of the neck and parascapular muscles, and postural training. Minimum follow-up duration was 12 months for both cohorts.

Evaluation index

1. *Intra- and perioperative parameters:*

Incision length, surgical time, intraoperative blood loss, and perioperative complications were recorded.

2. *Clinical Outcomes Assessment:*

Neck and upper limb pain were evaluated using the Visual Analog Scale (VAS).

Neurological function was assessed using the Japanese Orthopaedic Association (JOA) score.

3. *Diagnostic criteria for C5 nerve root palsy:*[9]

New-onset postoperative weakness of the deltoid and/or biceps brachii (manual muscle testing [MMT] Grade < 3) without worsening of myelopathic symptoms following cervical decompression surgery.

Statistical analysis

Statistical analysis was performed using the SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were

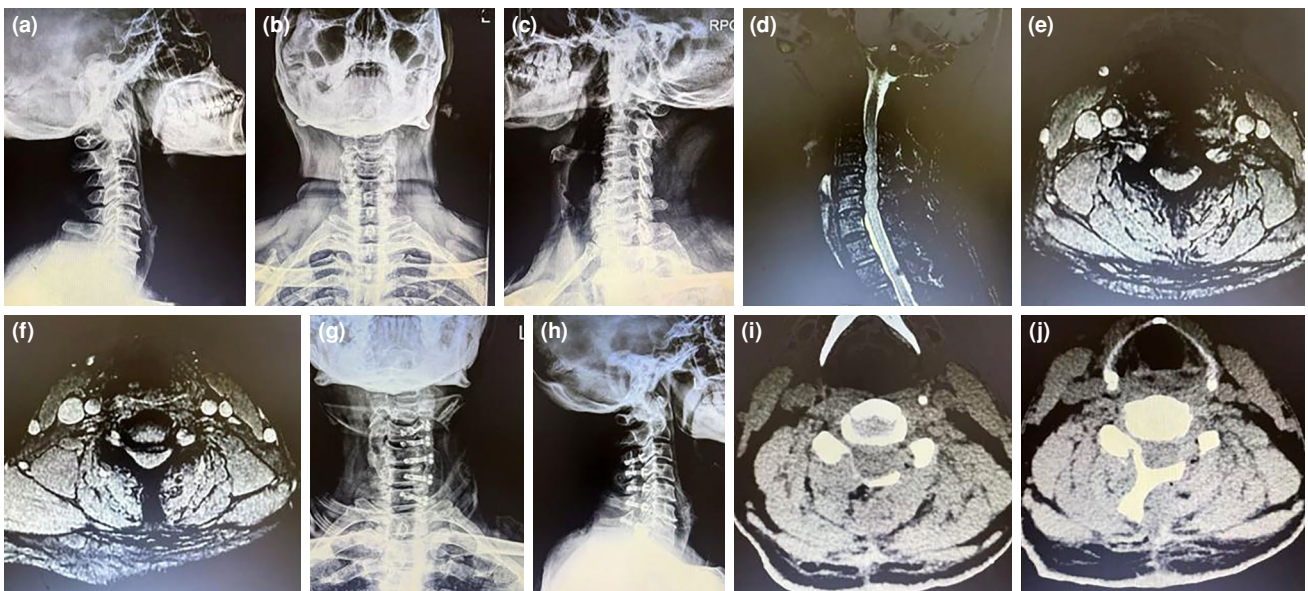


FIGURE 1. A 49-year-old male patient with CSM combined with radiculopathy underwent unilateral open-door laminoplasty combined with foraminoplasty. **(a, b)** Preoperative anteroposterior and lateral cervical X-rays showed no significant cervical instability or kyphotic deformity; **(c)** Oblique view revealed left foraminal stenosis at C5/6 and C6/7; **(d)** Preoperative sagittal MRI demonstrated spinal canal stenosis and spinal cord compression at C3-7; **(e, f)** Preoperative axial MRI indicated mild left foraminal narrowing at C4/5 and C5/6; **(g, h)** Postoperative X-rays confirmed well-maintained cervical curvature; **(i, j)** Postoperative CT scans showed sufficient left foraminal expansion at C4/5 and C5/6, with adequate spinal canal decompression and no compression of the spinal cord or nerve roots at the corresponding levels.
CSM, cervical spondylotic myelopathy; MRI, magnetic resonance imaging; CT, computed tomography.

expressed in number and frequency. Intragroup comparisons across different time points were analyzed using one-way analysis of variance (ANOVA). Intergroup comparisons were conducted with independent samples t-tests. Categorical data were compared using the chi-square tests. A p value of < 0.05 was considered statistically significant.

RESULTS

The most frequently involved segments were C3-C7, affecting four levels. No significant differences were observed between the groups regarding age, sex, body weight, height, body mass index (BMI), disease duration, or number of affected segments ($p > 0.05$) (Table I).

Perioperative outcomes revealed that Group B had a significantly longer mean operative time (168.6 ± 13.2 min) compared to Group A (132.3 ± 23.8 min, $p < 0.001$). Intraoperative blood loss was also greater in Group B (340.5 ± 69.2 mL) than in Group A (251.2 ± 31.3 mL, $p < 0.001$). Incision length did not differ significantly between the two groups ($p > 0.05$) (Table II).

TABLE I
Baseline characteristics of patients

	Group A		Group B			
Variables	n	Mean ± SD	n	Mean ± SD	χ^2/t	p
Age (year)		70.6 ± 10.6		72.9 ± 9.2	–0.924	0.359
Sex						
Male	16		20			
Female	14		10			
Height (m)		1.66 ± 0.05		1.66 ± 0.06	–0.392	0.696
Weight (kg)		63.1 ± 7.9		63.7 ± 8.4	–0.284	0.777
Body mass index (kg/m^2)		22.9 ± 2.4		23.0 ± 2.7	–0.134	0.894
Smoking						
Yes	23		20			
No	7		10			
Segment						
C3-7	16		13			
C3-6	9		12			
C4-7	5		5			
Course of disease (year)		3.9 ± 1.1		4.0 ± 1.2	–0.112	0.911
Total	30		30			

SD, standard deviation.

TABLE II
Comparison of perioperative results between the two groups

	Group A		Group B			
Variables	n	Mean ± SD	n	Mean ± SD	χ^2/t	p
ASA classification					0.863	0.650
I	6		4			
II	9		12			
III	15		14			
Surgical time (min)		132.3 ± 23.8		168.6 ± 13.2	–7.304	< 0.001
Incision length (cm)		13.6 ± 1.2		13.7 ± 1.1	–0.339	0.735
Intraoperative blood loss (mL)		251.2 ± 31.3		340.5 ± 69.2	–6.444	< 0.001
Total	30		30			

SD, standard deviation; ASA, American society of Anesthesiologists.

TABLE III
Comparison of VAS and JOA between the two groups

Variables	Group A Mean ± SD	Group B Mean ± SD	*t*	*p*
Time point				
Preoperative	9.0 ± 0.9	8.8 ± 1.0	0.800	0.427
Last time	13.9 ± 0.7	15.2 ± 1.1	–5.138	< 0.001
p	<0.001	<0.001		
Neck and upper limb pain (VAS)				
Preoperative	4.9 ± 1.0	5.0 ± 0.9	–0.263	0.793
Last time	1.9 ± 0.9	1.3 ± 0.8	0.283	0.006
p	< 0.001	0.006		

VAS, Visual Analog Scale; JOA, Japanese Orthopaedic Association; SD, standard deviation.

TABLE IV
Comparison of perioperative complications between the two groups

Complication	Group A n	Group A %	Group B n	Group B %	*t*	*p*
Infection of incision	1	3.3	2	6.7	0.351	0.554
Axial pain	3	10.0	2	6.7	–0.943	0.347
C5 nerve root palsy	5	16.7	0	0	5.455	0.020
Radiating pain in the upper limb	4	13.3	0	0	4.286	0.038
Cerebrospinal fluid leakage	1	3.3	2	6.7	0.351	0.554

All patients completed a minimum follow-up of 12 months. At the final assessment, both groups exhibited significant improvements from baseline in VAS scores for neck and upper limb pain and JOA scores ($p < 0.05$ for all). Although preoperative scores were comparable between the groups ($p > 0.05$), Group B demonstrated superior JOA scores and lower VAS scores at final follow-up compared to Group A ($p < 0.05$) (Table III).

Complication profiles differed between the groups. C5 nerve root palsy was the most common complication in Group A; all affected patients showed partial to complete recovery following treatment with anti-inflammatory medications, neurotrophic agents, and physiotherapy. In contrast, no instances of C5 palsy or persistent upper limb radicular pain occurred in Group B, representing a significantly lower incidence than in Group A ($p < 0.05$). Superficial surgical site infections occurred in one patient in Group A and two in Group B, all resolving with extended antibiotic use and wound care. Additionally, two cases of incidental dural tear with cerebrospinal fluid leakage occurred in Group B during foraminotomy; both were managed successfully through delayed drain removal and prophylactic ceftriaxone, without further sequelae (Table IV).

DISCUSSION

For patients presenting with multilevel CSM involving more than three segments, unilateral open-door laminoplasty is widely regarded as a standard surgical intervention.[10,11] However, in cases where radiculopathy coexists with imaging-confirmed foraminal stenosis, laminoplasty alone is often insufficient to achieve adequate nerve root decompression. Some patients may even experience aggravated radicular symptoms after surgery, a phenomenon often attributed to nerve root tethering secondary to posterior shifting of the spinal cord following canal expansion.[6] This complication is further explained by the fixed anatomical constraints of the bony foramen: nerve roots, which arise with relatively large diameters from the cord, must pass through narrow and funnel-shaped intervertebral foramina, creating inherent susceptibility to entrapment.[12] Consequently, in patients with clinical and radiographic evidence of nerve root

compression, supplemental foraminoplasty performed concurrently with laminoplasty should be considered.

Previous studies, including the work by Lee et al.,[13] reported that the combination of laminoplasty and posterior foraminotomy resulted in more effective relief of arm pain compared to laminoplasty alone, without compromising spinal alignment or stability.[13] Consistent with these findings, an internal review conducted at our institution in 2020 indicated suboptimal outcomes in upper limb radiculopathy when laminoplasty was performed alone, leading us to adopt adjunctive foraminotomy in selected cases. The present analysis further supports this approach: although Group B (laminoplasty with foraminotomy) was associated with longer operative duration and greater blood loss, it exhibited significantly more favorable functional recovery, as evidenced by JOA scores, and greater reduction in neck and arm pain on the VAS compared to Group A (laminoplasty alone). These improvements can be attributed to direct decompression of the nerve roots through foraminal enlargement, underscoring the value of combined procedures in alleviating radicular symptoms.

Notably, no instances of C5 palsy were observed in Group B within our series, although this complication remains a potential risk. Komagata et al.[14] reported a 0.6% incidence of C5 palsy following laminoplasty combined with bilateral foraminotomy at C4-C6. The etiology of C5 palsy remains multifactorial and may involve intraoperative traction, thermal injury from drilling, incomplete decompression, or reperfusion injury.[15-17] In our cohort, the incidence of C5 palsy was significantly higher in Group A than in Group B. Among those affected, four cases occurred on the open-door side, possibly due to greater spinal cord drift on that side[18] in the context of preexisting C4-5 foraminal stenosis.[19] Therefore, patients presenting with preoperative radicular symptoms, neurological deficits such as diminished reflexes or muscle weakness, and corresponding imaging evidence of stenosis should be considered high-risk for C5 palsy, and may benefit from prophylactic foraminotomy. In asymptomatic patients without radiographic evidence of neural compression, however, additional foraminotomy may be unnecessary.

The potential risk of iatrogenic instability or segmental kyphosis is one of the primary concerns regarding laminoplasty with foraminotomy. Current evidence suggests that preserving over 50% of the facet joint during foraminotomy sufficiently maintains stability while achieving neural decompression.[13,20] Accordingly, we recommend careful undercutting and enlargement of the foramen using a laminectomy punch, with continual assessment of facet integrity throughout the procedure.

Nonetheless, several limitations should be acknowledged in this study. First, its single-center, retrospective design with a relatively short follow-up period may limit the generalizability of our findings. Second, the modest sample size increases the risk of statistical bias, particularly in the evaluation of complication rates. Third, the lack of quantitative analysis of cervical sagittal parameters, such as C2-C7 Cobb angle, cervical sagittal vertical axis, and T1 slope, represents another limitation. Although lateral radiographs were routinely obtained and patients with evident kyphosis were excluded, future studies incorporating these measurements would provide deeper insight into postoperative alignment changes and their correlation with clinical outcomes. Future multi-center, large-scale, prospective studies involving quantitative sagittal measurements are needed to confirm these outcomes and better establish clinical guidelines.

In conclusion, the combined procedure of unilateral open-door laminoplasty combined with foraminoplasty offers a comprehensive surgical solution for multilevel mixed cervical spondylosis, effectively addressing concurrent spinal cord compression and nerve root entrapment, with the added benefit of decreased C5 palsy rates.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Y.A.R., Y.X.P.: Conception and design; Y.Y., R.H.T., Y.L.K.: Collection and assembly of data; Y.A.R., Y.X.P., C.J.D.: Analysis and interpretation of the data; Y.A.R., Y.X.P.: Drafting of the article; C.J.D.: Statistical expertise; Y.A.R.: Critical revision of the article for important intellectual content. All authors read and approved the final manuscript.

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the sole responsibility of the authors. The authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

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