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Original Article

Laminoplasty with adjunct anterior short segment fusion for multilevel cervical myelopathy associated with local kyphosis

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Abstract

Background: When treating patients who have multilevel cervical spondylotic myelopathy (MCSM) with short-segment kyphosis, instability, or major anterior foci, long-level anterior decompression with fusion is often a standard method but can cause obvious loss of range of motion and usually needs further posterior stabilization. For MCSM with correctable kyphosis or simple instability, laminectomy with lateral-mass instrumented fusion is also a treatment of choice, but all the involved segments are immobilized. Combining expansive open-door laminoplasty (EOLP) and anterior short-segment fusion may be an alternative treatment to save more motion segments.
Methods: This study included 109 patients who exhibited MCSM with combined local kyphosis, instability, and anterior pathology, and received EOLP and concomitant anterior short-segment fusion. The patients were enrolled from August 2005 to July 2012. Nurick scores and Japanese Orthopedics Association cervical myelopathy scores were used to evaluate the functional outcomes. Follow-up plain films were collected and magnetic resonance imaging was conducted to assess the radiographic outcomes.
Results: One year after the operation, the Japanese Orthopedics Association recovery rate was 83.4 ± 16.6%. The improvement in the functional scores and decrease in neck pain were significant. The canal width improved without further collapse at 12 months. The preservation of range of motion was approximately 57% at 1 year.
Conclusion: EOLP with adjunct anterior short-segment decompression fusion yields an excellent outcome for MCSM patients who exhibit concomitant short-segment kyphosis, instability or major anterior pathology. Performing laminoplasty first is safer for the spinal cord due to its posterior shifting while anterior procedures are being done.

Keywords: anterior cervical decompression fusion; expansive open-door laminoplasty; major anterior pathology; multilevel cervical spondylotic myelopathy

1. Introduction

Surgical treatment of multilevel cervical spondylotic myelopathy (MCSM) appeared to yield superior early results in comparison to conservative treatment for pain relief, weakness, and sensory deficits.[1] Laminoplasty was proven effective at treating MCSM as a relative motion-preservation procedure.[2] This procedure requires at least 10° of lordosis to allow a posterior shift of the spinal cord.[3] Expansive open-

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door laminoplasty (EOLP) can cause preexisting kyphosis to progress, as well as segmental instability, both of which are contraindications of this procedure and are not uncommon conditions in MCSM.[4] A laminectomy combined with posterior instrumented fusion may resolve this problem; however, additional complications, such as limited range of motion (ROM), hardware failure, pseudarthrosis, and adjacent segment degeneration (ASD) were reported following fusion surgery.[5]

Anterior cervical decompression fusion (ACF), including anterior cervical discectomy fusion (ACDF) and anterior cervical corpectomy fusion (ACCF), is typically favored for directly removing anterior pathology and correcting kyphosis. The most common complications of long-level ACF include pseudarthrosis, ASD, and the collapse of fused segments. According to a survivorship analysis, 25% of patients developed ASD within 10 years after ACF.[6] The overall pseudarthrosis rate of ACDF was 10% and increased as the level fused increased.[7]

When MCSM occurs concurrently with short level local kyphotic deformity, instability and major anterior foci, long-level anterior decompression with fusion may be enough to solve the problem, but it sacrifices most motion segments and often requires additional posterior stabilization for stable fusion environment. For those cases of MCSM with correctable kyphosis or simple instability, laminectomy with lateral mass instrumented fusion is also indicated, but all the involved segments are immobilized. In this study, we evaluated a new method of EOLP with adjunct short-segment ACF as a reasonable procedure for adequate decompression, effective local foci removal, and preserving motion for this condition.

2. Methods

2.1. Preoperative evaluation and patient data

The authorization of a Buddhist Tzu Chi General Hospital Research Ethics Committee was obtained for this retrospective study (IRB101-100). There were 109 patients (59 men, 50 women) who underwent combined EOLP and adjunct short-segment ACDF from August 2005 to July 2012 were included. The inclusion criteria were: (1) C3–7 spinal stenosis with spinal cord compression; (2) diagnosis as CSM based on the symptoms and the results of physical examination by orthopedic doctors; and (3) combination of one- or two- level kyphosis, instability or major anterior pathology. Japanese Orthopedic Association (JOA) scores, Nurick scores, and visual analog scale (VAS) scores were used to assess preoperative neurological function and axial neck pain. All patients underwent anteroposterior, neutral lateral, and dynamic radiography and magnetic resonance imaging (MRI) before surgery. The preoperative cervical curvature was evaluated by measuring the angle between the lower endplate of C2 and the upper endplate of C7 at a neutral lateral view. The ROM was determined based on the difference of the angles between the lower endplate of C2 and upper endplate of C7, measuring using dynamic views. Table 1 shows the characteristics of the patients.

Table 1
Demographic and preoperative data ($n = 109$).

Item	Mean ± SD
Age	54.6 ± 10.2
Sex	
Male	59 (54.1)
Female	50 (45.9)
Myelomalacia	
No	65 (59.6)
Yes	44 (40.4)
Symptom duration time (mo)	15.2 ± 14.2
Nurick score	2.7 ± 0.9
Neck pain VAS	5.4 ± 1.1
JOA Score	10.9 ± 2.6
Cervical curvature (°)	7.7 ± 7.5
Pavlov ratio	0.66 ± 0.06
ROM (°)	23.8 ± 12.0

Data are presented as n (%) or mean ± SD.
JOA = Japanese Orthopedic Association; ROM = range of motion; SD = standard deviation; VAS = visual analog scale.

2.2. Surgical technique

Patients were placed in the prone position, and 5 kg of skull traction was applied using Gardner–Wells tongs. EOLP was performed according to the methods of Hirabayashi et al[8] and O'Brien et al[9] after certain modifications. After bony gutters were created over both the hinge and open sides, the C3–7 laminae were elevated and secured with five pieces of prebent titanium miniplates (AO; Synthes, West Chester, PA, USA) to finish the EOLP procedure.[2] After posterior wound closure, patients were placed in the supine position with the head slightly extended. A Southwick–Robinson anterior cervical approach was used to expose the affected vertebral bodies and discs.[10] Protruded discs and osteophytes were removed using diskectomy. Subsequent interbody fusion was performed using artificial cages, autogenous tricorticate iliac bone grafts, or allogenous strut bone grafts, which were fixed using a titanium locking plate-and-screw system (Zephir; Medtronic, Humacao, Puerto Rico, USA).

2.3. Postoperative evaluation and follow-up

After surgery, it was recommended that patients wear rigid neck collars (VISTA; Aspen Medical Products, Irvine, CA, USA) for 3 months, and do adequate neck extension exercises under appropriate protection. VAS was used to assess the severity of axial pain at 2 weeks and 3 months postoperatively. JOA and Nurick scores were used to assess neurological function. The JOA recovery rate (RR) was calculated using JOA score data that evaluated improvement.[11] The formula was as follows:

$$(\text{postoperative score} - \text{preoperative score}) \times 100/[17(\text{full score}) - \text{preoperative score}].$$

During the postoperative follow-up, cervical spine radiographs (anteroposterior, neutral lateral, and dynamic views) were taken at 3 months, 6 months, 9 months, and 12 months postoperatively to observe changes in the cervical curvature and ROM. A computed tomography scan was conducted at 6 months to assess bone fusion, and MRI examination was performed at 12 months to confirm the enlargement of the spinal canal and decompression effects on the spinal cord. All cases were followed up for at least 12 months.

2.4. Statistical analysis

The SPSS software package, version 13.0 (SPSS Inc., Chicago, IL, USA), was used for statistical analysis. To assess statistical significance, an unpaired Student *t* test was used for comparison of preoperative and postoperative data. The level of statistical significance was set as $p < 0.05$. Age > 65 years, sex, and preoperative data such as existence of myelomalacia, Nurick score, VAS, Pavlov ratio, and ROM were set as independent variables of JOA recovery rate. To determine the independent variable with the greatest contribution, the stepwise methods of generalized linear modeling were applied. The final selection of the independent variables was determined according to the adjusted R^2 value. Then a statistical analysis was done on each standard regression coefficient of these independent variables. Those with significance as $p < 0.05$ were finally selected as the factors influencing the surgical results. The value of the standard regression coefficient for each factor was considered to be the magnitude of the impact.

3. Results

3.1. Demographic and preoperative data

All of the patients received C3−7 laminoplasty at five levels. Anterior decompression was performed on one motion segment in 65 cases and on two motion segments in 44 cases. Among the 153 ACDF levels, allogenous strut bone grafts were used for 45 levels, autogenous tricorticate iliac bone grafts for 38 levels, and polyetheretherketone cages for the other 70 levels. The mean operation time was 4.2 ± 1.3 hours. The mean blood loss was 225.3 ± 21.4 mL. The mean length of hospital stay was 6.5 ± 1.5 days.

The mean patient age was 54.6 ± 10.2 years, and the mean duration of symptoms was 15.2 ± 14.2 months. Of the 59 men and 50 women, 44 had myelomalacia change at preoperative MRI. The average preoperative Nurick, JOA, and neck pain VAS scores were 2.7 ± 0.9, 10.9 ± 2.6, and 5.4 ± 1.1, respectively. The preoperative mean cervical curvature was 7.7 ± 7.5° lordosis, Pavlov ratio at C5 was 0.66 ± 0.06, and neck ROM was 23.8 ± 12.0° (Table 1).

3.2. Clinical outcomes

The average JOA scores improved from 10.9 ± 2.6 to 15.8 ± 1.2 (Table 2). The RR was 83.4 ± 16.6%. The average Nurick score, which represented the disability grade, decreased from 2.71 ± 0.90 to 0.32 ± 0.62. The level of functional recovery was significant ($p < 0.05$). Furthermore, neck pain VAS scores significantly improved at 2 weeks and 3 months postoperatively. No patients exhibited aggravated neck pain or C5 nerve palsy. Five patients exhibited temporary swallowing difficulties, but recovered within 1 month. Three patients exhibited temporary dysphonia, but recovered within 2 weeks.

Table 2
Preoperative (Preop) and postoperative (Postop) function status and its correlation to recovery rate ($n = 109$).

Items	Preop	Postop	Postop − Preop	Postop − Preop	
				t	*p*
Nurick score	2.7 ± 0.9	0.3 ± 0.6	−2.4 ± 0.7	−21.73	< 0.001
VAS (2 wk)	5.4 ± 1.1	3.9 ± 0.5	−1.5 ± 1.3	−7.29	< 0.001
VAS (3 mo)	—	0.8 ± 1.1	−4.6 ± 1.6	−17.90	< 0.001
JOA score	10.9 ± 2.6	15.8 ± 1.2	4.9 ± 2.2	13.96	< 0.001
Recovery rate	—	0.83 ± 0.16	—	—	—

Data are presented as mean ± SD.
JOA = Japanese Orthopedic Association; VAS = visual analog scale.

3.3. Radiographic outcomes

The average Pavlov ratio, which represented the canal width, improved from 0.66 ± 0.05 preoperatively to 1.14 ± 0.10 postoperatively, without a loosening of implants, the closure of laminae, collapse or pseudarthrosis of the hinge and anterior fusion sites at 12 months postoperatively (Table 3). Cervical curvature improved from 7.7 ± 7.6 lordosis to 16.1 ± 6.8 lordosis. ROM decreased from 23.8 ± 12.0° to 13.6 ± 6.9°. The preservation of ROM was about 57% at postoperative 1 year.

3.4. Regression analysis

JOA recovery rate was set as the dependent variable. Age ≤ 65 years, male sex, existence of myelomalacia, preoperative functional scores, and neck ROM were set as independent variables (Table 4). Preoperative Nurick score seemed to be the only significant risk factor correlated with the functional recovery rate at 2 years after the surgery.

Table 3
Preoperative (Preop) and postoperative (Postop) radiographic status and its correlation to recovery rate ($n = 109$).

Time	Cervical curvature	Pavlov ratio	Range of motion
Preop	7.7 ± 7.5	0.66 ± 0.05	23.8 ± 12.0
Postop 1 d	—	1.14 ± 0.10	—
Postop 3 mo	12.4 ± 5.6	—	15.2 ± 6.6
Postop 12 mo	16.1 ± 6.8	1.13 ± 0.10	13.6 ± 6.9
Postop 1d − preop[a]	—	−0.231/0.16	—
Postop 3 mo − preop[a]	0.054/0.75	—	−0.057/0.735
Postop 12 mo − preop[a]	−0.225/0.17	−0.159/0.34	0.060/0.720

Data are presented as *n* (%) or mean ± SD.
[a] r value/*p* value.

Table 4
Factors associated with the Japanese Orthopedic Association (JOA) recovery rate ($n = 109$).[a]

	Regression coefficient	95% CI	p
Intercept	1.197	0.765, 1.629	< 0.001*
Age (y)			
≤ 65	−0.001	−0.102, −0.100	0.981
> 65	References	References	NA
Sex			
Male	−0.007	−0.078, 0.063	0.833
Female	References	References	NA
Myelomalacia			
No	−0.019	−0.092, 0.054	0.602
Yes	References	References	NA
Preop Nurick score	−0.054	−0.103, −0.006	0.029*
Preop VAS	0.021	−0.016, 0.058	0.255
Preop Pavlov's ratio	−0.427	−1.013, 0.160	0.152
Preop range of motion	−0.001	−0.004, 0.002	0.351

*Considered statistically significant after test at $p < 0.05$.
[a] Dependent variable: JOA recovery rate.

3.5. Case presentation

A 69-year-old farmer presented with bilateral hand clumsiness, numbness in four limbs, and an impaired tandem gait, yielding a preoperative JOA score of 10 and Nurick score of 3. The neck pain VAS score was 4. Plain film revealed C5-6 local kyphosis (9° kyphosis) with spondylolisthesis (Fig. 1A). The preoperative ROM was 20°. A sagittal MRI view showed that C3–7 stenosis and obvious anterior pathology over C5-6 was causing severe compression to the spinal cord (Fig. 1B–F). C3–7 ACDF or ACCF could also be indicated for the patients' situation, but three motion segments would have been sacrificed. So we performed laminoplasty on C3–7 with adjunct C5–6 ACDF. The neck pain VAS score was 1 at 3 months. The postoperative JOA score was 17, and the Nurick score was 0 at 12 months. The JOA recovery rate was 100%. The cervical curvature exhibited 5° lordosis and a 12° ROM (Fig. 1G). Sixty percent ROM was preserved. Postoperative MRI at 1 year revealed a patent spinal cord without compression (Fig. 1H).

4. Discussion

In this study, we performed laminoplasty with adjunct short-segment ACDF to treat MCSM combined with one- or two- level kyphosis, instability or anterior major pathology and yielded moderate to excellent functional recovery with lower complication rates. Cervical ROM was preserved close to 60% at 1 year postoperatively. Most of the patients were discharged from the hospital smoothly in 1 week. Although either laminoplasty or ACF can solve most cases of cervical myelopathy, a single procedure is sometimes insufficient to yield effective decompression without causing further complications. The decompression effects of expansive open-door laminoplasty include both directly removing posterior compression elements (e.g., hypertrophied ligamentum flavum) and allowing posterior shift of the spinal cord away from anterior compression elements. However, inadequate indirect decompression after laminoplasty is associated with the risk of poor clinical outcome. Without removing the anterior pathology, or correcting kyphosis or instability, residual foci can cause consequent complications despite previous laminoplasty.[12] Adjunct anterior short-segment decompression fusion was expected to solve this difficult condition, facilitating the posterior cord decompression effect caused by laminoplasty and improving the results when treating MCSM.

Multilevel cervical stenosis can be effectively treated with long-level anterior cervical decompression and fusion. Anterior procedures can directly remove anterior pathology, correct kyphosis, and stabilize unstable segments. However, in multilevel cervical stenosis myelopathy, multisegmental ACDF or ACCF yield increased complication rates, including dysphonia, dysphagia, construction failure, adjacent segment disease, and fusion rates lower than anterior fusion of three or less motion segments.[13] According to the previous reports, the rate of graft/plate construct dislodgement of two-level corpectomy and fusion is 9%, and that of three-level corpectomy and fusion can reach 50%.[14] Additional posterior instrumentation may need to be considered to increase the construct stability and decrease the complication rate of long-segment anterior fusion. Long-level fusion through anterior or posterior methods appears to decrease ROM due to sacrificing all the motion segments that are related to the spinal stenosis. Laminoplasty has been proved to preserve more ROM than laminectomy with fusion or long-segment anterior fusion.[2,15] Based on the above points, combining posterior decompression with laminoplasty and anterior short segment decompression fusion is expected to preserve more motion segments and decrease the complication rates of long segment fusion surgery for MCSM associated with short-segment kyphosis, instability, or major anterior pathology.

Laminectomy with instrumented fusion for the management of MCSM has been proved to be a successful strategy for recovering neurological function and restoring the normal cervical lordotic alignment, and decreasing the morbidity of axial pain and C5 palsy.[16] For those patients with MCSM combined with correctable kyphosis and simple instability, it must be a more suitable method than laminoplasty only but causes neck stiffness by immobilization of all the related segments.[2] For those with local kyphosis, instability or major anterior pathology, anterior procedures may be unavoidable. In this study, laminoplasty with short-segment anterior fusion seemed to solve both long-level stenosis and short-segment foci at the same time to reach good outcomes for neurologic recovery and motion preservation.

Baba et al[17] reported that additional laminoplasty followed by anterior cervical fusion for multilevel spinal stenosis yielded favorable neurological recovery outcomes, prevented structural compromises from occurring adjacent to the fused vertebrae, and avoided the risk of myelopathy recurrence because of the narrow spinal canal. The incidence of dural penetration during anterior decompression fusion was reported

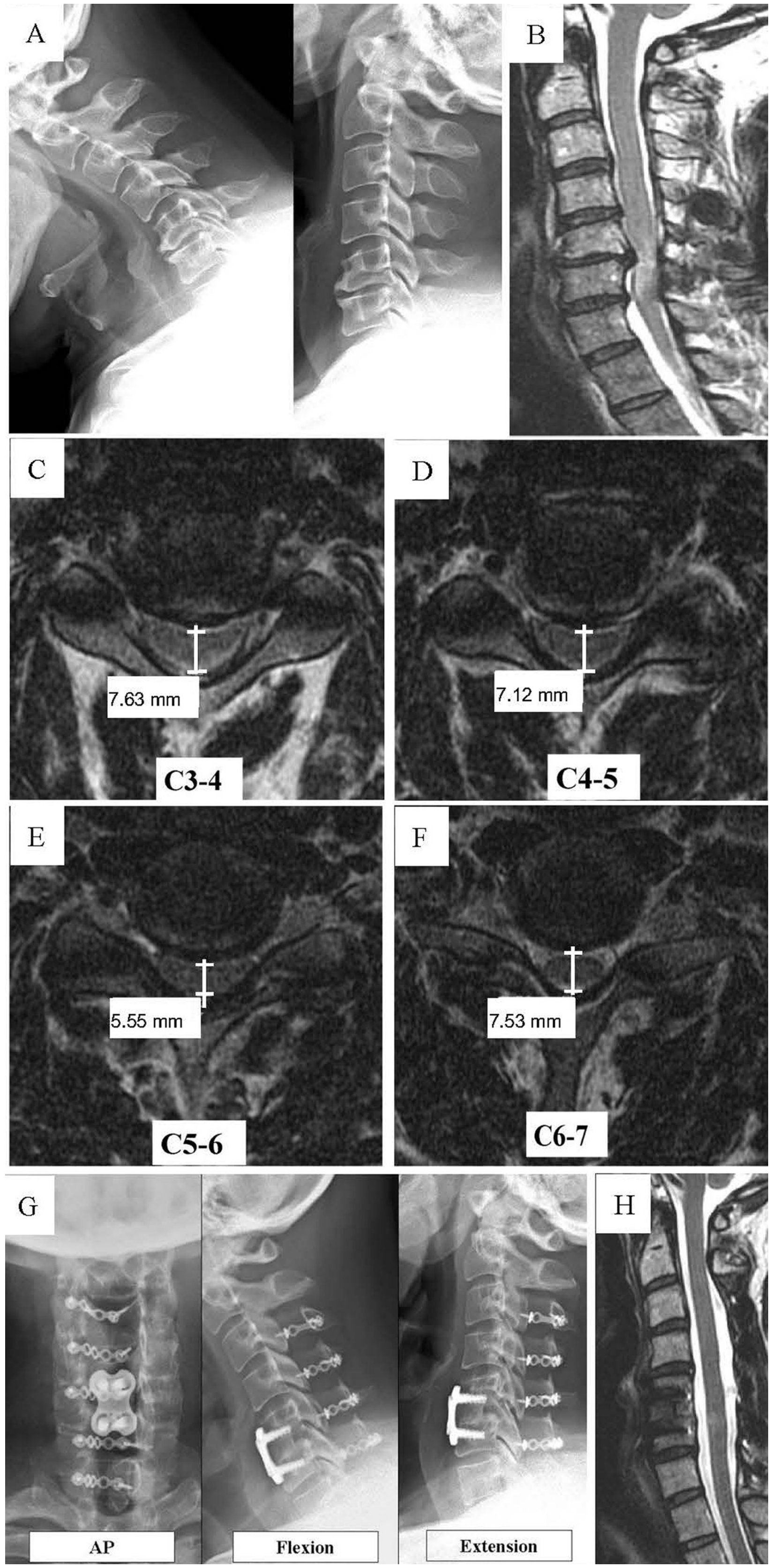

Fig. 1. (A) Preoperative radiograph in this case shows C3–4 local kyphosis with spondylolisthesis and (B) T2-weighted magnetic resonance imaging reveals C3–7 stenosis, exhibiting a large C3/4 anterior lesion compression to the spinal cord. Axial cuts of (C) C3/4, (D) C4/5, (E) C5/6, and (F) C6/7, shows the banana shape of the compressed spinal cord, especially C5/6. (G) Postoperative radiograph at 1 month demonstrates improved cervical curvature, and dynamic X-ray at 12 months shows no further collapse and preservation of neck range of motion. (H) Postoperative magnetic resonance imaging reveals patent spinal cord without compression.

as almost 2%, but that value could be larger in cases of severe stenosis.[18] Thus, we leveraged EOLP to shift the spinal cord posteriorly away from the anterior part, facilitating a safe and smooth ACF procedure. No cases of dural penetration occurred in our series. Compared with two-stage procedures, one-stage EOLP and ACF involves more time to change positions, doubles the stress on the soft tissue of the neck, and causes greater blood loss; thus, for patient safety, we arranged overnight intensive care unit admission for patients. The disadvantages of two-stage spinal surgery include two sessions of anesthesia, a prolonged admission course, increased nursing loading, and a poorer quality of life in the period between operations. In our series, the mean operative times, blood loss amounts, and RRs were comparable to the combined results of ACF and EOLP in previous studies.[15]

The cost and risk are indeed important to be considered and discussed with patients and their families preoperatively. The common choices for the patients enrolled in this study who suffered from MCSM associated with local kyphosis were long-segment fusion with decompression via anterior, posterior, or combined approaches. The cost of long-segment fusion is higher because it requires expensive medical instruments, such as lateral mass screws, body cages, long anterior plates, etc. By contrast, our new operation method only needs five pieces of titanium miniplate and short anterior fusion devices. It is cheaper than the cost of long fusion methods. Also, long fusion methods have higher rates of complication than ours. For example, anterior long decompression and fusion surgery (> 3 levels) may increase morbidity of swallowing difficulty, dysphonia, and swelling, and often need further posterior stabilization to achieve good union. By contrast, our method combines the advantages of laminoplasty as decompression with motion preservation and short anterior segment fusion to remove the major anterior foci without sacrificing other motion segments. The mean length of hospital stay is about 1 week. Based on the above-mentioned points, the cost and risk of this method is not higher than that for long-segment one-approach surgery. The major benefit of this new method is motion preservation.

In conclusion, combining EOLP with adjunct short-segment ACF appears to decompress the spinal cord effectively, removing the anterior pathology and resolving instability or kyphosis. Performing laminoplasty first is also a safer consideration for the spinal cord, due to its posterior shifting while doing anterior procedures. This also extends the indications for laminoplasty to preserve additional motion segments. Thus, this procedure, in spite of minimal morbidity, demonstrates superior outcomes for treating MCSM with short-segment anterior foci. Regarding study limitations, the results were limited by the fact that this was a retrospective study, and by the short-term nature of the follow-up study. Further large-scale prospective investigations with long-term follow-up periods are warranted.

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