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Preoperative Factors Affecting Postoperative Axial Symptoms After Single-Door Cervical Laminoplasty for Cervical Spondylotic Myelopathy: A Prospective Comparative Study

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: Postoperative axial symptoms (post-AS) after single-door cervical laminoplasty for cervical spondylotic myelopathy (CSM) are a common and severe complication that adversely affects normal daily activities. Their etiology remains unclear. It is important to know which preoperative factors are the most predictive of post-AS. Therefore, this study aimed to elucidate the preoperative factors affecting post-AS.

Material/Methods: A total of 102 patients with CSM who underwent single-door cervical laminoplasty between 2009 and 2015 were studied. According to operation date, patients were prospectively assigned to treatment with conventional laminoplasty (CL) or modified laminoplasty (ML). Preoperative clinical and radiological parameters were recorded. The incidence of post-AS with 2 procedures was compared prospectively. Multivariate analysis was used to determine the preoperative factors affecting post-AS.

Results: The incidence of post-AS after ML was significantly lower than after CL (P=0.010). ML and preoperative cervical C2–7 Cobb angle (CCA) were significant protective factors against post-AS (ML: P=0.011, odds ratio=0.302; CCA: P=0.042, odds ratio=0.947). Patients with post-AS had a lower preoperative CCA than patients without post-AS (P=0.043). The other preoperative factors were not significantly associated with post-AS.

Conclusions: The results of this study suggest that choosing ML procedure or selecting patients with high preoperative CCA can reduce the incidence of post-AS after single-door cervical laminoplasty for CSM, and that the other preoperative clinical or radiological parameters are less critical.

MeSH Keywords: **Neck Pain • Prospective Studies • Single-Door Cervical Laminoplasty**

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Background

CSM is one of the most frequently encountered disorders of the neurological system in the elderly population. Conventional single-door cervical laminoplasty (CL), designed by Hirabayashi [1] in 1977, has been widely used for treating CSM. In the CL method, the laminae are left open by stay sutures placed between the laminae and facet joint capsules at the same level. CL is simple and results in favorable outcomes [2,3]. However, it has been modified because of complications such as postoperative axial symptoms (post-AS) [4,5], laminar reclosure [6], reduced range of neck motion [7], and C5 palsy [8]. Titanium miniplate fixation is a modified laminoplasty (ML) that provides immediate and rigid fixation with satisfactory clinical outcomes [9]. Yeh et a.l [10] also demonstrated that laminoplasty using titanium miniplates is a safe and effective surgical alternative to CSM. However, post-AS after ML is still a common and severe complication [11].

Inn 1996, Hosono et al. first reported neck and shoulder pain after laminoplasty, referred to as "axial symptoms", which were more frequent after cervical laminoplasty compared with corpectomy [12]. The overall incidence of post-AS after the single-door cervical laminoplasty ranges from 29% [4] to 73.3% [5]. Although post-AS are not fatal, they are often severe enough to disturb normal daily activity and to become the chief postoperative complaint [12–14]. Reducing this complication by means of preoperative factors is very beneficial to surgeons and patients, so it is important to know which preoperative factors are the most predictive of the incidence of post-AS.

The etiology of post-AS remains unclear, and few researchers have attempted to characterize the relationship between post-AS and risk factors [11,13,15]. However, these studies were only indirect and retrospective, or used univariate analysis. A retrospective report including only the ML group showed that some factors, such as cervical range of motion and facet joints destroyed, might be associated with post-AS [15]. The major study limitation of this retrospective report was the lack of a control group, so it could not determine which surgical procedure was superior in reducing the incidence of post-AS. A prospective, comparative, multivariate analysis is needed to determine the most predictive preoperative factors for post-AS. The purpose of the present study was to elucidate the preoperative factors (risk or protective) that influence post-AS after single-door cervical laminoplasty for CSM alone, by prospectively comparing the surgical procedures of CL and ML and using multivariate analysis.

Material and Methods

The study was approved by the Ethics Committee of Liaocheng People's Hospital (Shandong, China) (Approval ID: 2009009). All subjects provided written informed consent and the research was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Population

Patients with CSM who underwent the single-door cervical laminoplasty between 2009 and 2015 at our institution were studied prospectively. From March 2009 to July 2011 the patients were allocated to the conventional laminoplasty group (CL group), and from September 2011 to September 2015 the patients were allocated to modified laminoplasty group (ML group).

Inclusion criteria were: 1) age from 40 to 75 years old, 2) decompression segments involving C3–C7, and 3) disease duration lasting at least 6 months. Exclusion criteria were: 1) cervical spondylotic radiculopathy, 2) cervical ossification of the posterior longitudinal ligament, 3) combined with other pathological types (e.g., tumor or injury, 4) patients with previous cervical surgery, and 5) simultaneous use of other fixed procedures.

A total of 102 cases were finally enrolled for analysis, including 44 cases in CL group and 58 cases in ML group. Medical records, radiological images, and questionnaires were used to collect the data.

Surgical technique

The techniques of single-door laminoplasty here were described previously [7,9]. Before surgery, we identified the open side according to the severity of symptom and radiography. After general anesthesia, the patient's neck was maintained in a neutral position. A posterior midline approach was performed. Using subperiosteum dissection, the spinal process, lamina, and lateral mass were exposed. Two-side gutters were made using a high-speed burr on 2 margins of the lamina. Total bone of 1 margin of the lamina was cleaned as an open side. If accessible, a 1.5-mm Kerrison rongeur was used to clean the inner cortex of the open side. Another margin of the lamina remained the inner cortex as a hinge side. The ligamenta supraspinale, ligamenta interspinalia, and ligamentum flavum at C2–C3 and C7–T1 were divided. Then, the laminae (C3–C7) were opened gently for laminoplasty. For patients in the CL group (Figure 1), the opened laminae were secured to facet joint capsules using sutures at all levels. In the ML group (Figure 2), the suitable sized miniplate for each level was selected for the opened laminae. The screws were inserted in miniplate to firmly anchor the lamina and the lateral mass. Five-level miniplate fixation (C3–C7) was completed. A cervical collar immobilized the neck of patients for 4 weeks. All patients were followed up 6 to 8 months after surgery.

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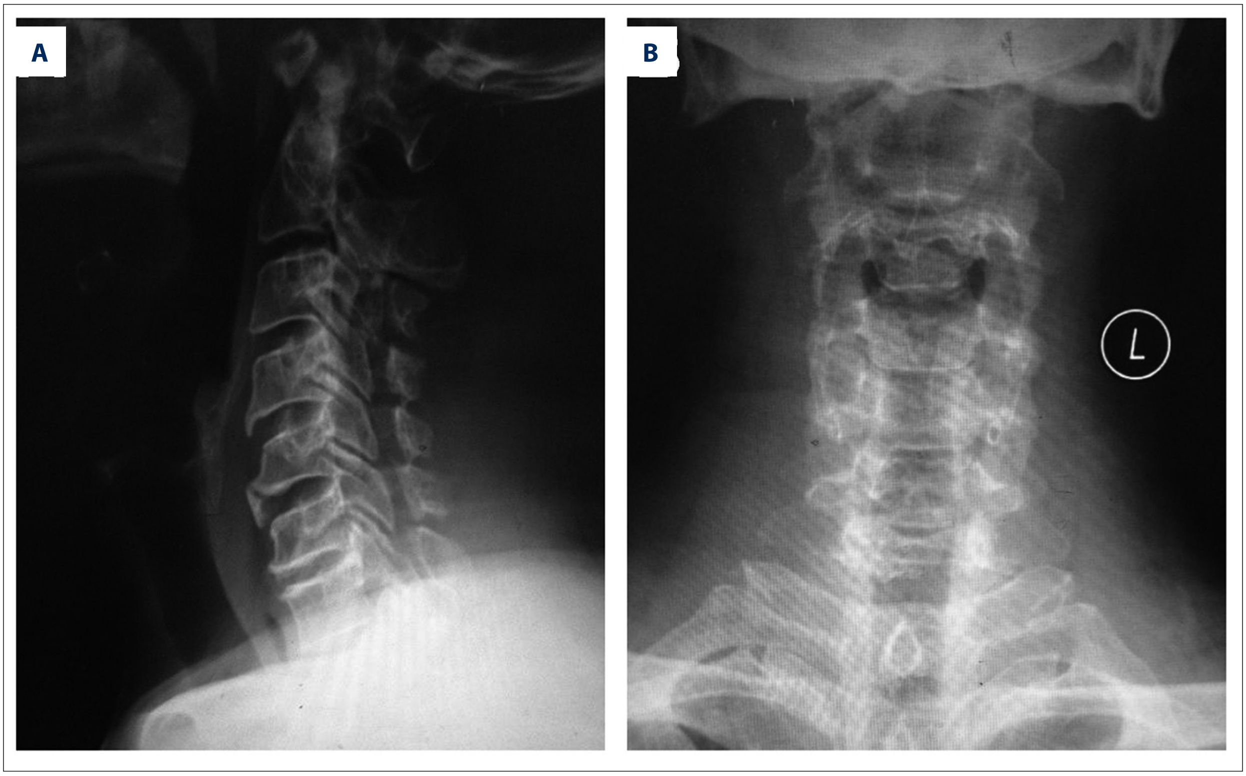

Figure 1. Postoperative lateral (**A**) and anteroposterior (**B**) radiographs of a 59-year-old man in the CL group.

Assessment of axial symptoms

Axial symptoms (AS), including neck stiffness and pain, shoulder stiffness and pain, and limited neck motion, were categorized according to the following 4 levels reported by Hosono et al. [4]: Good – no stiffness or pain; Minor – symptoms after minor exertion or cold that quickly recover, with no significant effect on daily activities; no limited neck motion; Major: symptoms appear frequently, daily activities are affected, and physical therapy or analgesic pills are required; and Severe: symptoms appear frequently and significantly affect daily activities, and analgesics or injection of anesthetics to the painful muscles are regularly needed.

Patients rated as Good or Minor exhibited no axial symptoms. Severe or Major axial symptoms lasting for more than 1 month were considered as axial symptoms. These symptoms were recorded preoperatively and postoperatively. The postoperative axial symptoms were evaluated at 6 to 8 months after surgery.

Preoperative clinical data collection

Clinical demographic data were collected in all patients, including age, sex, surgical procedure (CL or ML), operative time, blood loss, preoperative Japanese Orthopedic Association score (pre-JOA), and preoperative axial symptoms (pre-AS).

Preoperative radiological assessment

All patients underwent anteroposterior and lateral standing X-ray radiography and MRI scans preoperatively. Two authors (who were blinded to the patients) analyzed radiological parameters as follows and the average was recorded [11,15].

1. **Cervical lordosis**. The C2–7 Cobb angle (CCA) indicates the angle between 2 crossed perpendicular lines that extend parallel to the lower endplate of C2 and the upper endplate of C7 (Figure 3A).
2. **Anteroposterior diameter of the spinal canal (APD).** APD was measured using Wolf's method starting from the middle of the vertebral body's posterior border to the lamina's anterior border (Figure 3B).
3. **Cervical sagittal balance.** The cervical sagittal vertical axis (SVA) was defined using the distance between a plumb line dropped from the center of C2 and the posterior superior aspect of C7 (Figure 3B).
4. **Spinal cord parameters.** T2-weighted MR images were used to evaluate high signal intensity (HSI) of the spinal cord (Figure 4).

Statistical analysis

Data analysis was performed using SPSS 20.0 (IBM, Armonk, NY). Categorical variables were compared using Pearson's chi-square test. Continuous variables were compared using

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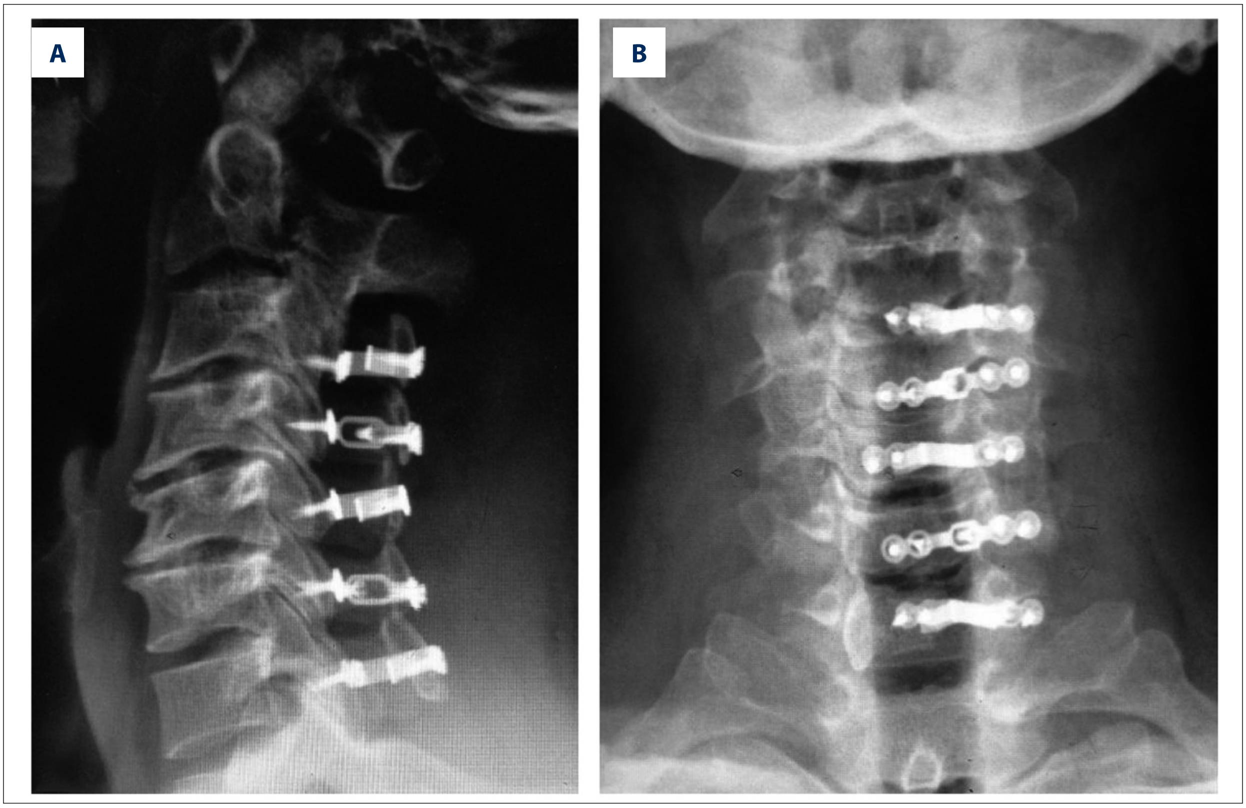

Figure 2. Postoperative lateral (**A**) and anteroposterior (**B**) radiographs of a 58-year-old man in the ML group.

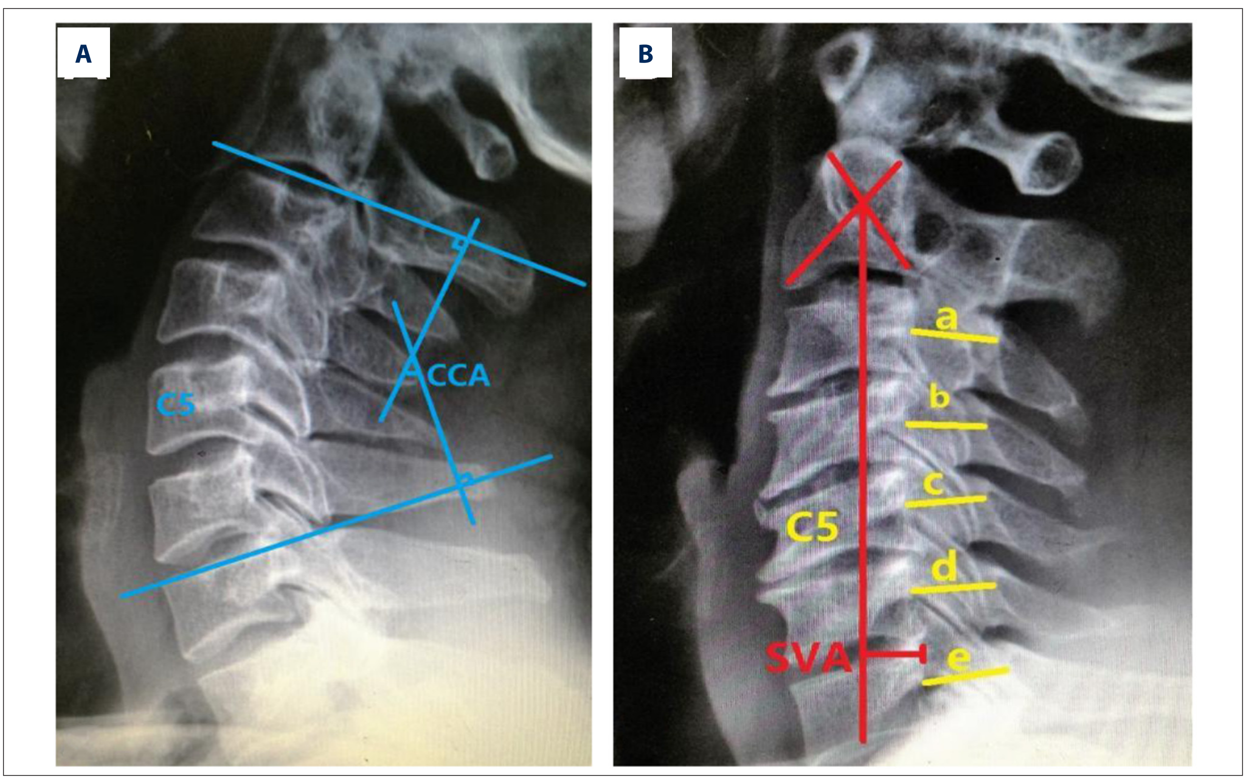

Figure 3. Preoperative lateral X-ray radiographs. (**A**) C2–7 Cobb angle (CCA); (**B**) Anteroposterior diameter of the spinal canal (APD)=(a+b+c+d+e) cm ÷5; Cervical sagittal vertical axis (SVA).

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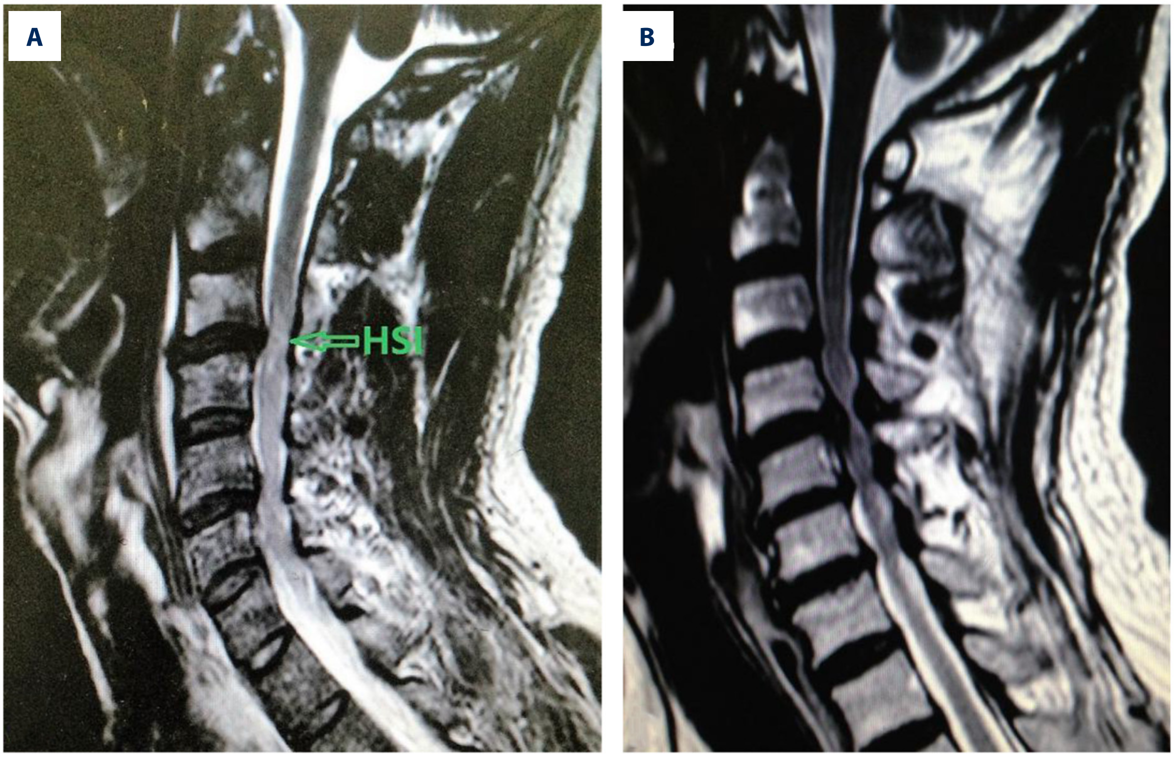

Figure 4. Preoperative sagittal MR images: (**A**) high signal intensity (arrow); (**B**) no high signal intensity.

a 2-tailed independent t-test. Preoperative factors associated with post-AS were identified by multivariate logistic regression analysis with odds ratios and a 95% confidence interval. A P value <0.05 was considered statistically significant.

Results

Preoperative clinical and radiological data

Titanium miniplate fixation was used to conduct laminoplasty in 58 patients, and suture fixation was used in 44 patients (Table 1). As shown in Table 1, no significant differences were seen between the 2 groups regarding age, sex, operative time, blood loss, pre-JOA, pre-AS, CCA, APD, HSI, and SVA.

Post-AS occurred in 41 of 102 cases (40.2%). Post-AS occurred in 24 of 44 cases of the CL group (54.5%) compared with 17 of 58 cases in the ML group (29.3%), demonstrating that the incidence of post-AS after ML was significantly lower than after CL (P=0.010) (Table 1).

Preoperative factor regression analysis

Multivariate logistic regression analyses revealed that ML and CCA were protective factors significantly associated with post-AS (ML: P=0.011, odds ratio=0.302, and CCA: P=0.042, odds ratio=0.947). By contrast, age, sex, operative time, blood loss, pre-JOA, pre-AS, APD, HSI, and SVA were not significantly correlated with the incidence of post-AS (Table 2).

Furthermore, patients with post-AS had a lower preoperative CCA (17.3±9.5°) than patients without post-AS (21.0±8.5°), and the difference (2-tailed independent t-test) was statistically significant (P=0.043) (Table 3).

Discussion

Post-AS after single-door cervical laminoplasty for CSM are common and severe complications that adversely affects normal daily living. Ohnari's report showed that post-AS are the most frequent complaints after cervical laminoplasty [13]. Their etiology remains unclear. Previous studies were only indirect and retrospective, or used univariate analysis. Reducing this complication by means of preoperative factors would be very beneficial to surgeons and patients. Therefore, this study elucidated the preoperative factors affecting post-AS. We found a significantly lower incidence of post-AS after ML than after CL, using a prospective comparative study. We found that ML and CCA were protective preoperative factors against post-AS in a multivariate logistic regression analysis,

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Table 1. Preoperative clinical and radiological parameters.

	CL group (n=44)	ML group (n=58)	P
Age (years)	57.1±8.1	56.3±8.8	0.684
Male, n (%)	38 (86.4)	50 (86.2)	0.982
Operating time (min)	129.9±9.2	133.2±13.2	0.290
Blood loss (mL)	354.1±14.6	358.8±13.1	0.101
Pre-JOA	8.9±0.5	9.1±0.6	0.199
Pre-AS, n (%)	11 (25.0)	19 (32.8)	0.394
Post-AS, n (%)	24 (54.5)	17 (29.3)	0.010*
CCA (°)	19.1±7.9	19.9±10.0	0.663
APD (cm)	1.4±0.1	1.4±0.2	0.837
HSI, n (%)	10 (22.7)	16 (27.6)	0.577
SVA (cm)	1.5±0.8	1.6±1.0	0.514

* Statistically significant. CL – indicates conventional single-door cervical laminoplasty (sutures); ML – modified single-door cervical laminoplasty (titanium miniplates); Pre-JOA – preoperative Japanese Orthopedic Association score; Pre-AS – preoperative axial symptoms; Post-AS – postoperative axial symptoms; CCA – C2–7 Cobb angle; APD – anteroposterior diameter of the spinal canal; HSI – high signal intensity on T2-weighted imaging of MRI; SVA – cervical sagittal vertical axis.

Table 2. Logistic regression analysis of factors influencing post-AS.

	Odds ratio	95% Confidence Interval	P
Age	0.005	0.975–1.083	0.525
Gender: male	0.554	0.158–1.939	0.355
ML procedure	0.302	0.120–0.762	0.011*
Operating time	1.017	0.976–1.060	0.426
Blood loss	1.018	0.979–1.058	0.383
Pre-JOA	0.673	0.286–1.580	0.363
Pre-AS	0.831	0.293–2.354	0.727
CCA	0.947	0.898–0.998	0.042*
APD	1.602	0.079–32.294	0.758
HSI	0.594	0.207–1.699	0.331
SVA	1.209	0.757–1.929	0.427

* Statistically significant. ML – indicates modified single-door cervical laminoplasty (titanium miniplates); Pre-JOA – preoperative Japanese Orthopedic Association score; Pre-AS – preoperative axial symptoms; CCA – C2–7 Cobb angle; APD – anteroposterior diameter of the spinal canal; HSI – high signal intensity on T2-weighted imaging of MRI; SVA – cervical sagittal vertical axis

Table 3. Comparison of CCA in patients with and without post-AS.

	Patients with post-AS (n=41)	Patients without post-AS (n=61)	P
CCA (°)	17.3±9.5	21.0±8.6	0.043*

* Statistically significant. CCA – indicates C2–7 Cobb angle; Post-AS – postoperative axial symptoms.

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but the other preoperative factors were not significantly associated with post-AS.

Several factors may affect the incidence of post-AS after laminoplasty and surgical technique may be one of them. A study demonstrated that the superiority of deep extensor muscle-preserving laminoplasty in terms of post-AS over CL for CSM [16]. The C7-sparing technique preserved the C7 spinous process and its paraspinal muscular attachment, with only 3% of the patients complaining of post-AS [17], which was in contrast to 70% of patients reporting post-AS [18]. Cervical laminoplasty that can conserve the unilateral posterior muscular-ligament complex may lower the rate of post-AS [19]. In our study, the total incidence of post-AS after the single-door cervical laminoplasty was 40.2%. The incidence of post-AS after CL was 54.5%, whereas the incidence of post-AS after ML was 29.3%, which demonstrates that the incidence of post-AS after ML was significantly lower than after CL. Our results are consistent with previous univariate studies [5,10]. Further multivariate analysis in the present study revealed that ML was a significant protective factor against post-AS and that ML reduced the incidence of post-AS.

We speculated that 2 procedural factors lowered the incidence of post-AS after ML. First, miniplate fixation interferes less with the facet joints than suture fixation. CL ensures the sutures remain between the laminae and facet joint capsule at all levels. However, retention of sutures damages the facet joint capsules. In a neurophysiologic study about facet joints, the stretched capsule activated nociceptors and possibly led to post-AS [20]. A retrospective report including only the ML group showed that facet joints destroyed by screws might be associated with post-AS [15]. The facet joints should be held intact to prevent the incidence of post-AS. Second, miniplate fixation reduces the micro-movements and muscle stimuli caused by nonunion hinge more effectively than suture fixation, because miniplates provide immediate rigidity of fixation, and better stabilization of the cervical spine, and increase the union on the hinge side [21]. A report also indicated that hinge nonunion might be a risk factor of post-AS after cervical laminoplasty [12].

Preoperative cervical alignment may be another factor playing a role in post-AS. Preoperative C2–C7 kyphosis and preoperative local kyphosis were reported to be probable risk factors for poor surgical outcomes [22]. Another study demonstrated that imaging limitations of posterior decompression in cervical myelopathy included preoperative lordosis less than 10° [23]. Du et al. showed that axial symptom severity was positively correlated with loss of cervical curvature index, which means that post-AS worsened with severe loss in the cervical curvature index [24]. Okada et al. [25] conducted a prospective, randomized study suggesting that a decrease in cervical lordosis or an increase in cervical kyphosis produces more post-AS. At 3 months after surgery, the lordosis angle was significantly higher in the symptom-free group than in the symptomatic group [26]. The present study further proved that preoperative CCA was negatively correlated with post-AS, suggesting that the incidence of post-AS was reduced by selecting patients with high preoperative CCA.

Preoperative CCA affecting post-AS may be explained by the following factors. The mean preoperative and postoperative lordosis was 16.2° and 11.4°, respectively, following cervical laminoplasty, along with a postoperative kyphosis of 4.8° [27]. Biomechanically, a straight cervical spine or kyphosis shows greater flexural stress than lordosis [28], which adversely affects the posterior musculature, resulting in post-AS. Chavanne et at [29] found that cervical lordosis less than 7.5° resulted in increased spinal cord intramedullary pressure. It is hypothesized that high residual pressure of the spinal cord is correlated with increasing post-AS. In patients with preoperative kyphotic deformity, the spinal cord was compressed by tethering over the apical vertebra or intervertebral disc [30]. In the present study, patients with post-AS had significantly lower preoperative CCA; postoperative CCA will be smaller than preoperative CCA, so the straighter lordosis of postoperative cervical spine causes post-AS.

Using multivariate analysis, we found that age and sex were not significantly associated with post-AS, similar to the results of some univariate studies [13,31] that found no significant difference in age between post-AS and no post-AS groups. A study [32] showed that post-AS was significantly higher in patients older than 70 years. Another study [33], on the contrary, found that age of more than 63 years significantly decreased post-AS. The previous studies showed that sex was not correlated with post-AS [13,31,33], except for one [26] in which post-AS occurred more in women than in men and the muscle strengths of men were stronger than in women. Comparative studies have shown that operative time [25] and blood loss [4,25] may also be related to post-AS. However, our multivariate analysis revealed that operative time and blood loss were not significantly associated with post-AS. Kato et al. [33] found no correlation between post-AS and pre-JOA in selective cervical laminoplasty, which was similar to our result. Another study [13] found no significant difference in pre-AS between patients with post-AS and no post-AS, which was consistent with our study. However, Yoshida's study [32] found that post-AS occurred primarily in patients who had pre-AS and continued to have them after surgery. This disagreement may be due to the different surgical procedures in Yoshida's study and our study. In the present study, preoperative APD, his, and SVA were not significantly associated with post-AS. A report on cervical ossification of the posterior longitudinal ligament (COPLL) showed that post-AS increased in patients

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with SVA ≥40 mm and high SVA was correlated with post-AS in the laminoplasty group [34], but our study did not confirm this relationship. This may be because the nature of COPLL and CSM is different. To the best of our knowledge, this is the first report investigating APD and HSI associated with the incidence of post-AS.

This prospective study has several limitations. First, it was not randomized, but patients assigned to the 2 groups according to operation date and the background data showed no significant differences preoperatively (Table 1). Second, few factors were analyzed in this study. The factors analyzed in this study were only preoperative and not postoperative parameters.

Conclusions

Post-AS after single-door cervical laminoplasty are a common and severe complication of CSM. A prospective comparative multivariate analysis is needed to determine the most predictive preoperative factors for post-AS. We showed significant evidence indicating the lower risk of post-AS with ML. This study suggests that ML and CCA were protective preoperative factors against post-AS following single-door cervical laminoplasty for CSM, and that the other preoperative factors are not significantly associated with post-AS. The incidence of post-AS was reduced by choosing ML procedure or selecting patients with high preoperative CCA. To the best of our knowledge, this is the first prospective study investigating surgical procedures associated with the incidence of post-AS.

Conflict of interest

The authors declare that they have no actual or potential conflicts of interest.

IRB approval/Research Ethics Committee

This study was approved by the Ethics Committee of Liaocheng People's Hospital. Patients provided written informed consent.

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