Analysis of Short-Term Prognostic Factors of Posterior Single Open-Door Laminoplasty in Patients with Cervical Spondylotic Myelopathy

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AIM: Posterior cervical expansive open-door laminoplasty (ELAP) is one of the main methods for the treatment of multilevel cervical spondylotic myelopathy (CSM). However, some patients are vulnerable to developing complications such as kyphosis and axial symptoms after ELAP, potentially facing adverse prognosis following the procedure. At present, there are few reports on the short-term prognostic factors in Chinese patients with CSM after undergoing ELAP. The main objectives of this study are to investigate the efficacy of ELAP in the treatment of CSM and to analyze the short-term prognostic factors.

METHODS: This study is a retrospective study. A total of 98 patients with CSM who received ELAP surgery in The First People's Hospital of Tongxiang City from May 2021 to October 2022 were selected as the study participants. The clinical efficacy of the ELAP was evaluated using visual analog scale (VAS), Japanese Orthopedic Association (JOA) score, and assessments based on imaging indicators. All patients were followed up for 1 year postoperatively. The short-term prognosis was analyzed according to JOA improvement rate, and the short-term prognostic factors were analyzed using multivariate logistic regression.

RESULTS: The JOA scores of 98 CSM patients at 1 year after operation were significantly higher than those before operation ($p < 0.001$), and their postoperative VAS score were significantly lower than those before operation ($p < 0.001$). The postoperative cervical curvature ($p < 0.001$), sagittal diameter of cervical spinal canal ($p < 0.001$) and distance between vertebral body and posterior edge of spinal cord ($p < 0.001$) were significantly improved relative to the corresponding preoperative values. There was no significant difference in cervical 2–7 Cobb angle before and after operation ($p = 0.979$). Multivariate logistic regression analysis showed that age ($p < 0.001$), course of disease ($p < 0.001$) and preoperative JOA score ($p < 0.001$) were independent risk factors affecting the short-term prognosis in CSM patients.

CONCLUSIONS: ELAP is a safe and effective therapeutic approach for CSM, whose short-term prognosis is related to age, course of disease and preoperative JOA score.

Keywords: expansive open-door laminoplasty; cervical spondylotic myelopathy; prognosis

Introduction

Cervical spondylotic myelopathy (CSM) is caused by the direct compression of the spinal cord caused by the degeneration of the cervical vertebral body and the degeneration of adjacent soft tissues, coupled with the influence of dynamic factors such as severe exercise or long-term bad posture, resulting in spinal cord compression or spinal cord ischemia, followed by spinal cord dysfunction. The main clinical manifestations of CSM include upper limb pain, lower limb numbness, dizziness, and insomnia [1], all of which have adverse repercussions on patients' quality of life. Due to the high level of disability and the limited effectiveness of non-surgical treatments, surgical interventions are often utilized [2]. Anterior cervical decompression and fusion is usually recommended for CSM of levels 1–2, while posterior cervical decompression is preferred for CSM with multiple levels (≥3) [3].

One of the primary methods for treating multilevel CSM is posterior cervical expansive open-door laminoplasty (ELAP), which expands the spinal canal space, alleviates nerve compression, and aids in the restoration of damaged nerves. ELAP offers the advantages of precise clinical outcomes and straightforward surgical procedure [4]. Previous research has demonstrated that compared to anterior cervical decompression and fusion, ELAP causes less trauma and better preserves the cervical spine's range of motion [5]. Nonetheless, some studies have indicated that certain CSM patients may experience complications such as kyphosis and axial symptoms after ELAP, with the incidence of postoperative axial symptoms reaching up to 80% [6, 7], negatively impacting the patients' prognosis. Therefore, it is crucial to analyze the factors that influence the short-term prognosis of CSM patients after undergoing ELAP.

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At present, most of the published studies reported the effect of anterior cervical surgery on CSM patients and the factors that lead to poor prognosis [8, 9], and the reports on the short-term prognostic factors in CSM patients after ELAP are relatively scarce in the literature. Thus, this study is designed to analyze the efficacy of ELAP in the treatment of CSM and the short-term prognostic factors in CSM patients after receiving the surgical operation.

Materials and Methods

Study Subjects

This study is a retrospective study. A total of 98 patients with CSM who underwent ELAP surgery in The First People's Hospital of Tongxiang City from May 2021 to October 2022 were selected as the study subjects. The inclusion criteria for this study are as follows: (i) patients diagnosed with CSM based on clinical symptoms such as neck and shoulder discomfort, limb numbness and weakness, reduced fine motor skills in the upper limbs, prominent sensation of tightness below the affected spinal segment, and positive findings on X-ray, computed tomography (CT), and magnetic resonance imaging (MRI); (ii) patients with spinal cord compression involving at least three segments; and (iii) patients meeting the indications for ELAP surgery. The patients with the following conditions were excluded: (i) other types of degenerative cervical diseases; (ii) concurrent cervical infectious diseases, traumatic fractures, kyphosis, spondylolisthesis, congenital spinal deformities, primary or metastatic cervical tumors, or metabolic bone diseases; (iii) history of spinal surgery; (iv) previous anterior surgery or posterior double-door laminoplasty; (v) presence of severe systemic diseases that made the patient unfit for ELAP surgery; and (vi) loss to follow-up. All patients included in this study provided informed consent, and the study was conducted in adherence to the principles outlined in the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of The First People's Hospital of Tongxiang City (2024-167-01).

Surgical Methods

All patients were routinely examined using MRI, cervical six-phase X-ray, and cervical CT before operation. The physiological curvature and stability of the cervical spine, as well as the formation of osteophytes and ossification of ligaments in the posterior margin of the vertebral body, were fully understood and mastered. According to the examination results, the compressed segment of spinal cord was determined and the decompression range was defined. The patients were positioned in a prone position and were subjected to routine disinfection and draping. General anesthesia was administered to each patient, with the head immobilized using a Mayfield external fixator to slightly tilt the cervical spine forward. C-arm X-ray fluoroscopy was utilized to determine the intervertebral space. An electrotome was utilized for stripping the muscle under periosteum, exposing lamina to the small joint process on both sides. Part of the spinous process was removed, while the posterior muscle and ligament complex were preserved to ensure maximum cervical stability. Additionally, osteophytes on the edge of the joint process and adjacent lamina at both ends of the incision were excised. The side with severe spinal cord compression was selected as the "open-door" side, while the other side was designated as the "hinge" side. A high-speed drill was employed to create a hole along the junction between the lamina and the lateral mass articular process on the hinge side, while preserving the inner bone plate. On the open-door side, a groove was made along the lamina and the lateral mass articular process. Laminectomy was then performed, and the lamina on the open-door side was sequentially pulled towards the lamina on the hinge side. The nerve dissector was employed to carefully separate the adhesion between the dura and the ligamentum flavum. As a result, the spinal cord could be seen bulging backwards.

A suitable titanium miniplate was selected and placed between the lamina at the root of the spinous process and the lateral mass on the open-door side, and securely fixed using self-tapping screws. Bipolar electrocoagulation was applied to completely halt bleeding. A vacuum drainage tube was inserted, and the incision was meticulously sutured layer by layer. Sterile dressing was then applied and secured, and an external cervical collar was utilized for immobilization. Postoperative antibiotic treatment was administered within 24–48 hours to prevent infections. The drainage tube was removed when the drainage volume fell below 50 mL per day. After four weeks of wearing the cervical collar, patients were instructed to initiate neck functional exercises and return to the hospital for regular follow-up.

Follow-up and Grouping Methods

All patients were followed up for 12 months after operation. MRI, X-ray, CT and assessment of clinical signs were conducted regularly every three months. The short-term prognosis was evaluated in terms of the Japanese Orthopedic Association (JOA) score improvement rate [10], which takes into account the assessments of lower limb motor ability, bladder function, sensory function, and upper limb mobility, with a total score of 17. A higher score indicates better functioning of the cervical spine. Based on the JOA improvement rate, patients were categorized into two groups: those with a good prognosis (JOA improvement rate $\geq$50%) and those with a general prognosis (JOA improvement rate $<$50%).

Outcome Measurements

Data Collection

Demographic information of patients including age, gender, course of disease, duration of surgery, amount of blood loss

during surgery, *etc.*, were obtained from electronic medical records. Based on the data collected, we calculated the rates of complications, such as spinal cord injury, cerebrospinal fluid leakage, incision infection, paralysis of cervical nerve roots, and recurrent closure.

Pain Assessment

The severity of pain before and after the operation was evaluated using visual analog scale (VAS), which ranges from 0 to 10. A higher score indicates more severe level of pain. The Cronbach's α coefficient of the VAS scale was 0.862 [11].

Measurements of Cervical Spine Imaging Indicators

Cervical curvature, C2–7 Cobb angle, sagittal diameter of the cervical canal, and retrogression distance of the cervical spinal cord were measured by two spine surgeons using an image processing system. The following parameters were assessed: (i) Cervical curvature: This was determined by measuring the acute angle formed by the extension line of the posterior edge tangent of the second and seventh cervical vertebrae on lateral X-ray films. (ii) C2–7 Cobb angle: This was determined by measuring the acute angle formed by the perpendicular line to the extension line of the tangent line of the inferior endplate of the C2 and C7 vertebral bodies on lateral X-ray films. (iii) Sagittal diameter of the cervical canal (anteroposterior diameter): This was measured as the shortest distance from the midpoint of the posterior edge of the vertebral body to the posterior wall of the spinal canal on CT transverse views. The average value for each segment was calculated. (iv) Retrogression distance of the cervical spinal cord: This was determined as the distance from the midpoint of the posterior edge of the vertebral body to the posterior edge of the spinal cord on MRI sagittal views. The average value for each segment was calculated.

Statistical Analysis

The data analysis was conducted using Statistical Product and Service Solutions (SPSS) 22.0 (IBM, Armonk, NY, USA). Shapiro–Wilk test was used to assess the data normality. Continuous data that conforming to the normal distribution are expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$), and the *t*-test was employed for comparative analysis of data. Categorical data are expressed as counts (percentages), and the comparison for this sort of data was performed using chi-square test. Multivariate logistic regression was performed on variables which showed statistically significant differences in univariate analysis. $p < 0.05$ was considered statistically significant.

Results

Baseline Characteristics and Surgical Data of Patients

A total of 98 patients diagnosed with CSM were included in this study, consisting of 61 males and 37 females. The age of the patients ranged from 43 to 77 years, with a mean age of 57.64 $\pm$ 5.90 years (Table 1).

None of the 98 patients experienced complications such as postoperative intraspinal hematoma, spinal cord injury, or C5 nerve root paralysis. Mild axial symptoms, characterized by a VAS score of 3 to 4, were observed in four patients. These symptoms were effectively alleviated through rehabilitation guidance. One patient experienced delayed wound healing due to fat liquefaction, but no bacterial growth was detected in wound secretion culture. The wound eventually healed after intensive dressing changes. No complications, such as internal fixation failure, vertebral plate collapse, or the occurrence of "re-closing door", were observed during the follow-up period in any of the patients.

Table 1. General information of patients (n = 98).

Variables		Statistics
Sex (n)	Male	61
	Female	37
Age (years, $\bar{x} \pm s$)		57.64 $\pm$ 5.90
Course of disease (months, $\bar{x} \pm s$)		16.76 $\pm$ 4.18
Body mass index (kg/m^2, $\bar{x} \pm s$)		28.34 $\pm$ 1.53
Surgical segment (n)	C3–6	26
	C4–7	43
	C3–7	29
ASA grade (n)	I	6
	II	81
	III	11
Complicated diabetes (n)		11
Complicated hypertension (n)		18
Operation time (min, $\bar{x} \pm s$)		134.96 $\pm$ 36.82
Amount of bleeding (mL, $\bar{x} \pm s$)		169.88 $\pm$ 48.48

ASA, American Society of Anesthesiologists.

Comparison of Cervical Spine Function and Pain Level before and after Operation

The JOA score of the CSM patients at one year after operation was significantly higher than that before operation, and the VAS score was significantly lower than that before operation (t = 13.696, 32.068; $p < 0.001$) (Table 2).

Table 2. Comparison of cervical spine function and pain level before and after operation.

Time point	*n*	JOA	VAS
Before operation	98	10.28 $\pm$ 3.31	5.06 $\pm$ 1.23
1 year after operation	98	15.19 $\pm$ 1.28	0.86 $\pm$ 0.41
t		13.696	32.068
p		<0.001	<0.001

Note: Data are expressed as $\bar{x} \pm s$.

JOA, Japanese Orthopedic Association; VAS, visual analog scale.

Table 3. Comparison of imaging indicators before and after operation.

Time point	*n*	Cervical curvature (°)	C2–7 Cobb angle (°)	Sagittal diameter of cervical canal (mm)	Vertebral body-posterior spinal cord distance (mm)
Before operation	98	19.26 ± 5.60	19.68 ± 4.66	11.41 ± 1.92	9.00 ± 1.35
1 year after operation	98	15.37 ± 4.84	19.70 ± 5.88	17.86 ± 1.62	13.34 ± 2.21
t		5.203	0.026	25.417	16.590
p		<0.001	0.979	<0.001	<0.001

Note: Data are expressed as $\bar{x} \pm s$.

Table 4. Univariate analysis of short-term prognosis in patients with CSM.

Variables	General prognosis group (*n* = 21)	Good prognosis group (*n* = 77)	χ^2/t	*p*
Age (years, $\bar{x} \pm s$)	61.76 ± 3.37	56.62 ± 5.95	3.787	<0.001
Gender (*n*)				
Male	13	48	0.001	0.971
Female	8	29		
Course of disease (months, $\bar{x} \pm s$)	21.87 ± 1.66	15.38 ± 3.55	8.116	<0.001
Preoperative JOA score (points, $\bar{x} \pm s$)	8.67 ± 0.48	10.71 ± 0.70	12.551	<0.001
Preoperative cervical curvature (°, $\bar{x} \pm s$)	17.97 ± 5.57	19.61 ± 5.61	1.189	0.237
Preoperative C2–7 Cobb angle (°, $\bar{x} \pm s$)	19.50 ± 2.75	19.73 ± 5.07	0.200	0.842
Cervical canal sagittal diameter (mm, $\bar{x} \pm s$)	11.69 ± 1.90	11.33 ± 1.93	0.760	0.449
Preoperative vertebral body-posterior spinal cord distance (mm, $\bar{x} \pm s$)	8.52 ± 1.58	9.12 ± 1.27	1.818	0.072
Postoperative complication (*n*)				
Yes	2	3	0.230	0.632
No	19	74		

CSM, cervical spondylotic myelopathy.

Comparison of Imaging Indicators before and after Operation

The postoperative cervical curvature, cervical canal sagittal diameter, and central spinal cord posterior edge distance of all 98 CSM patients were significantly improved relative to the values or conditions before operation ($t = 5.203$, 25.417, 16.590; $p < 0.001$). The comparison in C2–7 Cobb angle before and after the surgery revealed no statistically significant difference ($p > 0.05$) (Table 3).

Univariate Analysis of Short-Term Prognostic Factors in CSM

After the surgical procedure, a 12-month follow-up was conducted on all patients. During the last follow-up, the patients were categorized into two distinct groups based on their JOA score improvement rate. Among them, 21 cases were categorized under the general prognosis group, while 77 cases were classified in the good prognosis group. Statistical analysis of the postoperative prognosis of patients with CSM revealed significant differences in relation to age, course of disease, and preoperative JOA score ($p < 0.001$) (Table 4).

Multivariate Logistic Regression Analysis of Short-Term Prognotic Factors in CSM

Multivariate logistic regression analysis was performed on indicators that were identified as statistically significant independent variables in univariate analysis (these factors include age, course of disease, and preoperative JOA score, whose original values were used in analysis), with postoperative short-term prognosis status of CSM patients utilized as dependent variables (good prognosis = 0, general prognosis = 1, in the analysis). The results showed that advanced age, prolonged course of disease, and decreased preoperative JOA score were independent risk factors affecting short-term prognosis of CSM patients after surgery ($p < 0.001$) (Table 5).

Discussion

Compared to general cervical spondylosis, CSM involves more segments and causes a wider range of compression, greater damage to spinal cord and nerve function, a higher disability rate, and a poorer prognosis. The choice of surgical method for CSM remains a topic of debate. Advocates of anterior cervical surgery contend that anterior cervical subtotal corpectomy combined with discectomy allows for the direct removal of compressive factors such as intervertebral discs, posterior longitudinal ligaments, and hypertrophic osteophytes in front of the spinal cord [12]. This approach offers distinct advantages in the physiological reconstruction of the cervical spine structure. On the other hand, proponents of posterior surgery argue that posterior single-door surgery provides a simpler procedure, in which the spinal cord is moved backward to within the enlarged

Table 5. Multivariate logistic regression analysis of factors influencing short-term prognosis of CSM patients.

Factors	β	SE	Wald χ^2	p	OR	95% CI
Age	1.259	0.291	18.711	<0.001	3.521	1.990–6.228
Course of disease	1.110	0.315	12.422	<0.001	3.035	1.637–5.627
Preoperative JOA score	–0.120	0.036	11.095	<0.001	0.887	0.827–0.952

CI, confidence interval; OR, odds ratio; SE, standard error; β, regression coefficient.

spinal canal, effectively avoiding anterior compression and achieving a significant decompression effect [13]. Importantly, this approach is not invasive to the spinal canal, thereby greatly reducing the injury risk to dura mater and spinal cord compared to the anterior approach.

In recent years, there has been extensive discussion on the choice of surgical methods for patients with CSM [14, 15], the fused segment tends to be positioned at a higher level, resulting in reduced vertebral body motion and limited movement in the fused segment. This can lead to uneven disc force and stress concentration on the articular process, accelerating degeneration in adjacent segments and the cervical area. A prospective, multicenter clinical study has confirmed that the clinical effectiveness of anterior and posterior surgeries is comparable [16]. In light of these findings, we recommend posterior surgery as the preferred option for CSM patients, especially advocating ELAP by virtue of its easy-to-perform procedures and favorable outcomes. The results of our study revealed that the postoperative JOA improvement rate for CSM patients treated with ELAP was 78.57%. Notably, postoperative imaging indicators, JOA score, and VAS score all demonstrated significant improvement compared to preoperative measurements, consistent with findings reported in previous literature [17, 18]. This suggests that ELAP is a safe and effective treatment for CSM. However, it is worthwhile to emphasize that some patients with multilevel CSM may not experience substantial improvement in neurological function even after being operated on by skilled surgeons. Therefore, it is essential to explore the factors influencing short-term prognosis in order to enhance the outcomes of surgical interventions.

Our multivariate analysis identified age, course of disease, and preoperative JOA score as independent risk factors influencing the short-term prognosis of patients with CSM. The identification of these factors can be justified by the following: (1) *Age*: A patient's physical health condition tends to deteriorate with age, which may have a significant impact on the success of the surgical procedure and recovery. (2) *Course of disease*: Li *et al*. [19] have pointed out that the compression of spinal cord conduction tract in patients with long course of disease may cause secondary spinal cord ischemia and demyelination. Long-term compression may lead to irreversible pathological and physiological changes of spinal cord. Even if nutritional supply for spinal cord is improved after decompression, recovery of the degenerative spinal cord function presents huge challenges. Therefore, patients with long course of disease would face poor postoperative recovery and unfavorable short-term prognosis. (3) *Preoperative JOA score*: The preoperative JOA score serves as a vital indicator of cervical nerve function in patients, with a lower score indicating more severe CSM symptoms and increased spinal cord compression [20]. A prior study [21] discovered that patients with more severe preoperative spinal cord compression tend to have a worse prognosis. This could be because intense compression leads to irreversible pathophysiological changes in the spinal cord. Simple decompression surgery may not yield satisfactory improvement in neurological function. Therefore, implementing proactive early treatment and exercising caution during strenuous activities and weight-bearing are essential to aid postoperative recovery for these patients.

It is crucial to note that this study is not without limitations, which include a relatively brief follow-up duration, the absence of a comparison between the anterior and the posterior surgeries, and a lack of comprehensive investigation into the impact of specific surgical factors on short-term outcomes. Future research endeavors will entail enlarging the sample size, extending the follow-up period, and incorporating additional surgical approaches for a more exhaustive analysis.

Conclusions

In summary, ELAP proves to be a safe and effective approach to treating CSM, evidenced by the favorable long-term clinical outcome postoperatively and sustained efficacy. Age, course of disease, and preoperative JOA score stand as the factors influencing the short-term prognosis in CSM patients. Although the patients treated with ELAP may be at increased risk of late complications, reasonable postoperative management and regular follow-up can effectively reduce these risks. Future research should further optimize surgical techniques and postoperative care to improve the safety and effectiveness of ELAP.

Availability of Data and Materials

The original data involved in the present study are available from the corresponding author upon reasonable request.

Author Contributions

Conceptualization, methodology, and writing: YS. Investigation: YS, JY, JJQ. Formal analysis: JY. Writing and edit-

ing: YS, JJQ. All authors have been involved in revising it critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

All patients included in this study provided informed consent, and the study was conducted in adherence to the principles outlined in the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of The First People's Hospital of Tongxiang City (2024-167-01).

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Conflict of Interest

The authors declare no conflict of interest.

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