Cervical curvature changes following laminectomy with lateral mass screw fixation: Does it relate with spinal cord shift and clinical efficacy

Shu-bing Hou

the third hospital of Shijiazhuang city

Xian-ze Sun (✉ doctors2020@sina.com)

The third hospital of Shijiazhuang city

Feng-yu Liu

the third hospital of shijiazhuang city

Rui Gong

the third hospital of shijiazhuang city

Zheng-qi Zhao

the third hospital of shijiazhuang city

Kuan Lu

the third hospital of shijiazhuang city

Yan-bing Liu

the third hospital of shijiazhuang city

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Abstract

Background

Laminectomy with lateral mass screw fixation (LCSF) is an effective operation type for the treatment of cervical spondylotic myelopathy (CSM), however, the cervical curvature loss is often observed in some patients after operation. Will the cervical curvature change affect the spinal cord drift distance and the decompression effect? The aim of this study is to investigate the effects of different cervical curvature on spinal cord drift distance and clinical efficacy.

Methods

A total of 78 cases of CSM patients underwent LCSF were included in this retrospective study. The cervical curvature was measured according to the Bordon method 6 months after the operation, and the patients were divided into two groups. Group A: 42 cases with reduced cervical curvature ($0 < \text{the cervical lordosis depth} < 7 \text{ mm}$) and group B: 36 cases with normal cervical curvature ($7 \text{ mm} \leq \text{the cervical lordosis depth} \leq 17 \text{ mm}$). The spinal cord drift distance, laminectomy width, neurological functional recovery, axial symptom (AS) severity and the occurrence of C5 palsy in both groups were observed.

Results

The cervical lordosis depth was (5.1 ± 1.2) mm in group A and (12.3 ± 2.4) mm in group B ($P < 0.05$). The laminectomy width was (21.5 ± 2.6) mm in group A and (21.9 ± 2.8) mm in group B ($P > 0.05$). The spinal cord drift distance was (1.9 ± 0.4) mm in group A and (2.6 ± 0.7) mm in group B, with statistically significant difference between the two groups ($P < 0.05$). The postoperative JOA scores in both groups were significantly increased ($P < 0.05$), and there was no significant difference in the neurological recovery rate (61.5% vs 62.7%) between the two groups ($P > 0.05$). According to the grading standard of AS, the severity of AS in group A was significantly higher than that in group B ($P < 0.05$). Three cases (7.1%) of C5 palsy occurred in group A and 4 cases (11.1%) occurred in group B ($P > 0.05$).

Conclusion

After LCSF, more than half of the patients had cervical curvature loss. The smaller of the cervical curvature was, the shorter distance the spinal cord drifted backward. The loss of cervical curvature was related to the severity of axial symptoms, rather than the improvement of neurological function and C5 palsy.

Introduction

Cervical spondylotic myelopathy (CSM) is a common spinal degenerative disease, accounting for about 10%-15% of the total incidence rate of cervical spondylosis. The clinical manifestations include limb numbness and weakness, difficulty in walking, unstable in holding, tendon hyperreflexia, and defecation and urination dysfunction in severe cases [1]. Therefore, CSM patients should receive timely operation treatment once they are clinically diagnosed. The operation objectives include the release of spinal cord compression, the restoration of cervical sequence and the resolution of potential cervical instability [2]. CSM patients with multi-segmental (≥ 3 levels) spinal cord compression are usually treated with posterior decompression operation. Among the many posterior decompression procedures, laminectomy with lateral mass screw fixation (LCSF) is the most applicable procedure for the above operation objectives. The lateral mass screw can simultaneously fix the middle column and the posterior column of the cervical vertebrae. In addition to providing strong immediate stability, it can also achieve correction of the cervical sagittal sequence through a longer arm of force [3–4]. Moreover, selective laminectomy can be performed intraoperatively according to the range and width of the prominent tissues [5].

The most prominent problem in the laminectomy is that the loss of cervical curvature and progression of kyphosis will be easily observed during long-term follow-up [4, 6]. The placement of lateral mass screw has successfully solved the problem of kyphotic deformity, but the problem of reduced curvature of cervical spine remains. After laminectomy, the spinal cord will drift backward under the action of “bowstring principle”. Will the change of the postoperative cervical curvature affect the spinal cord drift distance, the neural functional recovery and the occurrence of adverse events? In this study, we divided CSM patients into 2 groups according to the normal and abnormal postoperative cervical curvature, and observed the differences in related indicators between groups.

1 Patients And Methods

1.1 Patients

Clinical data of 78 cases of CSM patients with normal cervical curvature underwent LCSF treatment at the Third Hospital of Shijiazhuang City from January 2015 to January 2018 were retrospectively analyzed. Six months after operation, the cervical curvature was measured by Bordon method [7] and the patients were divided into 2 groups: 42 cases in group A with reduced cervical curvature ($0 < \text{the cervical lordosis depth} < 7 \text{ mm}$) and 36 cases in group B with normal cervical curvature ($7 \text{ mm} \leq \text{the cervical lordosis depth} \leq 17 \text{ mm}$). There were no significant differences in sex, age, disease course, intraspinal occupation rate, lamiectomy range and follow-up time between the two groups ($P > 0.05$) (Table 1). This retrospective study was approved by the Ethics Committee of the Third Hospital of Shijiazhuang City. All subjects provided written informed consent and the research was conducted in accordance with the principles of the Declaration of Helsinki.

Table 1
Baseline characteristics of the 2 groups

Group	Gender (cases)		Mean age (years)	Disease course (months)	Follow-up time (months)	Intraspinal occupation rate (%)	Laminectomy range (cases)		
	male	female					C3-7	C3-6	C4-7
Group A (42 cases)	18	24	57.3 ± 13.1	12.8 ± 3.6	16.3 ± 3.4	56.9 ± 13.4	24	12	6
Group B (36 cases)	19	17	56.6 ± 12.7	11.6 ± 3.3	17.8 ± 3.7	55.2 ± 12.6	19	13	4
<i>t</i> / χ^2 -value	0.765		0.238	1.524	1.864	0.574	0.563		
<i>P</i> -value	0.382		0.812	0.131	0.066	0.568	0.755		

1.2 Inclusion and Exclusion Criteria

Inclusion criteria: (1) The symptoms, signs and imaging data were consistent with cervical spondylotic myelopathy, (2) The cervical curvature was within normal range and the compression level ≥ 3 segments, (3) Clinical follow-up of at least 12 months was obtained with complete imaging data, (4) The cardiopulmonary and cerebral function were within the normal range and physically able to tolerate surgical treatment.

Excluding criteria: (1) Combined with thoracic and lumbar spinal stenosis, (2) with cervical kyphosis, (3) with cervical fracture, infection, tumor, abnormal coagulation function.

1.3 Operation Methods

After successful general anesthesia, the patient was turned into a prone position, with the head fixed on the Mayfield head frame. A posterior midline incision was made. The spinous process and lamina were separated and exposed outward to the outer margin of the lateral mass. A length of 12–16 mm lateral mass was screwed into the cervical lateral mass based on the Magerl method [8], and a diameter of 3 mm high-speed grinding drill (Stryker, USA) was used to make a triangle-shaped bone gutter at the transition of laminae and lateral mass. The medial cortex of the lamina was grinded to the paper thickness, and then removed by the Kerrison rongeur. After the ligamentum flavum of the head end and the tail end was separated, the laminae were slowly lifted and removed by a towel forceps grasping the root of the spinous process. The laminectomy width should be expanded outwardly according to the

prominent range to maintain the well fluctuation of dural sac. The titanium rod of suitable length was cut and fixed longitudinally after bending.

1.4 Imaging evaluation

Photoshop CS6 software (Adobe Systems Inc., USA) was used to measure the imaging data. X - ray, CT and MR imaging of cervical spine were performed 6 months after operation. The cervical lordosis depth was measured by Bordon method [7]: a straight line (a) was drawn from the posterior lower margin of the odontoid process of axis to the posterior lower margin of the C7 vertebral body, and an arc (b) was drawn along the posterior margin of each cervical vertebra. The maximum distance of the vertical line from (a) to (b) was the cervical lordosis depth (c). (Fig. 1A, C and 2A, C) The laminectomy width in each segment was measured on the CT cross-sectional image, and the average laminectomy width = $(b_1 + b_2 + b_3 + \dots + b_n)/n$ [5]. On the med-sagittal image of cervical MRI, the spinal cord drift distance at C5 level was measured as: the postoperative distance between the posterior edge of the C5 vertebral body and the midpoint of the spinal cord after surgery – the preoperative distance [5] (Fig. 1B, D and 2B, D)

1.5 Neurological function and complications evaluation criterion

The Japanese Orthopaedic Association (JOA) 17-point scoring system was used to evaluate neurological function before and after operation [3]. Neurological recovery rate = $(\text{postoperative score} - \text{preoperative score}) / (17 - \text{preoperative score}) \times 100\%$. Axial symptoms (AS) are often manifested as postoperative neck pain with neck and shoulder stiffness, tension, and discomfort of sore and swollen [9]. According to the evaluation criteria developed by Hosono et al [10]. patients were divided into 4 grades: Good-no stiffness or pain; Minor- symptoms after minor exercise or cold, no significant impact on daily activities, neck movement was not restricted; Major- symptoms occurred frequently, daily activities were affected and require physical therapy or oral analgesics; Severe- symptoms severely interfered with daily activities and required regular oral or intramuscular injection of pain medications. C5 palsy was manifest as postoperative deltoid and/or biceps paralysis without obvious cause, mainly manifested as mild muscle weakness. Some patients may have intractable pain or sensory disturbance in the C5 innervation area [5]. All data were measured and graded by two doctors independently, and the average of the two was used as the final result.

1.6 Statistical Method

SPSS (Version 20.0; IBM, Chicago, IL, USA) statistical software was used to analyze the data. The measurement data were expressed as (mean $\pm$ standard deviation). Two-sample t test was used for comparison between groups. Repeated measures at different time points were compared by repeated measures analysis of variance (RT-ANOVA). Proportions by chi-square test, and grades by the Kruskal-Wallis rank sum test. Two side P values < 0.05 were considered statistically significant.

2 Results

2.1 Comparison of imaging data

The cervical lordosis depth in group A and group B was (5.1 ± 1.2) mm and (12.3 ± 2.4) mm, respectively ($P < 0.05$). The laminectomy width was (21.5 ± 2.6) mm in group A and (21.9 ± 2.8) mm in group B, which was not statistically significant ($P > 0.05$). The spinal cord drift distance in group A was (1.9 ± 0.4) mm and in group B was (2.6 ± 0.7) mm, which there was statistically significant difference between groups ($P < 0.05$). Table 2

Table 2
Comparison of imaging data between the 2 groups

Group	Laminectomy width (mm))	Spinal drift distance (mm)	The depth of cervical lordosis (mm)	
			Preop	6 months postop
Group A (42 cases)	21.5 ± 2.6	1.9 ± 0.4	12.9 ± 2.8	$5.1 \pm 1.2^*$
Group B (36 cases)	21.9 ± 2.8	2.6 ± 0.7	13.1 ± 2.6	12.3 ± 2.4
t-value	0.653	5.517	0.325	14.740
P-value	0.515	< 0.001	0.746	< 0.001
Compared to pre-operation, $*P < 0.05$				

2.2 Comparison of neurological function

At the point of 3 months postoperative and final follow-up, the JOA scores had a significantly increase in both groups ($P < 0.05$), and no significant difference was noted between the two groups ($P > 0.05$). The neurological recovery rate was (61.5 ± 12.3) % in group A and (62.7 ± 13.6) % in group B, and there was no statistical difference ($P > 0.05$). Table 3

Table 3
Comparison of neurological recovery between 2 groups

Group	JOA score			Recovery rate (%)
	preoperative	3 months postop	Final follow-up	
Group A (42 cases)	7.4 ± 1.2	12.2 ± 2.4*	13.3 ± 3.0*	61.5 ± 12.3
Group B (36 cases)	7.6 ± 1.1	12.5 ± 2.6*	13.5 ± 3.2*	62.7 ± 13.6
t-value	0.762	0.529	0.284	0.409
P-value	0.449	0.597	0.776	0.683
Compared to pre-operation, * $P < 0.05$				

2.3 Comparison of AS and C5 palsy

According to the grading standard of axial symptoms (AS), the severity of AS in group A was significantly higher than that in group B ($Z = -2.092$, $P = 0.036$). Three cases (7.1%) of C5 palsy occurred in group A and 4 cases (11.1%) occurred in group B, no significant difference was exist between groups ($P > 0.05$).

Table 4

Table 4
Comparisons of AS severity and of C5 palsy incidence between the 2 groups

Group	AS severity				The incidence of C5 palsy [cases (%)]	
	Good	Minor	Major	Severe	Yes	No
Group A (42 cases)	16	13	7	6	3(7.1)	39(92.9)
Group B (36 cases)	20	11	4	1	4 (11.1)	32 (88.9)
Z/ χ^2 -value	-2.092				0.373	
P-value	0.036				0.542	

3 Discussion

Laminectomy is a surgical procedure with more clinical applications. By removing the posterior laminae, the volume of the spinal canal was effectively enlarged and the spinal cord moves backwards under the action of the tension band, thus avoiding the lasting damage caused by the compressions. It is suitable

for patients with multi-segment cervical disc herniation, continuous ossification of posterior longitudinal ligament, severe spinal canal encroachment and clamp type of compression [1, 3–6, 8]. Some literatures had reported that for the patients underwent laminectomy without fixation, the cervical curvature will have a lost of 4° in the short-term follow-up (1 year after operation) [6], and 21% (9/42) of patients developed postlaminectomy deformity in median follow-up (4 years after operation) [11]. After intraoperative fixation with lateral mass screws, the trend of progressive cervical curvature loss and high frequency of kyphosis deformities were effectively controlled, but the cervical curvature became smaller in some patients still existence [3, 5]. From the analysis on anatomy and biomechanics, both open-door laminoplasty and laminectomy will destroy the spinous process, vertebral plate and posterior ligaments complex to varying degrees, resulting in loss of effective attachment points of the cervical posterior muscle group, weakening of the muscle tension band, loss or straightness of curvature due to the failure to maintain the original cervical curvature [4, 6, 9, 11–12]. It has been reported that maintaining a good physiological curvature can make cervical spine more elastic, relieve shock and buffer stress during movement, and play a role in protecting the spinal cord [7].

Through imaging measurement and clinical data analysis, borden et al [7]. found that the normal cervical curvature should be in the state of lordosis, and the cervical lordosis depth ranged from 7 mm to 17 mm. When the cervical lordosis depth is less than 7 mm, it means the cervical curvature decreases, and when the numerical value is greater than 17 mm, it means the cervical curvature increases. According to the above theory, we conducted a retrospective analysis of 78 CSM patients with normal cervical curvature treated with LCSF, and found that no patients had increased cervical curvature. Forty-two patients with reduced cervical curvature (group A) and 36 patients with normal cervical curvature (group B), the cervical lordosis depth was (5.1 ± 1.2) mm and (12.3 ± 2.4) mm, respectively. According to the statistical analysis, the patients with reduced postoperative cervical curvature accounted for 53.8% among all the included patients. What caused the result that more than half of the patients developed abnormal cervical curvature after operation? We consider the poor positioning of cervical vertebra during the operation as one of the key factors. In the prone position, the trunk is higher than the head and the cervical vertebra is in a forward flexion state. If the cervical lordosis is not restored by elevating the head before nut locking, the reduced cervical curvature will appear after operation. Secondly, the intraoperative curvature of the titanium rod is one of the key factors. By increasing the curvature of the titanium rod, the poor preoperative curvature of patients can be corrected [4, 13]. The normal cervical lordosis can be affected by the undersized curvature of the titanium rod as well. Thirdly, the destruction of cervical osseous structure, the loss of effective attachment points of extensor groups and the weakening of muscle tension are also key factors inducing the reduced postoperative cervical curvature [14–15].

Therefore, will the neurological function recovery and the occurrence of adverse events affected by the reduced postoperative cervical curvature? In this study, the widths of laminectomy in both groups were generally the same (21.5 mm vs 21.9 mm). However, there was significant difference in the postoperative drift distance, which was (1.9 ± 0.4) mm in group A and (2.6 ± 0.7) mm in group B. The post-operative neurological function of both groups recovered significantly and the recovery rate of both groups showed

no significant statistical difference (61.5% vs 62.7%). Although it had been reported that the significant loss of postoperative cervical curvature or kyphosis was a risk factor for poor prognosis [3–4], we believe that the recovery effect of nerve function is mainly related to the sufficient or insufficient decompression of the spinal cord, and the reduced postoperative cervical curvature will not affect the recovery of nerve function. The transverse diameters of the cervical spinal cord differed significantly in different segments. Even at the widest C5 segment, the transverse diameter of the spinal cord was only 13 mm [16]. Theoretically, during laminectomy, the laminectomy width is only required to be greater than the transverse diameter of the corresponding segment of the spinal cord. Zhao et al [5]. found that the postoperative neurological function of the patients recovered significantly by setting the laminectomy width as 16.7 mm. Therefore, in this study, the laminectomy width of more than 21 mm could completely decompress the spinal cord. In addition, we believe that the spinal cord drift distance is related to cervical curvature, agreeing with the opinion of Baba et al [17]. After laminectomy, the effective space of the spinal canal will be released, and the dural sac will drift backward under the action of the “bowstring principle” while expanding. The drift distance is an imaging manifestation of the tensile stress generated by the cervical curvature, rather than the evidence of the sufficient or insufficient decompression of the spinal cord.

We are still unknown about the specific mechanism of the formation of AS and C5 palsy. Some literatures had reported that the destruction of muscle-ligament complex and articular capsule, the atrophy of posterior cervical muscles and the change of cervical curvature and cervical instability are associated with the occurrence of AS [3–4, 6, 9–10, 12]. However, C5 palsy is associated with multiple mechanisms such as ischemia and hypoxia, segmental spinal cord disorders, and embolism caused by increased nerve root tension [5, 13, 18–19]. Zhao et al [5]. and Du et al [13]. found that the incidence of postoperative C5 palsy significantly decreased by reducing the nerve root tension with nerve root canal decompression. Lau et al [4]. believed that the increase of postoperative cervical lordosis was negatively correlated with the severity of axial pain, especially for lordosis greater than 20°. While the increased cervical lordosis would promote the backward drift of the spinal cord, and further increase the tension of C5 nerves, leading to the occurrence of C5 palsy [20]. For this contradiction, since the balance point of cervical curvature is difficult to select, it is difficult for spine surgeons to balance the occurrence of AS and C5 palsy by controlling the cervical curvature. In this study, the postoperative severity of AS in group A with reduced cervical curvature was significantly higher than that in group B with normal curvature. Although the incidence of C5 palsy in group B was higher than that in group A (11.1% and 7.1%, respectively), there was no statistical difference between both groups. Therefore, we can make a conclusion that, as long as the postoperative cervical curvature is maintained as the normal level as that before the operation, it will form a new balance between reducing AS and avoiding the occurrence of C5 palsy, neither increasing the severity of AS nor inducing the occurrence of C5 palsy.

Conclusion

After the laminectomy with lateral mass screw fixation, more than half of patients had cervical curvature loss, which was related to the anteflexion of the fixed cervical vertebra, small bending of the titanium rod

and the destroy of the posterior neck muscle attachment point. The smaller the cervical curvature was, the shorter distance the spinal cord drifted backward. The loss of cervical curvature was related to the occurrence of axial symptoms, rather than the neural functional recovery and C5 palsy.

Abbreviations

LCSF: Laminectomy with lateral mass screw fixation; CSM: Cervical spondylotic myelopathy; AS: axial symptom; JOA: Japanese Orthopedic Association

Declarations

Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

S-BH performed the data collection, analyzed and interpreted the patient data, and wrote the manuscript. S-XZ performed background research for the topic, conducted the whole study, and prepared the manuscript for submission. FY and RG performed the data collection. All authors read and approved the final manuscript.

Ethics approval and consent to participate

All experimental protocols in this research were approved by The Third Hospital of Shijiazhuang City Ethics Committee, and informed consent was obtained from all patients. The methods were carried out in accordance with the relevant guidelines, including any relevant details.

Consent for publication

Informed consent was obtained from all individual participants included in the study.

Competing interests

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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Figures

Figure 1

A 59-year-old male patient suffered from numbness in both hands and intermittent claudication for 13 months. A: Preoperative X-ray showing degenerative change of cervical vertebra, and the cervical lordosis depth was 13.2mm. B: Preoperative MRI showing cervical disc herniation with spinal stenosis at C3-7 segments. C: Patient underwent C3-7 LCSF, X-ray film showed a significant reduction in cervical curvature 6 months after operation, and the cervical lordosis depth was 5.3mm. D: Postoperative MRI showing an adequate spinal decompression, with a backwards drift distance was 1.6 mm.

Figure 2

A 58-year-old female patient suffered from numbness and weakness in four limbs for 15 months. A: Preoperative X-ray showing hyperostosis in the anterior cervical vertebrae, and the cervical lordosis depth was 13.9mm. B: Preoperative MRI showing disc herniation with ligamentum flavum hypertrophy at C3-7 segments and the spinal cord severely compressed. C: Patient underwent C3-7 LCSF, X-ray showing the cervical curvature maintained well, and the cervical lordosis depth was 12.7mm. D: Postoperative MRI showing the spinal canal was smoothly, with a drift distance was 2.9mm.