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Original Article

Laminoplasty and simultaneous C2 semi-laminectomy with internal fixation in treating ossification of the posterior longitudinal ligament in cervical discs at C2 segment

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Abstract: Objective: To explore the effect of open-door laminoplasty and simultaneous C2 semi-laminectomy with lateral mass screw fixation (LSLF) in treating ossification of the posterior longitudinal ligament (OPLL) in cervical discs at C2 segment. Methods: In this retrospective study, 76 patients diagnosed with OPLL in cervical discs at C2 segment from November 2016 to May 2019 were included. These patients were assigned into a LSLF group (n=41, LSLF surgery) and LF group (n=35, laminectomy and lateral mass screw fixation) according to the treatment they received. The surgery time and intraoperative blood loss were recorded. Improvements in neurological function (JOA score), cervical curvature index (CCI), spinal cord drift distance, cross-sectional area (CSA) of the posterior muscles from cervical spine, occurrence of C5 palsy, and severity of axial symptoms were evaluated between LSLF group and LF group. Results: Compared with LF group, the operative time was longer and blood loss volume was higher in LSLF group ($P<0.05$). No statistical difference was found in decompression width between LSLF group and LF group, while the drift distance of spinal cord in LSLF group was larger than that in LF group ($P<0.05$). No obvious differences were observed in anteroposterior dural sac diameter after the surgery between LSLF group and LF group. CSA in LF group decreased more than that in LSLF group ($P<0.05$). No remarkable difference was obtained in CCI at the final follow-up between LSLF group and LF group. The NDI score after surgery in the LSLF group was significantly decreased compared to LF group ($P<0.05$), while no differences were observed in JOA scores or the neurological recovery rate between LSLF group and LF group. The occurrence of C5 palsy in the LSLF group was 4.9%, which was less than that of LF group (20.0%). In contrast to LF group, postoperative axial symptoms in LSLF group were decreased ($P<0.05$). Conclusion: Compared to LF, LSLF could better improve neck functions, and reduce the severity of axial symptoms and the occurrence of C5 palsy for patients with OPLL at C2 segment.

Keywords: Ossification of the posterior longitudinal ligament, laminoplasty, laminectomy, C5 palsy, axial symptoms

Introduction

In the pathologic process of cervical ossification of posterior longitudinal ligament (OPLL), calcium is deposited abnormally in the posterior longitudinal ligament under actions of many factors. It can lead to progressive cervical spinal stenosis, and the spinal cord is gradually compressed, which can cause numbness and weakness of the limbs, difficulty in walking, increased muscle tone, and positive pathologic signs. In severe cases, dysfunction of urination may happen [1-3]. The incidence of OPLL in East Asian countries is relatively high. Systematic epidemiological studies had found that the prevalence of cervical OPLL ranged from 1.9% to 4.3% in a population of over 30 years old in Japan. In Korea and China, the prevalence was 3.6% and 1.7%, respectively [2]. There is no effective drug to reduce and stop the occurrence and progress of OPLL in clinical practice. Surgical decompression is the only valid method for the therapy of OPLL of the cervical spine.

Anterior decompression can remove the OPLL directly by cervical discectomies and/or corpectomies to avoid the compression and impinging of the spinal cord [2, 3], but for OPLL that is at C2 segment, it is extremely hard to decompress the spinal cord. As an indirect decompression, the posterior approaches relieve spinal cord compression by expanding the effective volume of the spinal canal. It is especially suitable for patients with spinal cord compression involving more than 3 levels of segments, K-line positive, and cervical OPLL involving the C2 segment [1, 4-6]. Various posterior decompression surgeries have been described, including laminectomy with internal fixation [4], open-door laminoplasty [5, 6] and laminoplasty with internal fixation [5, 7], each with unique characteristics and benefits. Since the spinous process of C2 is an critical attachment point for the semispinalis cervicis, laminectomy and laminoplasty will lead the loss of the muscle attachment point, which weakens the function of the semispinalis cervicalis in the resisting axial load and tension [8]. On the premise of preserving the C2 spinous process to the greatest extent, how to adequately decompress the spinal cord for OPLL patients involving C2 segment is a major challenge faced by spinal surgeons. Focus on this problem, we tried to perform laminoplasty and simultaneous C2 semi-LSLF and LF surgeries to treat patients with OPLL involving the C2 segment, to clarify whether there is a clinical discrepancy between two groups.

Materials and methods

General information

Seventy-six patients diagnosed with OPLL at C2 segment of cervical spine who accepted decompression from November 2016 to May 2019 were retrospectively enrolled in this study. Patients were assigned into a LSLF group and a LF group according to the surgical methods. 41 patients (23 males and 17 females with an age of 61.2±8.3 years old) received laminoplasty and simultaneous C2 semi-LSLF surgery and 35 patients (17 males and 18 females with an age of 60.8±8.1 years old) received LF surgery. All of the patients signed the written informed consent forms. This research was approved by the ethics committee of the Third Hospital of Hebei Medical University (No. S2021-030-1). The follow-up time was one year at least. The regular outpatient clinic visit, telephone follow-up, or return visit at interval of three months was performed.

The criteria of inclusion and exclusion

The inclusion criteria: (1) patients with typical clinical manifestations of OPLL, such as numbness and weakness of limbs, holding instability, increased muscle tension, knee reflex hyperreflexia, positive pathological signs; (2) patients with multi-segmental spinal cord compression (≥3 segments) involving C2 segment; (3) patients with normal heart, liver and kidney function and could tolerate the decompression surgery; (4) patients with good compliance and able to carry out regular clinical follow-up.

The exclusion criteria: (1) patients with spinal canal spinal stenosis from thoracic or lumbar vertebra; (2) patients with concurrent fractures of cervical spine, tumors, developmental abnormalities and infections; (3) patients with coagulation disorders, recent infection and inflammatory reaction; (4) patients with a history of cervical spine surgery.

Surgical procedure

After successful anesthetization, the patient was flipped to a ventricumbent position and the head was placed on the field. A longitudinal incision behind the neck was made to expose the inferior cervical spinous lamina and process, and it was extended to the outer edge of the lateral mass on both sides.

LSLF group: the semispinalis cervicis that adhered to the lower part of C2 spinous process was stripped by electrotome, a dome-like decompression on the C2 lamina was created by using the high-speed grinding drill (Stryker, USA) of 3 mm diameter, and the lower spinous process and the inferior 2/3 part of the lamina, and cranial C2 lamina were polished off without dissecting the attached muscles. According to Magerl method [9], the lateral mass screws and pedicle screws (Medtronic, Inc., USA) of proper length were inserted into the vertebrae. Open-door laminoplasty was conducted in the subaxial vertebrae.

The cortex inside the vertebral lamina was kept and the medial and lateral cortices were removed. The side with fewer symptoms was applied as the hinge side, while the side with more symptoms was applied as the open side. The spinous process was trimmed to a suitable length, the head and caudal interspinous ligament and ligamentum flavum were cut off, and then, the lamina was slowly lifted to 40°. The cervical spine was adjusted to a proper curvature, the titanium rod was placed into the U-shaped groove of the nail tail after pre-bending and locked, and then a 10# mersilk was used to pass through the spinous process root and fix the opened lamina on the titanium rod.

LF group: According to Magerl method [9], the lateral mass screws and pedicle screws (C2) (Medtronic, Inc., USA) of proper length were inserted into the vertebrae. The high-speed grinding drill of a diameter of 3 mm (Stryker, USA) was used to build bilateral slots at the line of transition between lateral masses and vertebral laminae, and then the inner and outer cortex were removed. The ligamentum flavum was cut off at the head and tail, and the spinous process root was clamped with Kocher forceps, followed by slowly lifting and removing the laminae at the compressed level.

After the drainage tube was inserted into the wound, absorbable thread (Ethicon, Johnson & Johnson) was used to suture the wound layer by layer. The drainage tube was removed after drainage volume <30 ml/d. A hard collar was applied for 4-6 postoperative weeks.

Evaluation values

The preoperative and postoperative neurological function was evaluated by the points-scoring system from Japanese Orthopaedic Association (JOA), which was based on questionnaires and direct patient examinations [3]. A grade evaluation standard proposed by Hosono et al. [10] was adopted to evaluate the postoperative axial symptoms (AS), including severe (analgesics or routine anesthetics injection required for the painful muscles), moderate (requiring physical therapy), and mild (requiring no treatment). C5 palsy featured as new incidence of deltoid and/or biceps brachii paralysis after surgery, usually with a mild myasthenia and C5 dermatome sensation disturbances [6, 8]. The scores of Neck Disability Index (NDI) was applied to evaluate the pain and function of neck pre- and post-operatively [11].

The cervical curvature index (CCI) was applied to examine the curvature change of cervical spine. The lateral X-ray of the cervical spine was taken with the patients in a neutral position. Line A was made from C2 to C7 vertebral posterior inferior angle, and vertical distances from C3-6 vertebral posterior inferior angle to b was a1, a2, a3, a4. CCI=(a1+a2+a3+a4)/b ×100% [7, 8]. With the help of Photoshop CS2 image measurement software (Adobe Systems Inc., United States), the decompression width © was measured, that was the distance between the inner edges of the remnant lamina. The canal occupying ratio at the C2 level was evaluated from the cross-sectional image of the CT. Spinal cord drift distance (d): The distance from the posterior edge of the C3 vertebral body to the midpoint of the spinal cord in the midsagittal MR images of cervical spine was examined pre- and post-operatively, d=d2-d1 [12]. The cross-sectional areas (CSA) of the posterior muscles of cervical spine were measured by AutoCAD software (Autodesk Inc., United States) at one year after surgery. Based on transverse MR images at C3-4 level, the areas of trapezius, semispinalis cervicis, splenius capitis, semispinalis cervicis, multifidus, semispinalis capitis, longissimus capitis, posterior scalene, levator scapulae, longissimus cervicis, medial scalene and anterior scalene muscles were calculated. The anteroposterior dural sac diameter (e) on the midsagittal MR images of cervical spine involving C2 segment was measured [8].

Statistical analyses

Clinical and radiographic values were processed by SPSS statistical software package (Version 20.0; IBM Corporation, United States). The data among different timepoints were compared using LSD-test after ANOVA. Comparison between groups was conducted by T-test or Chi-square test. A threshold of $P<0.05$ by a two-tailed test was regarded as a significant difference.

Results

Comparison of general data

No obvious differences were found in the age, gender, course of disease, follow-up time, occupying ratio, OPLL morphologic types, or decompression segments between the two groups, as shown in **Table 1**. The imageological results of patients before and after LSLF or LF are shown in **Figures 1** and **2**.

Table 1. General conditions compared between two groups

Data	LSLF group N=41	LF group N=35	t/χ^2 value	*P* value
Gender			0.598	0.439
Male	23	17		
Female	17			
Age (years)	61.2±8.3	60.7±8.1	0.264	0.792
Disease course (months)	21.3±3.8	20.1±3.4	1.439	0.154
Follow-up period (months)	17.9±2.5	18.2±2.7	0.502	0.616
Occupying ratio (%)	55.9±7.6	54.6±7.3	0.756	0.451
OPLL morphologically types			0.583	0.747
Continuous	17	12		
Segmental	8	9		
Mixed	16	14		
Decompression segments			1.015	0.798
C2-4	3	2		
C2-5	13	15		
C2-6	18	13		
C2-7	7	5		
Length of hospital stay (days)	5.7±0.8	6.0±0.9	1.538	0.128

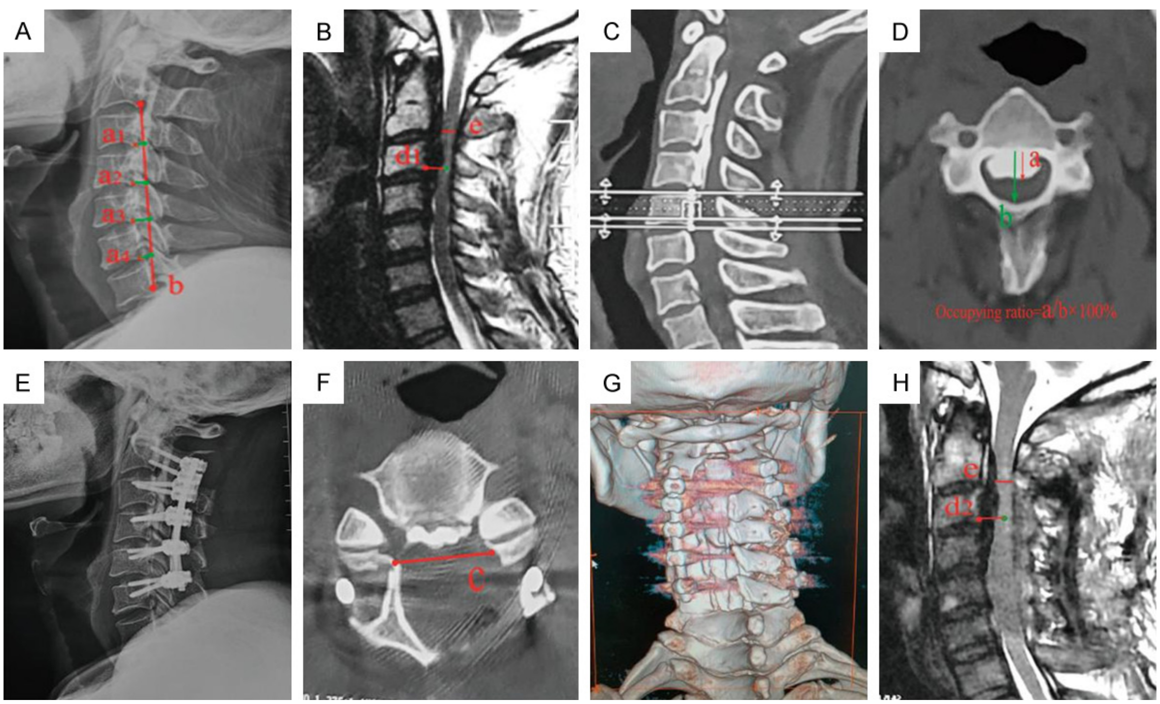

Figure 1. A 56-year-old male patient with numbness and weakness of limbs for 16 months in LSLF group. A: Preoperative X-ray showed the formation of OPLL in the posterior edge of the vertebral body, involving C2 segment; B: MRI showed cervical canal stenosis at C2-6 level with spinal cord compression; C: Sagittal reconstruction of CT showed the OPLL in continuous type; D: Cross-section of CT demonstrates the condition of spinal canal occupation; E: Postoperative X-ray showed laminoplasty and simultaneous C2 semi-laminectomy with lateral mass screw fixation; F: Postoperative cross section of CT showed lamina opening angle and opening width; G: 3D reconstruction of CT showed the decompression and internal fixation range; H: Postoperative MRI showed a sufficient decompression and the spinal cord drifting backward, the anteroposterior dural sac diameter was increased at C2 segment.

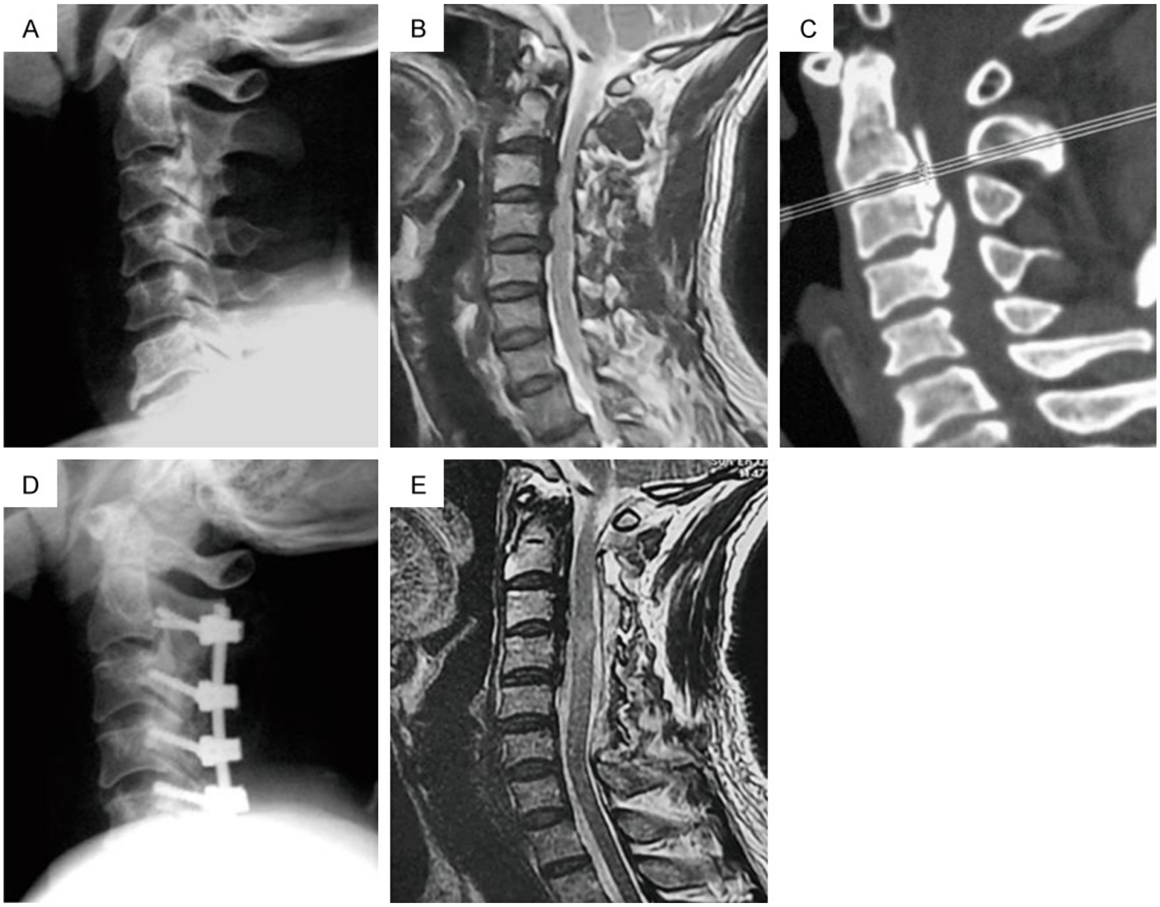

Figure 2. A 58-year-old male patient with numbness of hands and unsteady walking for 17 months in LF group. A: Preoperative X-ray showed the cervical curvature straightened and the ossified tissue formatted at the posterior margin of the vertebral body; B: MRI showed cervical canal stenosis at C2-5 level with spinal cord compression; C: Sagittal reconstruction of CT showed the OPLL in segmental type; D: Postoperative X-ray showed laminectomy with lateral mass screw fixation; E: Postoperative MRI showed the spinal canal smoothly, the spinal cord drifting backwards significantly, and the anteroposterior dural sac diameter increased at the C2 segment.

Comparison of intraoperative data

All patients were successfully operated and there were no spinal cord or nerve injuries during the operation. In the LSLF group, the mean operative time was (165.9±25.1) min and the intraoperative blood loss volume was (327.5±53.7) ml, and those in the LF group were (139.3±22.6) min and (293.8±49.2) ml, respectively. The differences were significant (all $P<0.05$).

Comparison of postoperative imaging data

No significant differences were obtained for decompression width between two groups, but the drift distance of spinal cord in LSLF group was larger in contrast to LF group ($P<0.05$). After the surgery, the anteroposterior dural sac diameter increased obviously in both groups ($P<0.05$), but no statistical differences were observed between two groups. The cross-sectional areas of the posterior cervical muscles in two groups decreased significantly ($P<0.05$), and patients from LSLF had a more significant decrease as compared with LF group ($P<0.05$). At the final follow-up, the index of CCI in both groups increased significantly in contrast to the preoperative level ($P<0.05$), but there was no statistical difference between LSLF group and LF group, as shown in **Table 2**.

Comparison of neurological function and neck function

After surgery, the JOA score significantly increased in the LSLF group and LF group ($P<0.05$), and there was no statistical differ-

Table 2. Comparison of imaging data between two groups

Group	Decompression width (mm)	Spinal cord drift distance (mm)	Anteroposterior dural sac diameter (mm)		cross sectional of posterior cervical muscles (cm²)		CCI (%)	
			Preop	3 months postop	Preop	1 year postop	Preop	Final follow-up
LSLF group (41 cases)	20.3±2.5	3.4±0.8	8.1±1.6	11.6±2.3*	35.3±4.6	32.1±3.3*	15.6±2.7	17.8±2.9*
LF group (35 cases)	21.1±2.7	2.8±0.5	8.3±1.7	12.7±2.5*	36.1±4.9	27.8±2.9*	16.2±2.5	18.3±3.1*
t value	1.340	6.298	0.527	2.029	0.733	5.983	0.998	0.725
P value	0.184	<0.001	0.599	0.059	0.465	<0.001	0.321	0.470

Note: CCI: cervical curvature index. Compared with before surgery, *P<0.05.

Table 3. Comparison of neurological function and neck function recovery between two groups

Group	NDI score			JOA score			Recovery rate (%)
	Preop	3 months postop	Final follow-up	Preop	3 months postop	Final follow-up	
LSLF group (41 cases)	13.4±2.6	9.7±1.8*	8.1±1.2*	7.3±1.8	11.7±2.6*	13.1±3.0*	60.8±10.2
LF group (35 cases)	13.7±2.8	12.3±2.2*	9.4±1.5*	7.1±1.6	12.3±2.7*	13.3±3.2*	62.6±11.3
t value	0.483	5.666	4.196	0.507	0.985	0.280	0.729
P value	0.629	<0.001	<0.001	0.613	0.327	0.779	0.467

Note: NDI: Neck disability index; JOA: Japanese Orthopedic Association. Compared with before surgery, *P<0.05.

Table 4. Comparison of complications between the two groups

Group	C5 palsy		Axial symptoms		
	Yes	No	Severe	Moderate	Mild
LSLF group (41 cases)	2 (4.9%)	39 (95.1%)	2 (4.9%)	13 (31.7%)	26 (63.4%)
LF group (35 cases)	7 (20.0%)	28 (80.0%)	7 (20.0%)	13 (37.1%)	15 (42.9%)
χ^2 value	4.139			-2.095	
P value	0.041			0.036	

ence in neurological recovery rates between LSLF group and LF group (60.8% vs. 62.6%). The NDI score significantly decreased in two groups (P<0.05), but patients from LSLF group exhibited a significantly lower score than those in LF group (P<0.05), as shown in **Table 3**.

Comparison of postoperative complications

The occurrence of C5 palsy was 4.9% in LSLF group and 20.0% in LF group (P<0.05). Postoperative axial symptoms in LF group were more severe than those in the LSLF group (P<0.05), suggesting that the LSLF group experienced milder axial symptoms than the LF group. The average follow-up time was (18.1±2.6) months. In the period of follow-up, there was no loosening of screws, prolapse, or "opened lamina reclosing" phenomenon, as shown in **Table 4**.

Discussion

The occurrence of cervical ossification of the posterior longitudinal ligament (OPLL) is related not only to genetic factors, but also closely related to the external environment, and the two factors interact and promote each other [2]. It has been reported that the radiologic progression of cervical OPLL is a gradual aggravation process. Ossification foci of posterior longitudinal ligament can grow in the spinal canal at longitudinal plane and transverse plane. Its lateral extension speed is 0.4 mm/year and longitudinal extension speed is 0.67 mm/year [13]. The morphology of OPLL can usually be classified as 4 types: segmental, continuous, mixed, and localized [1, 13]. Chiba et al. [14] found that mixed and continuous type OPLL could be predictive of radiographic progression with an average growth in superior extension and inferior extension of 1.5 mm and 1.3 mm at one year respectively, and an average increase in thickness of anteroposterior of 1.1 mm. In this study, OPLL had extended to C2 segment, and the spinal cord was compressed seriously. With the help of CT scan and sagittal reconstruction, it is found that mixed type accounts for the highest proportion, reaching 39.3%, followed by continuous type (38.2%), and the lowest was continuous type (22.3%). The canal occupying ration reached 55.3%.

Since cervical OPLL is increasing, conservative treatment cannot control the progress of OPLL. Once the clinical symptoms are shown, the patients need to undergo surgical treatment as soon as possible. Cervical OPLL can be treated by an anterior (i.e., corpectomy and fusion) [3] or posterior (i.e., laminoplasty or laminectomy with/without fusion) approach [4, 6-8, 11], or both. The best surgical approach depends on the type of ossification, extension of OPLL, the sagittal sequence of the cervical spine, the degree of spinal stenosis, and whether there is a history of cervical spine surgery. In this study, OPLL had extended to the C2 segment, so decompression from the anterior approach would greatly increase the technical difficulty and higher complication rates. In this circumstance, spine surgeons have tended to choose posterior decompression [4, 6, 11, 13]. In the study by Sun et al. [6], open-door laminoplasty involving dome-like decompression of C2 was used to treat OPLL. This procedure has the characteristics of less intraoperative bleeding and low complications. However, during follow-up, it was found that the cervical Cobb angle significantly decreased from 11.9° to 8.2°. Other studies found that for cervical degenerative myelopathy with or without kyphosis, LF surgery could significantly improve the curvature of cervical spine after surgery [12, 15]. Moreover, Saito et al. [16] elucidated that a large segmental motion at the peak of the OPLL was an independent risk factor associated with a poor outcome, and Ha et al. [11] concluded that laminectomy with instrumented fusion would provide more stabilization and could suppress the progression of OPLL thickness. Therefore, the implantation of stabilizing devices such as lateral mass screws is essential for laminectomy. Multi-segment laminectomy, especially for the defect in the C2 spinous process, will inevitably lead to the loss of valid points of attachment for the posterior muscles of cervical spine represented by cervical semispinous muscle, leading to atrophy of the posterior muscles of cervical spine and a high occurrence of axial symptoms [8].

In this study, we tried open-door laminoplasty combined with simultaneous C2 semi-LSLF surgery and LF operation for OPLL patients involving the C2 segment. Since the LSLF group had dome-like decompression, open-door laminoplasty and fixation fusion at the same time, therefore, the LSLF group experienced longer mean operative time and more blood loss than the LF group. Although partial C2 lamina retention and the laminae opening to a certain angle in the LSLF group would limit the spinal cord backward drift, the neurological function of the two groups were significantly restored after the operation, and no difference was obtained in neurological recovery rates between the LSLF group and LF group (60.8% vs. 62.6%). The distance of spinal cord drift is very susceptible to decompression range, decompression with [12] and cervical curvature [17]. The distance of drift is not positively associated with the recovery of neurological function, but is closely related to the incidence of C5 palsy [17, 18]. In the present study, the distance of spinal cord drift in LSLF group was significantly larger than that in LF group, which corresponded to the incidence of C5 palsy was 4.9% in LSLF group and 20.0% in LF group. We conclude that the anteroposterior dural sac diameter can truly reflect the relief of spinal cord compression. The present research showed that the anteroposterior dural sac diameter in two groups increased obviously, but no difference was observed between the LSLF group and LF group.

Compared with C2 segment laminectomy, C2 semi-laminectomy only removes parts of the spinous process and the lower 2/3 of the lamina, which can not only achieve sufficient decompression of the C2 spinal cord, but also retain the relative integrity of the spinous process and provide important attachment for the semispinalis cervicis. The proportion of posterior extension force caused by the cervical semispinalis in the total contraction force of the posterior cervical muscles was 37%. The mechanical stabilization device formed by cervical semispinalis and C2 spinous process played a critical action in retaining the posterior tension of the cervical spine and physiological lordosis [8, 10, 19]. The rest laminae were opened to 40°, and then the laminae were fixed to the titanium rod on the opposite side with silk thread. This procedure maintained the integrity of cervical spinal canal, and avoided re-compression of the scar tissue, and at the same time, the posterior cervical muscles could attach to bony structures, thereby reducing postoperative cervical muscle atrophy [8]. In this study, the cross-sectional areas of the posterior muscles of cervical spine in both groups were reduced obviously in contrast to that before surgery, but the LF group atrophied more severely than the LSLF group. Moreover, postoperative axial symptoms in the LF group were more severe than those in the LSLF group, and the NDI score recovered more significant in LSLF group than in LF group.

Axial symptoms are one of the most frequently reported postoperative complications following cervical spine operation in clinical practice. It has been reported in the literature that the occurrence of axial symptoms may be associated with factors including muscle-ligament complex injury, posterior cervical muscle atrophy, capsula articularis destruction, loss of cervical curvature or lodorsis, loss of spinal stability, or long time wearing of a neck collar [8, 10, 12, 17, 20-22]. In order to relive the axial pain, Chen et al. [21] applied C3 laminectomy and reconstructed the midline structures in situ during the laminoplasty. Yang et al. [8] designed a new titanium plate to re-construct the posterior extensor attachment-point, so as to achieve better improvement of cervical curvature and decrease the atrophy of muscle, especially, decrease the axial symptoms severity. Du et al. [22] found that the cervical curvature loss would lead to a high incidence of axial symptoms either in laminectomy or laminoplasty. The patients from the research were fixed with lateral mass screws, and their cervical curvature was significantly restored when compared with preoperative level. With the help of image measurement software, CSA of the posterior muscles of cervical spine decreased more severely in the LF group than in the LSLF group. We deduced that the atrophy of the posterior muscles of cervical spine would aggravate axial pain, which would further affect sleep, work, reading, concentration and driving. These aspects are the main items of the NDI scoring system, resulting in a higher NDI scores for patients in the LF group after surgery.

This study has some limitations. First, the sample size was not large enough. Second, more long-term indicators are needed to be evaluated. Third, the mechanisms of LSLF surgery were not investigated. Therefore, conducting a prospective, multicenter, randomized controlled and large-sample clinical study on LSLF surgery for treating patients with OPLL involving C2 segment is warranted to provide more evidence.

In conclusion, both LSLF and LF can improve the neurological function and cervical curvature for OPLL patients involving C2 segment. Despite the surgical trauma, LSLF could decrease the C5 palsy by controlling the distance of spinal cord drift and reduce the severity of axial symptoms by decreasing the atrophy of posterior cervical muscles.

Disclosure of conflict of interest

None.

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