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Extension of decompression to C2 doesn't affect the spinal sagittal parameters compared with standard open-door laminoplasty

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Abstract

We modified and extended laminoplasty to the upper cervical spine on patients with canal stenosis associated with upper cervical spinal ossified lesions. However, whether the extended decompression range of laminoplasty can cause further effects on cervical stability is rarely studied at present.

A retrospective study to analyze the relationship between the surgical levels and cervical sagittal parameters effects was performed in patients with cervical spondylosis myelopathy who had undergone posterior cervical expansive open-door laminoplasty with/without extending to C2.

In total, 64 patients were divided into 2 groups according to the surgical levels. Radiologic outcomes of occipito-cervical angle (C0-2 Cobb angle), CL C27 Cobb angle, cervical sagittal vertical alignment, T1-Slope (T1S), T1S minus CL (T1S–CL), spino-cranial angle and center of the sella turcica–C7 SVA (St-SVA) were evaluated on lateral X-rays of the cervical spine at pre-operation, post-operation, and 2-year follow-up. The patient's health-related quality of life was obtained including neck disability index, Japanese orthopaedic association scores, and visual analog scale.

Changes in sagittal parameters were observed in both groups after surgery. T1S, cervical sagittal vertical alignment, and T1S-CL significantly increased and CL decreased in 2 groups of patients postoperative. After a 2-year follow-up period, the C0-2 Cobb angle was found to increase compared to preoperative records. In addition, there were no significant differences in spino-cranial angle and st-SVA between preoperative and 2 years follow-up measurements. Health-related quality of life was improved in both groups and was not significantly different.

Herein, the parameters indicated a tilting forward of the lower cervical spine and a more lordotic upper cervical spine to maintain a horizontal gaze in patients. However, C2 to 7 laminoplasty was performed to achieve satisfactory clinical results without significantly changing the spinal sagittal parameters.

Abbreviations: AS = axial symptoms, C0-2 Cobb angle = occipito-cervical angle, CL = C2-7 Cobb angle, cSVA = cervical sagittal vertical alignment, EODLP = extension of open-door laminoplasty, HRQOL = health-related quality of life, JOA score = Japanese orthopaedic association scores, NDI = neck disability index, ROM = range of motion, SCA = spino-cranial angle, T1S = T1-Slope, VAS = visual analog scale.

Keywords: cervical vertebrae, decompression, laminoplasty, spinal cord diseases, spondylosis

1. Introduction

Due to the reliability of the long-term clinical efficacy and simplicity of operation since its invention, laminoplasty has become a common surgical procedure in spinal surgery.[1–3] Based on the bowstring principle it can expand the volumes of the spinal canal and achieve the effect of indirect decompression by moving the spinal cord dorsal shift. However, patients with canal stenosis associated with upper cervical spinal ossified lesions may not achieve full decompression due to C3-7 laminoplasty limited range. As a result, we modified and extended laminoplasty to the upper cervical spine. But

WW and CX contributed equally to this work.

Informed consent was waived due to the retrospective nature of the study.

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

The study design was approved by the ethics committee of Shanxi Bethune Hospital.

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laminoplasty itself may damage the posterior paravertebral muscle and ligament structures during lamina exposure, this may lead to the loss of cervical stability, axial symptoms (AS), and even kyphosis deformity, which ultimately affect patients' outcomes.[4,5] Whether the extended decompression range of laminoplasty can cause further effects on cervical stability is rarely studied at present.

The cervical spine is the central axis that supports the canter gravity of the skull and visual balance, stability and mobility are its major functional characteristics. In recent years, several studies propose the use of cervical parameters to characterize the sagittal balance and evaluate the preoperative status and prognosis of patients.[6] This study conducted a retrospective analysis of patients who had undergone laminoplasty with/without extending to C2 at our hospital and measured sagittal parameters of the cervical spine before, after the operation immediately, and 2 years duration of follow-up. We then analyzed the relationship between the surgical levels and cervical sagittal parameters effects.

2. Methods

2.1. General data

We retrospectively reviewed the clinical and radiological data from patients with cervical myelopathy who underwent laminoplasty with/without extending to C2 in our hospital between February 2014 and December 2017. This study was approved by the Institutional Review Board of the authors' affiliated institutions. The inclusion criteria were as follows: Imaging and neuroelectrophysiologic examinations suggested cervical spondylosis myelopathy; Complicated with obvious signs of spinal cord injury; and Underwent laminoplasty; Patients who had been followed up for at least 24 months after the operation. Exclusion criteria included: Patients with instability or congenital deformity of the cervical spine; Patients who cannot stand up to take radiographs; Patients with trauma, infection, or a tumor; previous history of cervical spine surgery and; Incomplete follow-up or imaging data.

The patients were divided into 2 groups based on the decompressed ranges: those who underwent C3 to 7 laminoplasty placed in the traditional-type laminoplasty group (C); those who underwent C2 to 7 laminoplasty in the extended laminoplasty group (E).

2.2. Surgical approach

2.2..1. Extension of open-door laminoplasty (EODLP) to C2. As reported previously, an extension of open-door laminoplasty was performed on C2 to 7 level.[4]

2.2..2. C3-7 open-door laminoplasty. Standard open-door laminoplasty was performed on C3 to 7 level.

2.3. Imaging evaluation

The imaging parameters of the lateral X-ray of the cervical spine were measured preoperatively, postoperatively, and 2 years later follow-up. The evaluated imaging parameters

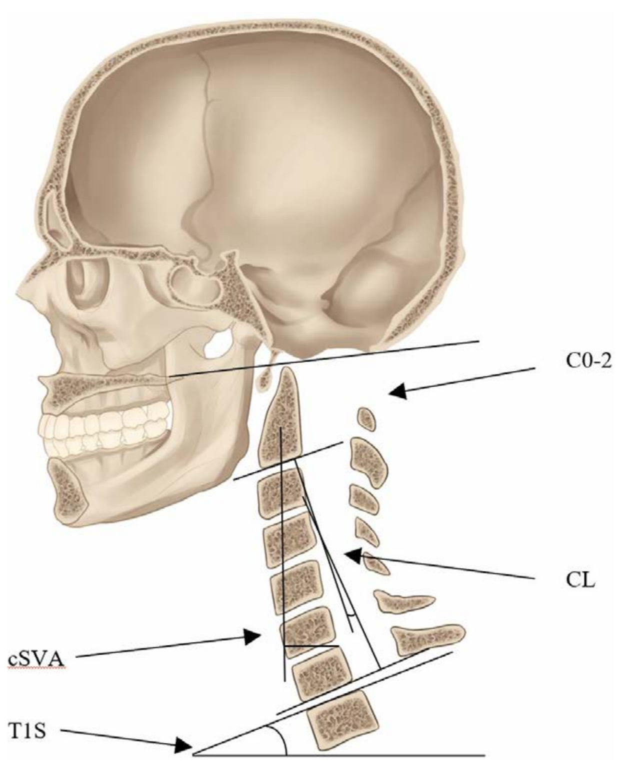

Figure 1. Measurements of radiological parameters, including C0–2 Cobb angle, CL, cSVA, and T1S on cervical lateral radiograph. C0–2 Cobb angle = occipito-cervical angle, CL = C2–7 Cobb angle, cSVA = cervical sagittal vertical alignment, T1S = T1-Slope.

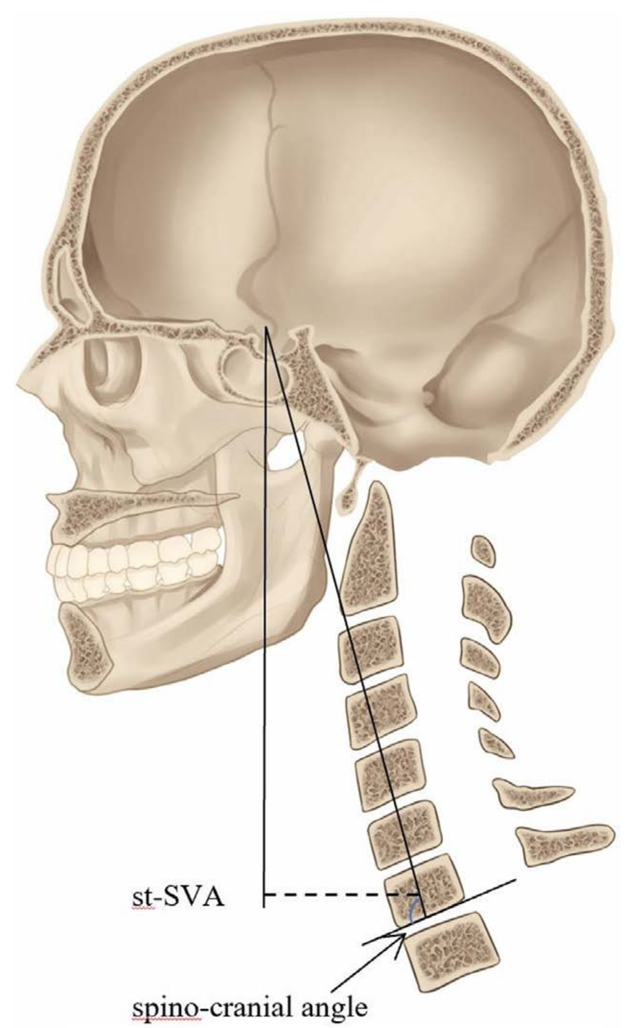

Figure 2. Spino-cranial angle (SCA) and the center of the sella turcica-C7 sagittal vertical axis (St-SVA) were measured to evaluate the cranial sagittal balance. SCA = spino-cranial angle, St-SVA = center of the sella turcica–C7 SVA.

included: the occipito-cervical angle (C0–2 Cobb angle), which is the angle between the McGregor line and the inferior surface of the axis; the C2 to 7 Cobb angle, which is the intersection angle between the line perpendicular to the line parallel to the C2 lower endplate and the line perpendicular to the line parallel to the C7 lower endplate; cervical sagittal vertical alignment (cSVA), which is the horizontal distance from the line vertical to the C2 vertebral geometric canter to the posterior edge of the C7 vertebral upper endplate; the T1-Slope (T1S), angle between a horizontal line and the superior endplate of T1; the T1S–CL: Mismatch between T1 slope and CL; spino-cranial angle (SCA): was defined as the angle between the C7 slope and the straight line joining the middle of the C7 end plate and the middle of the sella turcica; and St-SVA was defined as the distance between a plumb line hung from the center of the sella turcica and the center of the C7 body. All imaging parameters were measured by 3 spine surgeons. The observers were blinded to the clinical and neurological status of the patients. We have chosen the C7 slope to substitute T1S when it could not be visualized in some radiographs.[7] Measurement methods are shown in Figures 1 and 2.

2.4. Clinical outcome evaluation

Neurological outcomes were evaluated using the Japanese orthopaedic association scores (JOA score), and the recovery rate was calculated by Hirabayashi's method. Recovery rate = (postoperative score − preoperative score)/ (17 − preoperative score) × 100. Recovery rates at the last follow-up was ranked as ≥ 75% = excellent; 50% to 74% = good; 25% to 50% = fair; and < 25% = poor. The functional status of patients' cervical spine was assessed by the neck disability index (NDI). The degree of neck pain was evaluated using a visual analog scale (VAS) (0–10). AS occurrence was evaluated based on the criteria of Zeng[8]: According to the severity of patients' symptoms and impact on daily life divide neck status into 4 levels, "'Excellent'" and "'good'" represented no AS, "'fair'" and "'poor'" represented AS presence. Also, surgical outcomes including operation time and intraoperative blood loss been recorded.

2.5. Statistical analysis

Statistical analysis was performed using SPSS software version 22.0. The statistical description of measurement data

Table 1

Demographic and baseline characteristics.

	Group E (n = 32)	Group C (n = 32)	*t* value	X^2 value	*P*
Gender (male: female)	18/14	19/13		0.064	.80
Age, yr	61.50 ± 4.88	60.04 ± 2.87	1.458		.15
Disease duration, months	29.13 ± 1.61	29.17 ± 2.55	−0.074		.91
Follow-up, months	29.12 ± 4.52	26.75 ± 7.38	1.55		.126
Operation time, min	140.54 ± 11.22	136.57 ± 9.92	1.499		.139
Blood loss, mL	240.43 ± 44.93	219.29 ± 39.97	1.989		.051
JOA	7.55 ± 0.92	7.98 ± 1.22	−1.357		.18
NDI	12.32 ± 2.73	12.10 ± 3.63	0.553		.582
VAS	7.52 ± 0.67	7.29 ± 1.05	1.097		.277

Note: Values in data cells represent mean standard deviation (degree).
JOA = Japanese Orthopedic Association, NDI = neck disability index, VAS = visual analog scale.
* $P < .05$ between preoperative and final follow-up.

Table 2

Comparison of the cervical sagittal parameters between postoperative and 2 years follow-up in two groups.

	Group E	Group C	*P*
C02			
Postop	19.28 ± 4.53	20.55 ± 5.10	.294
2 yr	21.02 ± 5.01	21.72 ± 4.32	.552
CL			
Postop	10.09 ± 5.86	11.33 ± 4.32	.34
2 yr	10.15 ± 6.87	8.08 ± 6.19	.209
cSVA			
Postop	20.84 ± 4.88	20.69 ± 4.68	.903
2 yr	22.83 ± 5.22	21.67 ± 3.86	.316
T1S			
Postop	23.58 ± 3.50	23.98 ± 3.67	.66
2 yr	24.49 ± 4.30	25.60 ± 2.99	.233
SCA			
Postop	90.28 ± 11.44	91.09 ± 10.18	.763
2 yr	91.19 ± 12.13	90.25 ± 8.31	.72
St-SVA			
Postop	27.15 ± 4.39	26.06 ± 4.31	.322
2 yr	27.16 ± 3.96	26.58 ± 4.27	.57
T1S-CL			
Postop	13.49 ± 6.84	12.65 ± 5.09	.579
2 yr	14.34 ± 8.89	17.53 ± 7.98	.136

Notes: Values in data cells represent mean ± standard deviation (degree).
C02 = C0-2 Cobb angle, CL = C2–7 Cobb angle, cSVA = cervical sagittal vertical alignment, SCA = spino-cranial angle, St-SVA = center of the sella turcica–C7 SVA, T1S = T1-Slope, T1S-CL = T1S minus CL.
* $P < .05$ between preoperative and postoperative.

was expressed as mean ± standard deviation. The independent-sample t-test was used to compare the difference in mean between the 2 groups. The chi-square test was used to test the difference between the 2 groups. The correlation analysis method between the 2 variables of measurement data was the Pearson test. $P < .05$ was considered statistically significant.

3. Results

3.1. Demographics

A total of 64 patients, including 37 males and 27 females, were enrolled. Their ages ranged from 48 to 76 years old. Of the 64 patients, 32 patients (19 males and 13 females) in group (C) underwent conventional C3 to 7 laminoplasty and a total of 32 patients (18 males and 14 females) underwent C2 to 7 laminoplasty in group (E). There were no significant differences in age, gender, operation time blood loss, or duration of follow-up among the 2 groups perioperatively (Table 1).

3.2. Cervical sagittal parameters

Changes in sagittal parameters were observed in both groups after surgery. T1S, cSVA, and T1S-CL significantly increased, and C2 to 7 Cobb angle (CL) decreased in 2 groups of patients postoperative. At the 2 years later follow-up, the C0 to 2 Cobb angle was found to increase compared to it preoperatively. In addition, there were no significant differences in SCA and st-SVA between preoperative and 2 years later follow-up measurements. Table 2 shows the values of these parameters over different periods. The changes in cervical sagittal parameters of the 2 groups were not significantly different (Figs. 3 and 4).

3.3. Correlation analysis

The C0 to 2 Cobb angle was negatively correlated with the CL and SCA but positively correlated with the cSVA, T1S, and T1S-CL. There was also a close correlation between the T1S and cSVA (Pearson = 0.597), CL (Pearson = -0.444), and SCA (Pearson = -0.421), respectively. The cSVA was positively correlated with the T1S (Pearson = 0.597) and negatively correlated with the CL (Pearson = -0.643). Table 3 and 4 show all these values and the correlation between the different parameters.

3.4. Clinical assessment

The preoperative health-related quality of life (HRQOL) of the 2 groups wasnot significantly different (Table 1). At 2 years later follow-up, the JOA score increased from 7.55 ± 0.92 to 13.42 ± 1.67, resulting in a JOA improvement rate of 73.91 ± 14.91% in the E group and the JOA score in the C group increased from 7.98 ± 1.22 to 13.71 ± 1.28, resulting in a JOA improvement rate of 70.06 ± 14.36%. The NDI and VAS scores also improved from 12.32 ± 2.73 to 8.08 ± 2.80 and 7.52 ± 0.67 to 1.84 ± 0.58 in the E group, versus 12.10 ± 3.63 to 7.81 ± 5.65 and 7.29 ± 1.05 to 1.53 ± 0.91 in the C group.

The postoperative NDI, JOA scores, and VAS of the 2 groups are presented in Table 5 and were not significantly different.

4. Discussion

4.1. Influence of laminoplasty on cervical sagittal parameters

For patients with multi-segmental cervical spondylosis myelopathy and spinal canal stenosis, laminoplasty has gradually become a major surgical approach, but the change of cervical sagittal parameters postoperative has triggered an avalanche of mixed reactions and debates from spinal surgeons. Severe

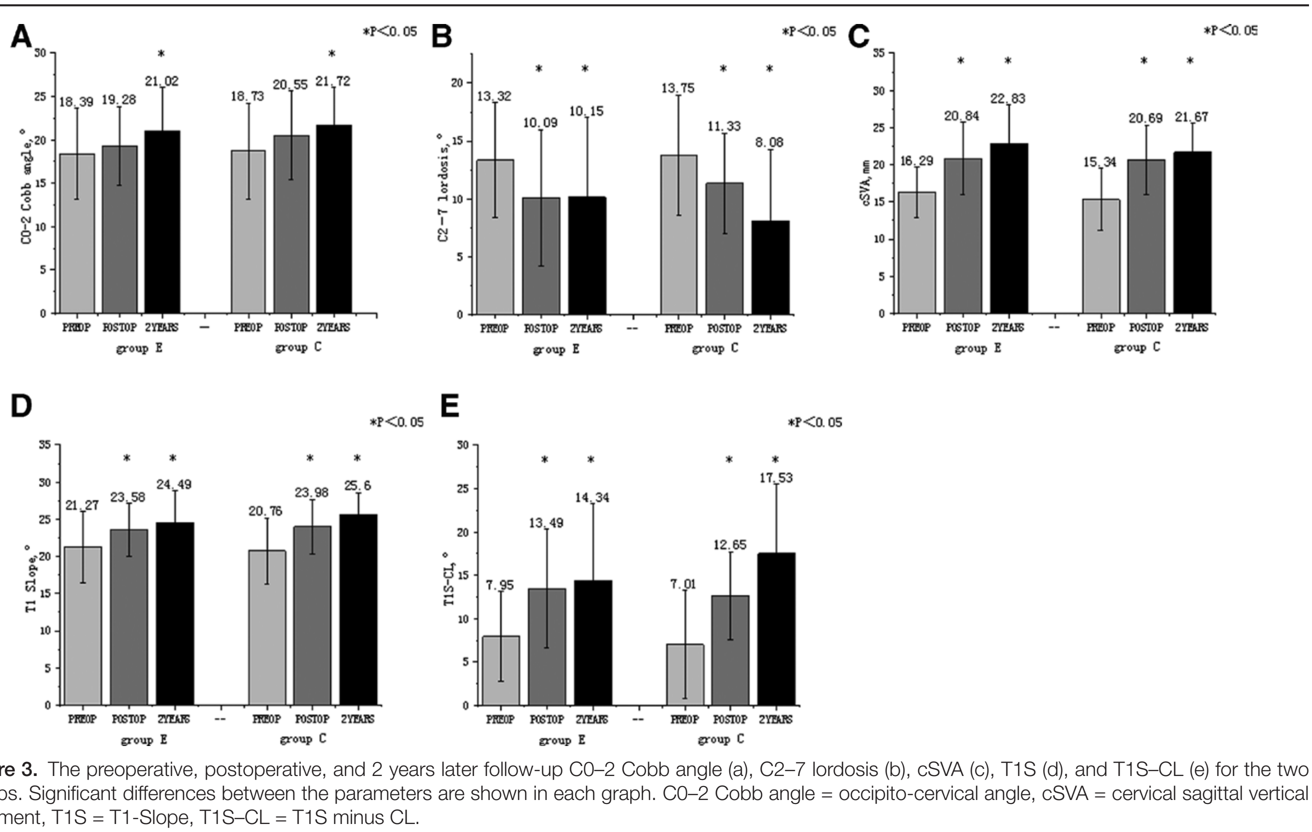

Figure 3. The preoperative, postoperative, and 2 years later follow-up C0–2 Cobb angle (a), C2–7 lordosis (b), cSVA (c), T1S (d), and T1S–CL (e) for the two groups. Significant differences between the parameters are shown in each graph. C0–2 Cobb angle = occipito-cervical angle, cSVA = cervical sagittal vertical alignment, T1S = T1-Slope, T1S–CL = T1S minus CL.

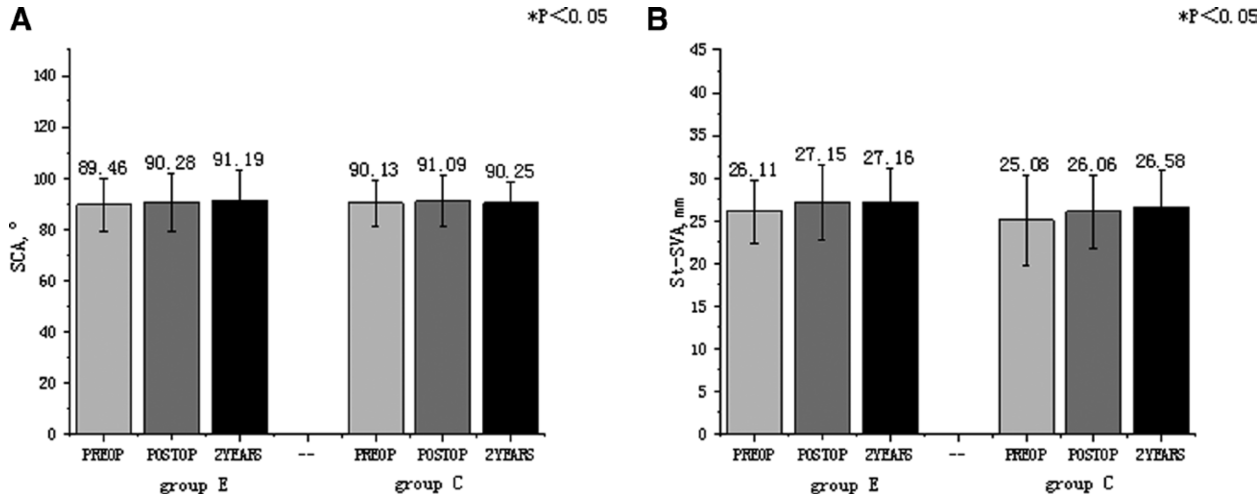

Figure 4. The preoperative and postoperative SCA (a) and st-SVA (b) in the two groups. No significant difference in SCA and st-SVA between preoperative and 2 years later follow-up measurements. SCA = spino-cranial angle.

Table 3

Pearson correlation of the parameters in group E.

	C02	CL	cSVA	T1S	SCA	St-SVA	T1S-CL
C02	X	–0.094	0.439*	0.544**	–0.516**	0.178	0.336
CL		X	–0.567**	–0.224	0.197	0.080	–0.882**
cSVA			X	0.696**	–0.518**	–0.245	0.775**
T1S				X	–0.446*	–0.037	.657**
SCA					X	0.192	–0.368*
St-SVA						X	–0.080
T1S-CL							X

C02 = C0-2 Cobb angle, CL = C2–7 Cobb angle, cSVA = cervical sagittal vertical alignment, SCA = spino-cranial angle, St-SVA = center of the sella turcica–C7 SVA, T1S = T1-Slope, T1S-CL = T1S minus CL.

* $P < .05$ (2 tailed).

** $P < .01$ (2 tailed).

Table 4

Pearson correlation of the parameters in group C.

	C02	CL	cSVA	T1S	SCA	St-SVA	T1S-CL
C02	X	–0.370*	0.412*	0.621**	–0.414*	0.137	0.520**
CL		X	–0.643**	–0.444*	0.166	–0.188	–0.942**
cSVA			X	0.597**	–0.263	0.416*	0.723**
T1S				X	–0.421*	0.333	0.719**
SCA					X	–0.350*	–0.287
St-SVA						X	0.271
T1S-CL							X

C02 = C0-2 Cobb angle, CL = C2–7 Cobb angle, cSVA = cervical sagittal vertical alignment, SCA = spino-cranial angle, St-SVA = center of the sella turcica–C7 SVA, T1S = T1-Slope, T1S-CL = T1S minus CL.

*$P < .05$ (2 tailed).

**$P < .01$ (2 tailed).

cervical sagittal alignment changes may lead to cervical instability, AS, and even kyphosis deformity, which ultimately affects patient HRQOL. Among the many implications of sagittal parameters, the cSVA and T1S are 2 important parameters in determining the offset of the cervical spine[9] (Fig. 5), which are significant correlations to HRQOL,[10] JOA score,[11,12] interlaminar bony fusions, and loss of cervical range of motion (ROM) after laminoplasty.[13]

In this study, we observed an increase in cSVA and T1S significantly in the 2 groups of patients who underwent laminoplasty. The increase of these 2 parameters represents a tilt-forward tendency for the cervical spine. With the increase of the T1S, some patients presented a loss of cervical lordosis and became straightened. However, these parameters were much lower than the threshold of cervical deformity proposed by previous studies.[14] This phenomenon may be caused by the detachment of the posterior cervical muscle-ligament complex during the exposure procedures, which was the predominant factor that maintains the dynamic and static stability of the cervical spine. Both increases in cervical lordotic and straight curves were probably the results of a global spine re-alignment occurring to prevent sagittal imbalance in patients.

Table 5

Comparison of NDI scores, JOA and VAS between two groups.

	NDI scores		JOA scores			VAS scores	
	Preop	2 yr follow-up	Preop	2 yr follow-up	Recovery rate (%)	Preop	2 yr follow-up
Group E	12.32 ± 2.73	8.08 ± 2.80	7.55 ± 0.92	13.42 ± 1.67	73.91 ± 14.91	7.52 ± 0.67	1.84 ± 0.58
Group C	12.10 ± 3.63	7.81 ± 5.65	7.98 ± 1.22	13.71 ± 1.28	70.06 ± 14.36	7.29 ± 1.05	1.53 ± 0.91
t value	0.277	0.187	−1.600	−0.791	1.050	1.035	1.638
P	.783	.852	.115	.432	.298	.305	.106

Notes: Values in data cells represent mean ± standard deviation.
Recovery rate = (postoperative score – preoperative score)/ (17 – preoperative score) × 100.
JOA = Japanese Orthopedic Association, NDI = neck disability index, VAS = visual analog scale.
* $P < .05$ between preoperative and final follow-up.

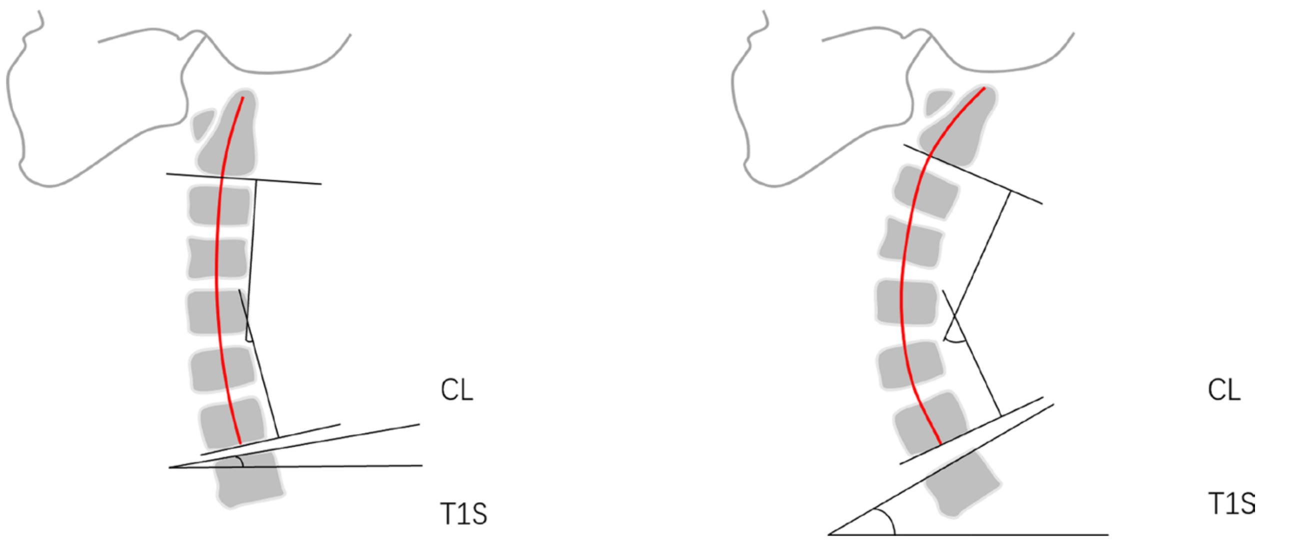

Figure 5. Relationship between T1 slope (T1S) and cervical lordosis (CL) in patients. A high T1S usually had a more lordotic alignment to ensure the center gravity of the skull and maintain visual field. CL = C2–7 Cobb angle, T1S = T1-Slope.

4.2. Compensating mechanisms in sagittal imbalance

Recent studies suggest that SCA and St-SVA would be 2 ideal parameters to evaluate the cranial sagittal balance.[15–17] In addition, CO–2 angle is regarded as a pivotal factor for determining the curvature of the upper cervical spine and works inversely with C2-C7 Cobb.[16] A high cervical lordosis usually had a low CO–2 angle, and vice versa.

In this study, postoperative SCA did not change significantly with the increase of T1S. On the other hand, the C0–2 angle was observed to increase postoperative in all groups and had a close positive correlation with cSVA and T1S. The reason we believe was that each part of the spine can interact with 1 another, a series of changes in the sagittal alignment of the spine can be regarded as a compensatory mechanism to adjust the entire spinal balance. As the most flexible segment, the cervical spine can compensate for sagittal imbalance by changing its sequence, particularly at the occipito-cervical junction which was the utmost movement range of the spine. An increased T1S can occur with thoracic hyperkyphosis and cause cervical spine anteversion resulting in high cSVA, the mass of the head was balanced over the reciprocal primary and secondary curves of the spine.[18] A large tilt forward of the cervical spine would lead the upper cervical spine to hyperextend. And the physiological mechanisms of the human body, which keep the head on a neutral axis in the optimal horizontal plane to ensure the canter gravity of the skull, maintain the visual field and reestablish sagittal balance.[6] All this comes down to 1 point: The cervical spine is the final compensatory mechanism for maintaining cranial cervical balance.

4.3. Postoperative AS, and indications of EODLP

Previous studies have demonstrated that complications from laminoplasty are less common than other procedures, including laminectomy combined with anterior decompression and spinal fusion.[19,20] However, preventing AS is still the key point to improving surgical outcomes because persistent axial pain has a significant negative impact on patients' quality of life.[21] The incidence of AS was reported as much as 45% to 80% of patients who had undergone laminoplasty.[19] Due to the fact that bilateral paravertebral muscles detachment from the lamina and cutting most of the posterior ligament structures are often required for the laminoplasty approach method which results in posterior cervical muscle-ligament complex impairment. It is commonly believed that weakening of the cervical spine stabilizer can lead to irreversible muscle denervated or atrophy, sagittal imbalance, loss of cervical ROM, and occurrence of AS.

In this study, the occurrence of AS was about 37%, 40%, respectively, and no statistical significance. Most AS patients experienced neck and shoulder pain, and stiffness in the early postoperative stages, which occurred primarily in the patients who had these symptoms before surgery. These symptoms gradually subsided within 8 months after surgery. The reason EODLP does not cause more instability than conventional laminoplasty may be due to the exposed procedures of C3 lamina in conventional laminoplasty also needs the semispinalis cervicis to be cut at its attachment point on the C2 spinous process. The extended surgical segments of EODLP did not cause additional damage to the vital structures of the cervical spine stabilizer.

We suggest that surgical indications for EODLP are as follows: upper cervical spine stenosis without instability; space available for the spinal cord at C2 level ≤ 14 mm on the MRI midsagittal image could be seen as a judgement standard for upper cervical myelopathy; patients who has a huge compression (occupying ratio ≥ 50%) at the posterior edge of C2 to 3 or C3 to 4 level that cannot be removed through the anterior cervical surgery, or the operation is high-risk of complication could be considered using this procedure. However, there are also some contraindications for this surgery; patients who have the upper cervical spine instability could not be performed the surgery only with this procedure; congenital upper spinal canal stenosis such as atlas or axis hypoplasia could not undergo this procedure because of varies anomalies the atlas and axis.

There were several limitations in this study. First, the number of patients was small, because upper cervical spinal stenosis was rarely observed, and the data were from a single center. Second, we didn't evaluate the cervical ROM, which was one of the important parameters for the cervical spine after laminoplasty. In addition, our study was lack of global spine sagittal alignment radiological examinations. Because each part of the spine has an intimate reciprocal relationship, compensations occurring in the cervical spine may affect other segments. Taking these parameters into account also enables us to understand the complications involved in this type of surgery. Essentially a large number of patients and long-time follow-ups are necessary for further study to evaluate the surgical outcomes and reasonable indications for the patients who undergo EODLP.

5. Conclusion

Herein, we retrospectively analyzed the relationship between surgical levels and cervical sagittal parameters in patients who had undergone laminoplasty extending to C2. The parameters indicated a tilting forward of the lower cervical spine and a more lordotic upper cervical spine to maintain a horizontal gaze in patients. However, C2 to 7 laminoplasty was performed to achieve satisfactory clinical results without significantly changing the spinal sagittal parameters.

Author contributions

Conceptualization: Wenxuan Wang, Chenhui Xue, Xun Ma.
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Investigation: Wenxuan Wang, Chenhui Xue.
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Validation: Xu Chen, Xin Zhang.
Writing – original draft: Wenxuan Wang, Chenhui Xue.
Writing – review & editing: Wenxuan Wang, Chenhui Xue, Xun Ma.

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