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Impact of global spine balance and cervical regional alignment on determination of postoperative cervical alignment after laminoplasty

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Abstract

The aim of this study is to analyze the combined impact of preoperative T1 slope (T1S) and C2-C7 sagittal vertical axis (C2-C7 SVA) on determination of cervical alignment after laminoplasty.

Forty patients undergoing laminoplasty for cervical spondylotic myelopathy (CSM) with more than 2 years follow-up were enrolled. Three parameters, including cervical lordosis, T1S, and C2-C7 SVA, were measured by preoperative and postoperative radiographs. Receiver operating characteristics (ROC) curve analysis was used to determine the optimal cut-off values of preoperative T1S and C2-C7 SVA for predicting postoperative loss of cervical lordosis. Patients were classified into 4 categories based on cut-off values of preoperative T1S and C2-C7 SVA. The primary outcome was postoperative C2-C7 SVA. Change in radiographic parameters between 4 groups were compared and analyzed.

Optimal cut-off values for predicting loss of cervical lordosis were T1S of 20 degrees and C2-C7 SVA of 22 mm. Patients with small C2-C7 SVA, no matter what the value of T1S, got slight loss of cervical lordosis and increase in C2-C7 SVA. Patients with low T1S and large SVA (T1 ≤20° and SVA >22 mm) got postoperative correction of kyphosis and decrease of C2-C7 SVA. However, patients with high T1S and large SVA (T1 >20° and SVA >22 mm) got mean postoperative C2-C7 SVA value of 37.06 mm, close to the threshold value of 40 mm.

Determination of cervical alignment after laminoplasty relies on the equilibrium between destruction of cervical structure, kyphotic force, and adaptive compensation of whole spine, lordotic force. Lower T1S means bigger compensatory ability to adjust different severity of cervical sagittal malalignment, and vice versa.

Abbreviations: CSM = cervical spondylotic myelopathy, HRQOL = health-related quality-of-life, SVA = sagittal vertical axis, T1S = T1 slope, TIA = thoracic inlet angle.

Keywords: global spinal balance, laminoplasty, sagittal vertical axis, T1 slope

1. Introduction

Sagittal malalignment of spine as a crucial factor in the pathogenesis of myelopathy is supported by several reports.[1,2] For patients with cervical spondylotic myelopathy (CSM), it is imperative to make a comprehensive assessment of global spine balance and cervical regional alignment respectively. Laminoplasty is the recommended surgical procedure for proper patient with CSM.[3,4] One of notorious morbidities following laminoplasty is postoperative loss of cervical lordosis, and kyphotic change of cervical curvature has negative effect on clinical outcome.[5,6] In recent years, some studies focus on prognostic significance of sagittal balance of whole spine and cervical regional alignment in predicting kyphotic change of alignment after laminoplasty.[7–11] T1 slope (T1S) and C2-C7 sagittal vertical axis (C2-C7 SVA) are representations of global sagittal balance and cervical regional alignment respectively, and each parameter is regarded as useful parameter for predicting kyphotic deformity after laminoplasty. Laminoplasty itself causes regional malalignment by disrupting posterior muscular-ligament complex.[12,13] However, magnitude of cervical lordosis is determined by not only regional deformity of cervical spine but also compensatory reaction of other spinal segments to maintain equilibrium of head and horizontal gaze.[14] In clinical practice, cervical regional alignment closely interacts with other spinal segments, including thoracic kyphosis, lumbar lordosis, pelvic incidence, and occipital-cervical junction. Thus, comprehensive assessment of these parameters is important to make a clinical decision for each patient with CSM. Regrettably, there is no study to discuss

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the concurrent impact of global spine balance and cervical regional alignment in 1 patient until now.

The purpose of this study is to investigate the combined impact of global spine balance, T1S, and cervical regional alignment, C2-C7 SVA, on determination of cervical alignment after laminoplasty. Thus, we hypothesize the following;

(1) determination of cervical lordosis is a dynamic process to maintain cervical compensation—keeping C2-C7 SVA within acceptable range for equilibrium of head position and horizontal gaze;
(2) patients with higher T1S require more cervical lordosis to maintain cervical compensation;[9]
(3) each patient has different T1S and C2-C7 SVA, representing various combinations of global spinal balance and cervical regional alignment;
(4) laminoplasty disrupts posterior muscular-ligament complex, and determination of postoperative cervical alignment relies on the equilibrium between destruction of cervical structure, kyphotic force, and adaptive compensation of whole spine, lordotic force;
(5) the severity of postoperative disability is correlated with postoperative sagittal malalignment (threshold C2-C7 SVA value of 40 mm).[13]

This study is a retrospective analysis to assess the effect of preoperative T1S and C2-C7 SVA on the postoperative cervical alignment - postoperative C2-C7 SVA.

2. Methods

2.1. Patient demographics

A review of medical record in our institution was conducted following Institutional Review Board approval (IRB: 1-102-05-032). From January 2005 to December 2014, 190 consecutive patients accepting cervical open-door laminoplasty in our institution were analyzed retrospectively. Inclusion criteria were summarized as below:

(1) diagnosis of CSM,
(2) no previous history of cervical spine surgery,
(3) no structural spinal deformity,
(4) the most cranial level of decompression was C3 and the most caudal level of decompression was C6 or C7,
(5) the follow-up interval was 24 months at least.

Those patients having other accompanied conditions—encompassing trauma, tumor, infection, and ossification of posterior longitudinal ligament were excluded from the study. Among them, 40 patients with CSM were enrolled in the final analysis.

2.2. Acquirement of radiographic parameters

Cervical lateral radiographs were taken in the standing position with the patient's head facing forward preoperatively and postoperatively. Three radiographic parameters were measured by using a picture-archiving communication system—T1S, C2-C7 SVA, and cervical lordosis.

T1S was defined as the angle between horizontal plane and T1 upper endplate. C2-C7 SVA was defined as horizontal distance between vertical line from the center of C2 and the posterior superior aspect of C7. The positive value of C2-C7 SVA indicated the center of C2 was anterior to the posterior superior aspect of C7, and vice versa. Cervical lordosis was obtained by measuring C2-C7 Cobb's angle, the angle between 2 lines perpendicular to the inferior endplates of C2 and C7. The positive value of cervical lordosis meant lordosis and negative value meant kyphosis. Methods of measurement were summarized (Fig. 1). Differences between preoperative and postoperative parameters were calculated respectively.

2.3. Assessment of postoperative cervical alignment for each category

The cut-off values of preoperative T1S and C2-C7 SVA were used to classify the patient population into 4 categories. The 4 categories were as follows:

(1) low T1S and small C2-C7 SVA;
(2) low T1S and large C2-C7 SVA;
(3) high T1S and small C2-C7 SVA;
(4) high T1S and large C2-C7 SVA.

The postoperative cervical alignment was assessed as postoperative C2-C7 SVA. Changes in the global sagittal balance, difference between preoperative and postoperative T1S, and cervical alignment, difference between preoperative and postoperative C2-C7 SVA, were also evaluated.

2.4. Statistical analysis

All data were presented as the mean ± standard deviation and calculated using the IBM SPSS Statistics 20. To evaluate the capacity of preoperative T1S and C2-C7 SVA in prediction of loss of cervical lordosis, we performed receiver operating characteristics (ROC) curve analyses. We reversed the dependent variable and independent variable and tested the all potential cut points of preoperative T1S and C2-C7 SVA. Optimal cut-off value was selected as 1 point with largest area under the curve (AUC). The patient population was then classified into four categories based on cut-off values of preoperative T1S and C2-C7 SVA. Two-way

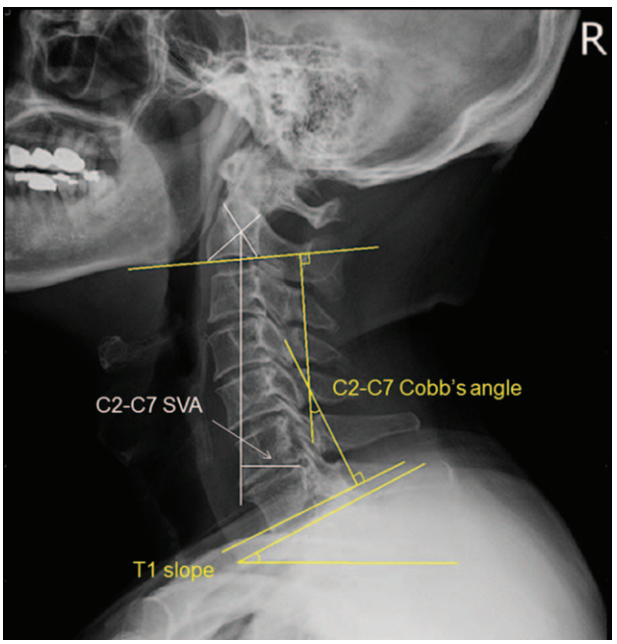

Figure 1. Illustration of spinal measurements—cervical lordosis, manifested as C2-C7 Cobb's angle, C2-C7 SVA and T1 slope. SVA = sagittal vertical axis.

analysis of variance (ANOVA) was used to examine the difference between each category. Statistical significance was set at $P < .05$.

3. Results

Among forty patients, 28 (70%) were male and the mean age at surgery was 64.7 ± 9.9 years.

3.1. ROC curve analyses and cut-off values

By the results of ROC curve analyses for postoperative change in cervical lordosis, preoperative T1S of 20 degrees and C2-C7 SVA of 22 mm were identified as optimal cut-off values. The AUCs were 0.5862 for cut-off value of T1S and 0.6350 for cut-off value of C2-C7 SVA (Fig. 2).

3.2. Comparison of clinicoradiological characteristics according to preoperative T1S

The clinicoradiological characteristics between high T1S group (T1S >20°) and low T1S group (T1S ≤ 20°) were summarized in Table 1. The mean preoperative T1S were 29.74° in high T1S group and 13.47° in low T1S group.

Patients in high T1S group had more preoperative lordotic curvature than those in low T1S group (12.97° vs 1.72°, $P = .012$). Preoperative C2-C7 SVA in high T1S group was larger than low T1S group (24.44 mm vs 13.42 mm, $P = .027$). Change in T1S was different significantly between high T1S group and low T1S group (4.10° vs −1.83°, $P = .014$). Changes in cervical lordosis and C2-C7 SVA were not different between 2 groups.

3.3. Comparison of clinicoradiological characteristics according to preoperative C2-C7 SVA

The clinicoradiological characteristics between large C2-C7 SVA group (C2-C7 SVA >22 mm) and small C2-C7 SVA group (C2-C7 SVA ≤22 mm) were summarized in Table 2. The mean values of preoperative SVA were 32.95 mm in large C2-C7 SVA group and 9.88 mm in small C2-C7 group. Patients with large C2-C7 SVA has larger T1S than those with small C2-C7 SVA (28.77° vs 21.76°, $P = .015$). Changes in T1S, C2-C7 SVA, and cervical lordosis were not different between large and small C2-C7 SVA groups.

3.4. Comparison of clinicoradiological characteristics according to preoperative T1S and C2-C7 SVA

Patients were divided into 4 categories based on cut-off values of T1S of 20° and C2-C7 SVA of 22 mm. The clinicoradiological characteristics between 4 categories were summarized in Table 3. There was significant difference in preoperative cervical lordosis ($P = < .001$) and C2-C7 SVA ($P = < .001$). Change in C2-C7 SVA was different significantly among 4 groups ($P = .049$), but change

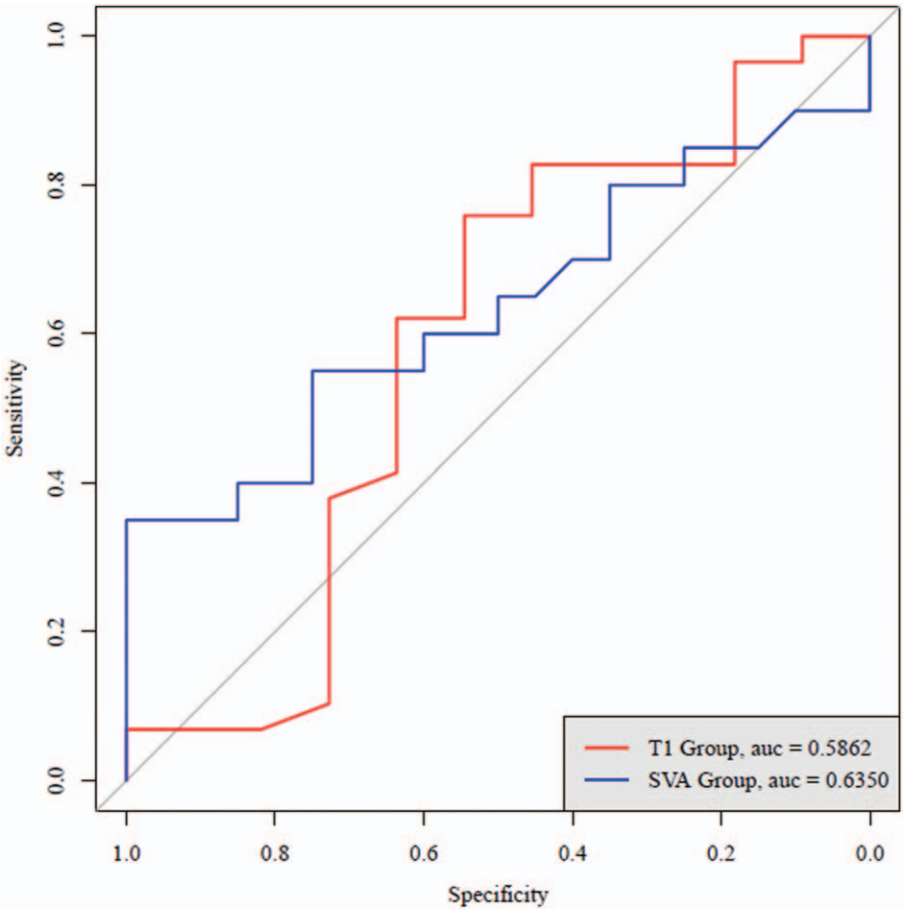

Figure 2. ROC curves of cut-off values of T1S and C2-C7 SVA for predicting loss of cervical lordosis. AUC results for cut-off values of T1S and C2-C7 SVA are 0.5862 and 0.6350 respectively. AUC = area under the curve, ROC = receiver operating characteristics, SVA = sagittal vertical axis, T1S = T1 slope.

Table 1

Comparison of clinicoradiological characteristics according to preoperative T1 slope.

	T1 slope ≤20°	T1 slope >20°	*P* value
No. of patients	11	29	
Demographics			
gender, male	8 (72.7%)	20 (69.0%)	.817
age, yr	59.82±7.36	66.55±10.38	.057
Radiographic parameters			
pre-op T1 slope, °	13.47±4.91	29.74±6.09	<.001*
post-op T1 slope, °	17.57±7.90	27.91±9.03	.002*
change in T1 slope, °	4.10±5.91	−1.83±6.69	.014*
pre-op cervical lordosis, °	1.72±10.72	12.97±12.40	.012*
post-op cervical lordosis, °	1.29±15.31	7.95±17.72	.279
change in cervical lordosis, °	−0.43±14.29	−5.02±13.69	.355
pre-op C2-C7 SVA, mm	13.42±15.81	24.44±12.65	.027*
post-op C2-C7 SVA, mm	12.82±14.77	29.29±21.20	.024*
change in C2-C7 SVA, mm	−0.60±20.94	4.84±16.11	.386

SVA = sagittal vertical axis.
* A P value of less than .05.

Table 2

Comparison of clinicoradiological characteristics according to preoperative C2-C7 SVA.

	C2-C7 SVA ≤ 22 mm	C2-C7 SVA >22 mm	*P* value
No. of patients	20	20	
Demographics			
gender, male	15 (75.0%)	13 (65.0%)	.490
age, yr	62.40±9.69	67.00±10.06	.149
Radiographic parameters			
pre-op T1 slope, °	21.76±9.93	28.77±7.34	.015*
post-op T1 slope, °	23.08±8.98	27.06±10.43	.204
change in T1 slope, °	1.32±6.46	−1.72±7.25	.170
pre-op cervical lordosis, °	13.51±11.96	6.25±13.03	.074
post-op cervical lordosis, °	7.79±14.54	4.46±19.69	.547
change in cervical lordosis, °	−5.73±8.44	−1.79±17.69	.375
pre-op C2-C7 SVA, mm	9.88±7.60	32.95±8.97	<.001*
post-op C2-C7 SVA, mm	15.19±12.88	34.32±23.08	.003*
change in C2-C7 SVA, mm	5.31±11.30	1.38±22.13	.484

SVA = sagittal vertical axis.
* A P value of less than .05.

in cervical lordosis was not (P=.109). After laminoplasty, patients with low T1S and large SVA (T1 ≤20° and SVA >22 mm) got more lordotic curvature (change in cervical lordosis: 19.10±2.83°) and decrease of C2-C7 SVA (change in C2-C7 SVA: −29.70±23.62 mm). The other 3 categories got loss of cervical lordosis and increase of C2-C7 SVA postoperatively (Fig. 3). The patients with high T1S and large SVA (T1 >20° and SVA >22 mm) got mean postoperative C2-C7 SVA value of 37.06 mm. Radiographs of representative case in each category were showed (Fig. 4).

4. Discussion

In recent year, a growing number of studies pay attention to the relationship between spinal balance and kyphotic deformity after laminoplasty. The concept of spinal balance includes global spine sagittal balance and cervical regional balance.

Knott et al emphasized the significance of T1S as useful parameter to evaluate the whole spine sagittal balance.[15] Lee et al proposed the standpoint of thoracic inlet angle (TIA)—existence of significant correlation between TIA and craniocervical alignment.[16] They stated that larger TIA produced a higher T1S, and a larger magnitude of cervical lordosis was required to maintain the equilibrium of head or vice versa. The importance of global spine sagittal balance to clinical outcome after laminoplasty was also confirmed by Oshima et al.[10] Although the association between cervical spine curvature and whole spine sagittal balance is controversial, cervical lordosis is thought as a compensatory mechanism to maintain equilibrium and forward gaze of head.[14,17–20] Some studies reported that patients with high T1S had more loss of lordosis after laminoplasty than those with low T1S.[8,9] However, Chou et al argued for no difference between high T1S group and low T1S group.[7]

Cervical regional alignment is another important consideration while performing posterior cervical reconstruction. Tang et al reported that larger C2-C7 SVA, 1 representation of cervical region alignment, affected health-related quality-of-life (HRQOL) scores negatively, and the severity of disability increased with positive sagittal malalignment.[13] Sakai et al announced that cervical sagittal imbalance, defined as center of gravity of the head (CGH)-C7 ≧ 42 mm, and advanced age were associated with kyphotic deformity after laminoplasty.[11] Due to there is no consensus about standard radiographic parameters of

Table 3

Comparison of clinicoradiological characteristics according to preoperative T1 slope and C2-C7 SVA.

	T1 ≤20° and SVA ≤22mm	T1 ≤20° and SVA >22mm	T1 >20° and SVA ≤22mm	T1 >20° and SVA >22mm	*P* value
No. of patients	9	2	11	18	
Demographics					
Gender, male	6 (66.7%)	2 (100.0%)	9 (81.8%)	11 (61.1%)	.510
age, yr	60.89±7.72	55.00±2.83	63.64±11.27	68.33±9.69	.126
Radiographic parameters					
pre-op T1 slope, °	12.64±5.06	17.20±1.41	29.22±5.56	30.06±6.53	<.001*
post-op T1 slope, °	16.73±7.52	21.35±11.67	28.27±6.49	27.69±10.46	.020*
change in T1 slope, °	4.09±5.52	4.15±10.25	−0.95±6.50	−2.37±6.94	.103
pre-op cervical lordosis, °	4.61±9.11	−11.30±8.49	20.79±8.70	8.19±12.05	<.001*
post-op cervical lordosis, °	−0.16±16.61	7.80±5.66	14.28±8.82	4.08±20.73	.272
change in cervical lordosis, °	−4.77±11.73	19.10±2.83	−6.51±4.87	−4.11±17.10	.109
pre-op C2-C7 SVA, mm	7.64±7.06	39.40±21.21	11.71±7.86	32.23±7.61	<.001*
post-op C2-C7 SVA, mm	13.51±16.41	9.70±2.40	16.56±9.76	37.06±22.71	.005*
change in C2-C7 SVA, mm	5.87±14.82	−29.70±23.62	4.85±8.15	4.83±19.70	.049*

SVA = sagittal vertical axis.
* A P value of less than .05.

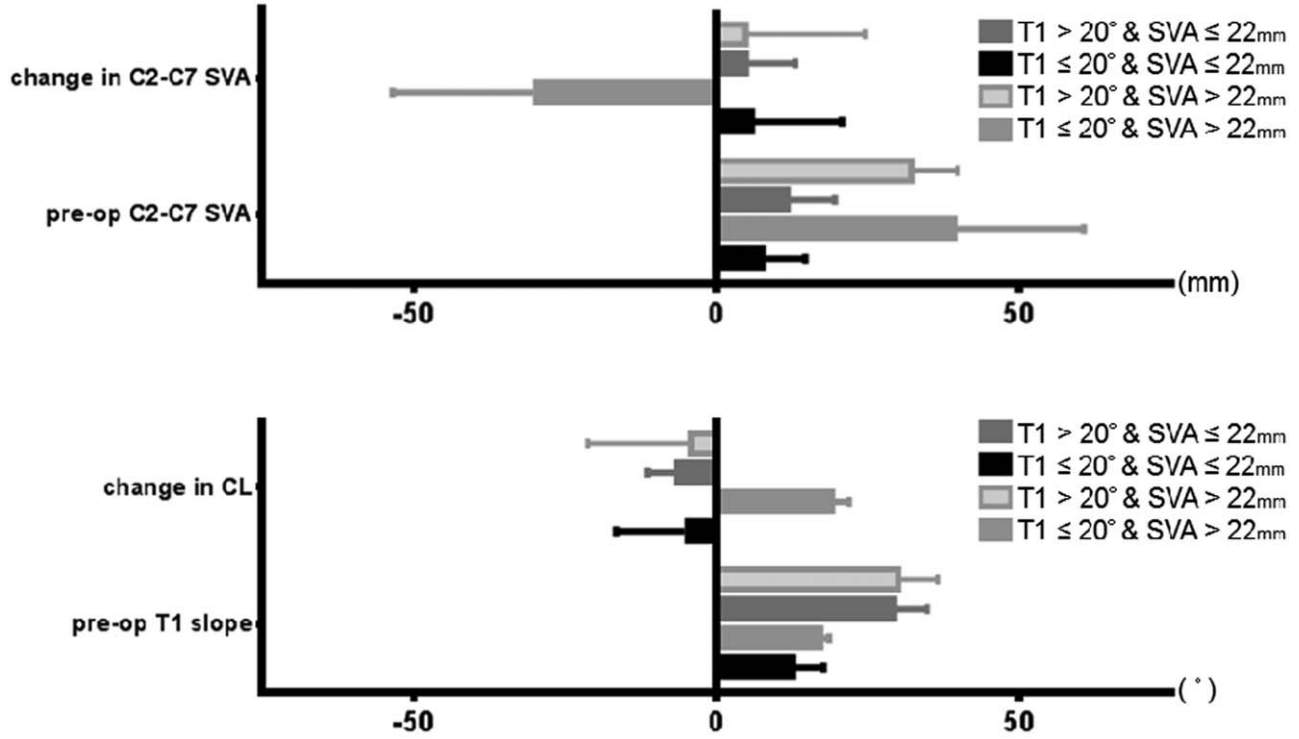

Figure 3. Changes in cervical lordosis and C2-C7 SVA after laminoplasty of each category. Patient with low T1S and large C2-C7 SVA (T1 ≤20° and SVA >22 mm) got obvious increase in cervical lordosis and decrease in C2-C7 SVA. Other categories got similar results, loss of cervical lordosis and increase in C2-C7 SVA. SVA = sagittal vertical axis, T1S = T1 slope.

posterior cervical reconstruction, we use ROC curve analyses to determine optimal cut-off values of T1S and C2-C7 SVA for predicting loss of cervical lordosis. At first, we classify the patients according to preoperative T1S of 20 degrees.

High T1S group has more lordosis than low T1S group, and this finding is compatible with previous reports.[13,14] Changes in cervical lordosis are not different significantly between high T1S group and low T1S group in our study. Next, we divide the patients based on preoperative C2-C7 SVA of 22 mm. Changes in cervical lordosis are not different between large and small C2-C7 SVA groups. Thus, the authors question the prognostic performance of T1S or C2-C7 SVA as useful parameter for predicting cervical malalignment after laminoplasty.

Although the pathophysiology of CSM is not fully understood, it is believed that CSM begins with degenerative change of disc.[21–24] The resultant decrease of cervical disc height cause loss of lordotic curvature and increase the load strength on the ventral aspects of vertebral bodies. Progressive kyphosis of cervical curvature damages the spinal cord through increased intramedullary pressure and reduced blood supply with neuronal loss and demyelination.[2,25,26] Because of sagittal alignment plays an important role in the pathogenesis of CSM, assessment of spinal structure, including global spine balance, and cervical regional alignment is necessary to make clinical decision. Among previous reports, only global spine sagittal balance or cervical regional alignment was discussed in 1 study. To the best of our knowledge, this is the first report to discuss the combined impact of global spine balance and regional alignment on loss of cervical lordosis after laminoplasty.

Kim et al proposed 1 hypothesis—the same degree of cervical lordosis might have a different meaning according to the degree of T1S.[9] They announced that patients with high T1S needed more cervical lordosis to maintain equilibrium. Therefore, cervical alignment could be within compensated or uncompensated condition. Our viewpoint, development of CSM as a dynamic process, agrees with their hypothesis. Accordingly, it is practical to assess each patient based on individual condition of global sagittal balance and regional alignment. The hypothesis of this study is that each patient has his own preoperative equilibrium between global spine sagittal balance and cervical regional alignment. Laminoplasty itself results in damage of posterior muscular-ligament complex and disrupts original cervical alignment. To compensate for this problem, global spine will make corresponding adaptation to reestablish the postoperative equilibrium between whole spine sagittal balance and cervical regional alignment.

In this study, the authors classify the patients into 4 categories according to cut-off values of preoperative T1S and C2-C7 SVA. T1S and C2-C7 SVA are representations of global sagittal balance and cervical regional alignment respectively. The patient with preoperative C2-C7 SVA larger than cut-off value is defined as uncompensated condition, and vice versa. Association between degree of cervical lordosis and clinical outcome is questionable, but loss of cervical lordosis after laminoplasty is the key determinant of postoperative C2-C7 SVA. Several papers have proved the correlation between cervical sagittal alignment (C2-C7 SVA) and regional disability, general health scores, and severity of myelopathy.[13,14] In this study, we use postoperative C2-C7 SVA as presentation of clinical outcome.

Patients with preoperative compensated condition—small C2-C7 SVA, no matter what the degree of T1S, get slight loss of cervical lordosis and increase in C2-C7 SVA. Patients with

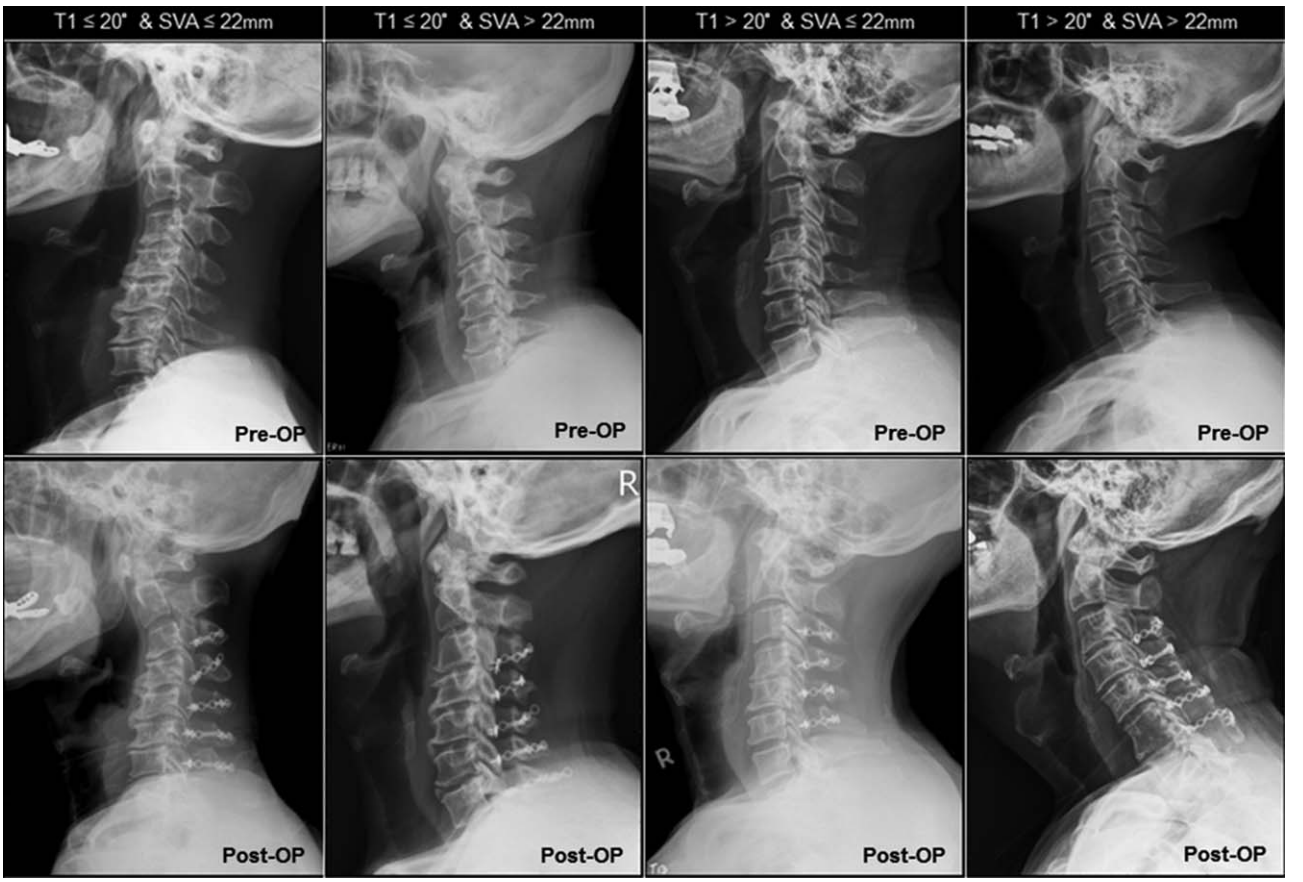

Figure 4. Preoperative and postoperative images of representative case in each category. Patient with low T1S and large C2-C7 SVA (T1 $\leq$20° & SVA >22 mm) got postoperative correction of kyphotic deformity and decrease in C2-C7 SVA. Other groups got postoperative loss of cervical lordosis and increase in C2-C7 SVA. SVA = sagittal vertical axis, T1S = T1 slope.

preoperative uncompensated condition, large C2-C7 SVA, have different change according to preoperative T1S. Those with high T1S and large C2-C7 SVA (T1 >20° and SVA >22 mm) get unsatisfactory postoperative C2-C7 SVA with mean value of 37.06 mm. The threshold value of postoperative C2-C7 SVA is 40 mm, and beyond which predicts severe disability.[13] Surprisingly, patients with low T1S and large C2-C7 SVA (T1 $\leq$20° and SVA >22 mm) get postoperative correction of kyphotic deformity and decrease in C2-C7 SVA. One interesting finding is that patients with low T1S, no matter what the value of preoperative C2-C7 SVA, get postoperative C2-C7 SVA located within relative normal range. In contrast, this phenomenon does not occur in patients with high T1S. Another amazing finding is that patients with low T1S get obvious increase in degree of T1S postoperatively than those with high T1S. Above results may be attributed to the compensatory ability of whole spine for maintaining equilibrium of head position and horizontal gaze.

Laminoplasty causes regional malalignment and loss of lordotic curvature by disrupting posterior muscular-ligament complex.[12,13,27] While facing disrupted cervical structure, secondary change of T1S is to increase magnitude of slope angle. Therefore, compensatory increase in cervical lordosis occurs in order to maintain equilibrium and horizontal gaze of head. That is to say, determination of final cervical alignment depends on the equilibrium between kyphotic deformity following laminoplasty and lordotic compensation of cervical spine. Patients with low T1S have more ability of compensation to maintain regional balance, keeping C2-C7 SVA within acceptable range. On the contrary, patients with high T1S have limited ability of compensation. Thus kyphotic force of disrupted cervical structure predominates over lordotic force, adaptive compensation of whole spine. Other factors have been reported to be associated with kyphotic deformity after laminoplasty, such as severity of posterior muscular-ligament complex damage and the cephalic level of decompression.[12,28] To avoid these variables, all patients have the same cranial level of decompression, C3, and surgical operation, traditional open-door laminoplasty, in this study. In clinical practice, it is very important to evaluate global sagittal balance and regional cervical alignment while performing planned laminoplasty for patients with CSM. By the result of our study, cut-off values of T1S of 20 degrees and C2-C7 SVA of 22 mm can help the surgeons to make preoperative assessment effectively. Patients with low T1S (T1S $\leq$20°) or compensated condition (C2-C7 SVA $\leq$22 mm) are suitable candidates for laminoplasty. On the other hand, the surgeons should keep in mind that the patients with preoperative large T1S and uncompensated cervical curvature (T1 >20° and SVA >22 mm) have high opportunity to get large postoperative C2-C7 SVA, an index of high severity of disability. This study is a retrospective analysis with several limitations. First, it is not exactly correct to regard change in T1S as representation of compensatory adaptation of whole spine. T1S is a feasible parameter to predict overall sagittal balance of spine, but the actual association between change in T1S and reciprocal

modification of whole spine sagittal balance is debatable nevertheless.[15] Second, this study lacks clinical parameters and HRQOL indices to support our results. Because the severity of disability following posterior cervical surgery is correlated with postoperative sagittal malalignment, the authors define postoperative C2-C7 SVA as primary outcome.[13] Having said that, the correlation between radiological outcome and functional outcome after laminoplasty is questionable.[7] Third, application of optimal cut-off values of T1S and C2-C7 SVA for patient classification is challenging. Development of CSM is a dynamic process; thus, the optimal cut-off values of T1S and C2-C7 SVA for each patient should be tailored based on age, gender, functional status, severity of spinal cord compression and other confounding factors. Finally, the sample size of this study is small with existence of uneven distribution of population between each category. Nonetheless, there is significant difference statistically in postoperative C2-C7 SVA according to patient classification in this study. This research provides novel classification strategy for patients with planned laminoplasty. Further extensive research to increase the sample size, to record clinical parameters and to measure the reciprocal change of thoracic kyphosis/lumbar lordosis after laminoplasty is helpful to confirm this interactive relationship.

5. Conclusion

Determination of cervical spinal curvature after laminoplasty relies on the equilibrium between destructive structure of cervical spine, kyphotic force, and adaptive compensation of whole spine, lordotic force. Laminoplasty causes disruption of posterior muscular-ligament complex and destroys original cervical alignment. After that, the global spine will make corresponding adaptation to maintain postoperative cervical alignment within acceptable range. This phenomenon is obvious in patients with preoperative low T1S. In contrast, patients with preoperative high T1S and large C2-C7 SVA have higher risk of postoperative cervical malalignment. Exhaustive assessment of global spine sagittal balance, T1S, and cervical regional balance, C2-C7 SVA, for each patient with CSM is important to make clinical decision.

Author contributions

Conceptualization: Bon-Jour Lin, Tzu-Tsao Chung, Chi-Tun Tang.
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Validation: Chin Lin, Yuan-Hao Chen.
Writing – original draft: Bon-Jour Lin.
Writing – review & editing: Bon-Jour Lin.

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