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The time course of cervical alignment after cervical expansive laminoplasty

Determining optimal cut-off preoperative angle for predicting postoperative kyphosis

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Abstract

Retrospective Cohort study

To analyze cervical lordosis angle (CLA) change after cervical expansive laminoplasty (CEL) over time, and to determine optimal cut-off angle for predicting postoperative kyphosis

Postoperative development of sagittal malalignment after laminoplasty is associated with neurological dysfunction and neck pain. However, there is no information on the serial CLA change over time and cut-off angle for predicting postoperative kyphosis

The Cobb angle between C2 and C7 in a series of lateral cervical X-rays in the neutral position was retrospectively reviewed for 36 months. And, the effect of time on CLA after CEL and the risk factors associated with postoperative cervical kyphosis (Cobb's angle $\leq 0°$) were analyzed. Also, the optimal cut-off angle for predicting postoperative kyphosis was determined.

A total of 110 cases of CEL for cervical myelopathy were enrolled from February 2005 to May 2010. The mean cervical alignment changed from $12.3 \pm 10.4°$ (mean ± standard deviation [SD]) at the preoperative evaluation to $8.2 \pm 11.6°$, $10.6 \pm 10.1°$, $9.1 \pm 10.0°$, $8.4 \pm 11.2°$, $8.5 \pm 10.5°$, $8.1 \pm 9.9°$, and $8.7 \pm 10.1°$ at 1, 3, 6, 12, 18, 24, and 36 postoperative months, respectively. The cervical lordosis showed statistically significant decreased at the 1st month, then the lordotic angle was partially restored at the 3rd, and 6th, and then no significant changes after the 6th. The only risk factor for kyphosis development was the preoperative CLA. The optimal cut-off preoperative angle for predicting postoperative kyphosis was 8.5°.

The decrease of CLA after expansive laminoplasty peaked in the 1st month. Some of the lordotic angles were restored in the 3rd and 6th months, before reaching a plateau after the 6th month. The optimal cut-off preoperative angle for predicting postoperative kyphosis was 8.5°.

Level of Evidence of their study: Level 4.

Abbreviations: CEL = cervical expansive laminoplasty, CLA = cervical lordosis angle, DS = degenerative spondylosis, JOA = Japanese Orthopaedic Association, OPLL = ossification posterior longitudinal ligament, ROC = receiver operating characteristic.

Keywords: cervical laminoplasty, kyphosis, sagittal alignment

1. Introduction

Postoperative development of sagittal malalignment after cervical expansive laminoplasty (CEL) is associated with neurological dysfunction and neck pain.[1,2] Preoperative cervical alignment is known to affect postoperative alignment.[3] If the alignment changes to a kyphotic angulation after expansive laminoplasty, unsatisfactory cord shifting may result in inadequate decompression of the spinal cord, possibly necessitating additional anterior surgery. Therefore, the physician needs to know the alignment changes over time after cervical laminoplasty for decision making and patient education. However, no information is available on kyphotic angle changes over time. Accordingly, the aim of this study was to assess the cervical alignment time course after expansive laminoplasty, determining the onset, progression, and long-term status of kyphotic angle changes and to investigate risk factors of post-operative cervical kyphosis and to determine optimal cut-off angle for predicting postoperative kyphosis.

2. Methods

2.1. Study design, setting, and patient population

The medical charts, operative notes, neurophysiological data, and radiological imaging studies of patients who underwent a CEL between February 2005 and May 2010 at a single institution were retrospectively reviewed. Patients who had the diagnosis of cervical spondylotic myelopathy or ossification posterior longitudinal ligament (OPLL) were included. Two laminoplasty techniques—

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unilateral open door laminoplasty, described by Hirabayashi, and midline splitting laminoplasty, described by Kurokawa and Tanaka—were included.[4–6] The extent of the laminoplasty was limited to C2 to T1. Patients who had had previous anterior cervical surgery, a history of rheumatoid arthritis, cerebral palsy, or tumors, a follow-up period of less than 1 year, or posterior cervical instrument fixation were excluded. We usually recommend the Philadelphia brace for 4 weeks at postoperative period to reduce muscle pain during wound healing period. Our study was conducted with the approval of the institutional review board (IRB local number; S2014-0022-0001).

2.2. Outcome measures

The primary outcome was to analyze the time course of cervical alignment by serial radiologic imaging after CEL. The secondary outcomes were to evaluate the risk factors affecting postoperative kyphosis when the cervical alignment did not change and to determine the cut-off value of the cervical alignment angle that predicted postoperative kyphosis.

2.3. Radiologic measurements

Two spinal neurosurgeons who had not attended the surgery retrospectively reviewed a series of lateral cervical X-rays in the neutral position and measured the Cobb angle between the lower border of the C2 body and the upper border of the C7 body (Fig. 1). The Cobb angle was serially measured preoperatively and at 1, 3, 6, 12, 18, 24, and 36 postoperative months. In this study, an alignment of $0° <$ the C2–7 Cobb angle was defined as lordosis and an alignment of $0° \geq$ the C2–7 Cobb angle was defined as kyphosis. Also, we expressed the increase of the C2-7 Cobb angle "the lordotic change" or "increase of cervical lordosis angle (CLA)" and the decrease of the C2-7 Cobb angle "the kyphotic change" or "decrease of CLA"

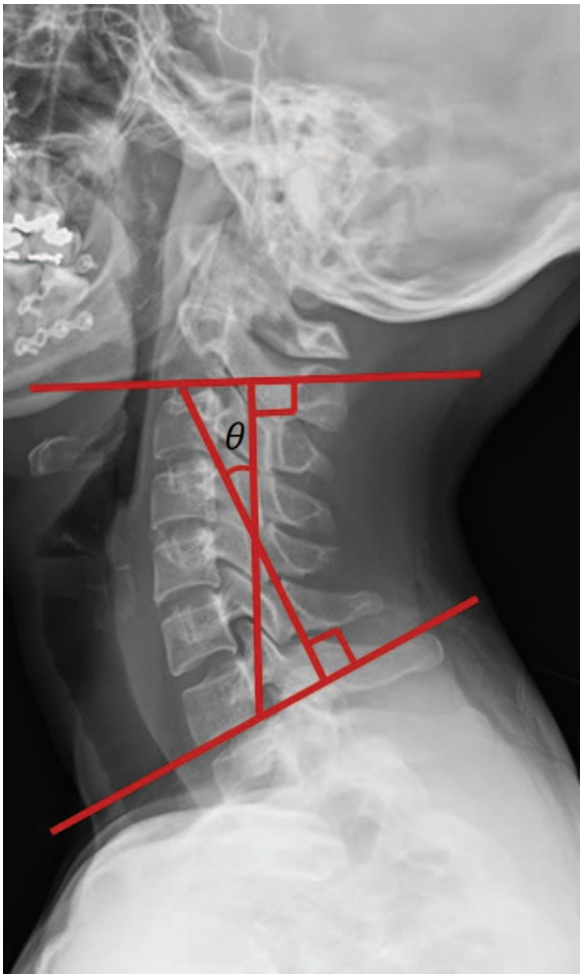

Figure 1. A lateral cervical X-ray in the neutral position showing a Cobb angle measurement between the lower border of the C2 body and the upper border of the C7 body.

2.4. Evaluation of risk factors for kyphosis development

Patients were divided into 2 groups based on whether they showed kyphosis ($0° \leq$ the C2–7 Cobb angle) or lordosis ($0° >$ the C2–7 Cobb angle) when the cervical alignment change reached a plateau. The clinical and radiological risk factors affecting postoperative kyphosis development were then evaluated.

2.5. Statistical methods

Data were imported into SPSS (version 20.1; SPSS Inc., Chicago, IL) for analysis. The primary outcome was to analyze significant angle changes over time using a linear mixed effects model. The linear mixed model included the pattern of covariance between repeated observations to account for the correlation between the observations within the patient. For the secondary outcome analysis unpaired Student *t* test or Mann–Whitney test for continuous variables and chi-square test or Fisher exact test for categorical variables were conducted to determine if there were statistically significant differences in the following baseline characteristics between the kyphosis and lordosis groups at 6 postoperative months, that is, sex, diagnosis at operation, weakness of extremities, preoperatively evaluated cause (trauma or spontaneous), ambulatory status, signal change at spinal cord, number of laminoplasties, method of laminoplasty, C2, C7, or T1 involvement, cervical alignment angle at the baseline preoperative evaluation, and the Japanese Orthopaedic Association (JOA) score at the preoperative evaluation and the last follow-up period. For determining the cut-off angle for predicting postoperative kyphosis, sensitivity and specificity were computed. Receiver operating characteristic (ROC) curves were drawn, and the area under the ROC curve along with its corresponding 95% confidence interval provided a measure of overall validity.

3. Results

A total of 130 cases of CEL were performed from February 2005 to May 2010. Of these, we excluded 16 cases due to limited observation data and 4 cases due to additional cervical surgery. A final cohort of 110 cases was enrolled and evaluated (Fig. 2).

3.1. Patient characteristics

The characteristics of the 110 study patients are summarized in Table 1. Of these, 85 patients were men (77.3%) and the mean age at the time of surgery was 57.4 ± 10.3 years. OPLL was diagnosed in 62 patients (56.4%) and degenerative spondylosis (DS) was diagnosed in 48 patients (43.6%). Weakness in the upper or lower extremities less than grade 4 was seen in 63 patients (57.3%). Six patients (5.5%) could not ambulate by

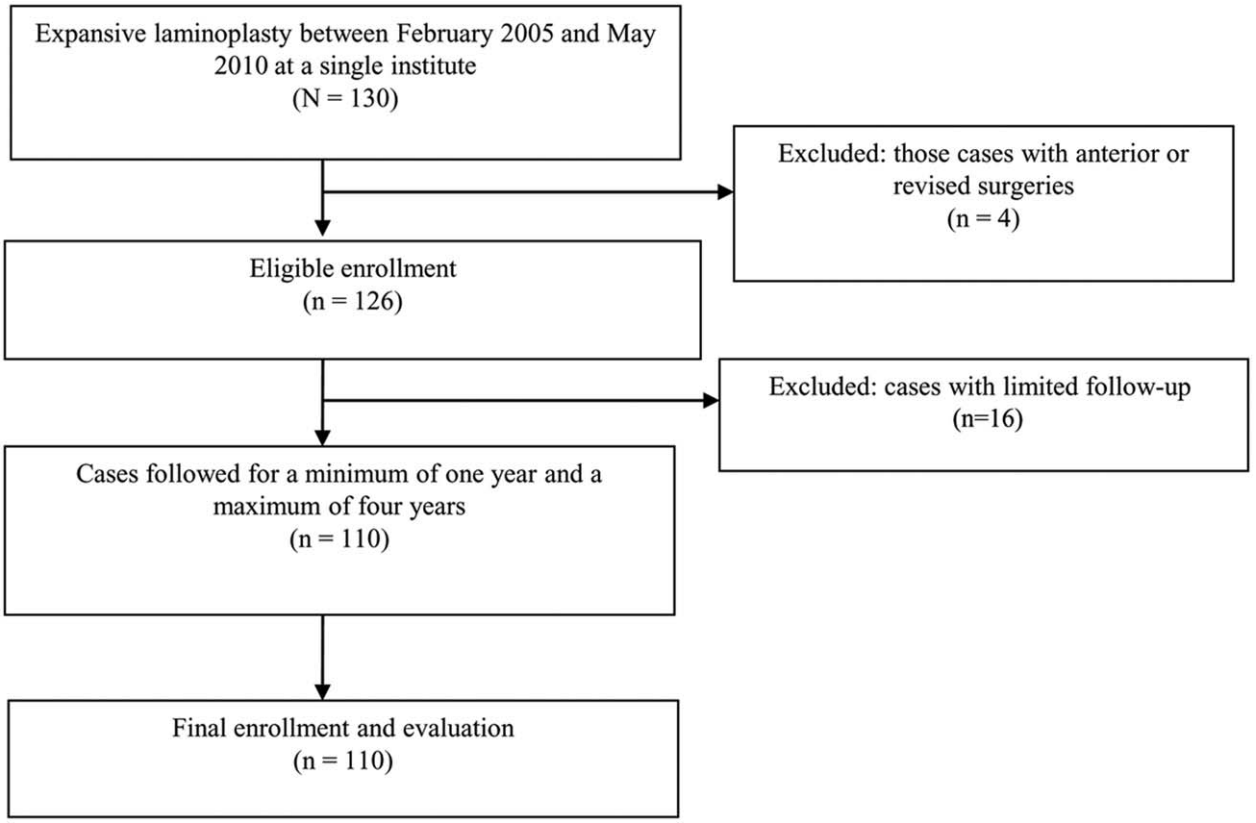

Figure 2. Flow diagram of patient enrollment and follow-up.

Table 1

Demographic and clinical characteristics of the study patients (N = 110).

Variable	Value
Age	57.41 (± 10.25)
Men	85 (77.3%)
Diagnosis at operation	
OPLL	62 (56.4%)
Degenerative spondylosis	48 (43.6%)
Weakness of extremities	63 (57.3%)
Ambulatory, non-ambulatory status	6 (5.5%)
Preoperative cause	
Trauma	19 (17.3%)
Spontaneously	91 (82.7%)
Symptom duration, days	25.10 (± 46.44)
JOA score at preoperative evaluation	12.98 (± 3.25)
Upper extremities	3.01 (± 1.18)
Lower extremities	3.29 (± 1.01)
Sensory	3.91 (± 1.17)
Bladder	2.77 (± 0.66)
JOA score at last follow-up	14.91 (± 2.38)
Upper extremities	3.37 (± 0.94)
Lower extremities	3.69 (± 0.71)
Sensory	4,93 (± 0.86)
Bladder	2.92 (± 0.41)
Signal change at spinal cord	86 (78.2%)
Number of laminoplasties	3.66 (± 1.034)
Method of laminoplasty	
Open door laminoplasty	73 (67.3%)
Midline splinting	36 (32.7%)
C2 involvement (laminectomy or -plasty)	6 (5.5%)
C7 involvement (laminectomy or -plasty)	21 (19.1%)
T1 involvement (laminectomy or -plasty)	3 (2.7%)

JOA = Japanese Orthopaedic Association, OPLL = ossification of posterior longitudinal ligament.

themselves. A signal change in the spinal cord was seen in 86 patients (78.2%) on magnetic resonance imaging (MRI). Symptoms appeared after trauma in 19 patients (17.3%). The mean duration from symptom onset to surgery was 25.1 ± 46.4 days. A unilateral open door laminoplasty was performed in 73 patients (67.3%), whereas a midline splinting laminoplasty was conducted in 36 patients (32.7%). The average number of the laminoplasty level was 3.7 (± 1.0). The numbers of cases of laminoplasty or laminectomy performed at the C2, C7, and T1 levels were 6 (5.5%), 21 (19.1%), and 3 (2.7%), respectively.

3.2. The change in cervical alignment over time after CEL

The numbers of observed patients at each period were 110, 93, 94, 88, 101, 51,56 and 45 at pre-operation, 1, 3, 6, 12, 18, 24, and 36 months postoperatively. Preoperatively, the mean baseline cervical alignment angle was 12.3° ± 10.4. After CEL, the maximum kyphotic change (decrease of CLA) was seen at 1 postoperative month (8.20 ± 11.6°, $P = .00$), which showed recovery in the lordotic angle restoration at the 3rd and 6th postoperative months (10.6 ± 10.1°, $P = .00$, and 9.1 ± 10.0°, $P = .04$, respectively). The alignment pattern reached a plateau after 6 months and was maintained for 3 years (8.4 ± 11.2°, $P = .24$; 8.5 ± 10.5°, $P = .89$; 8.1 ± 9.9°, $P = .71$; and 8.7 ± 10.1°, $P = .48$ at 12, 18, 24, and 36 months, respectively) (Fig. 3). The alignment angle change according to preoperative diagnosis dividing into DS and OPLL was analyzed. The trend of alignment change was similar in 2 groups, but the time reaching to the plateau was different. The kyphotic angle change in both groups peaked in the 1st month (14.0 ± 10.6 → 10,8 ± 11.5, $P = .01$ in DS

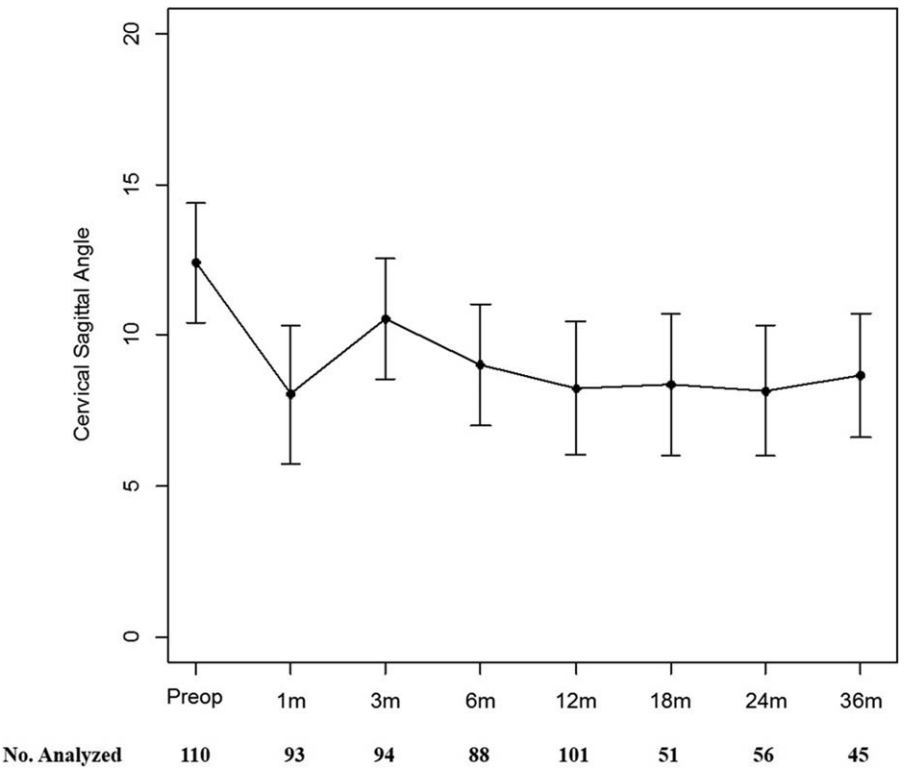

Figure 3. Cervical sagittal alignment change over time after cervical expansive laminoplasty. (linear mixed model was applied. and each observation point represent mean ± standard deviation).

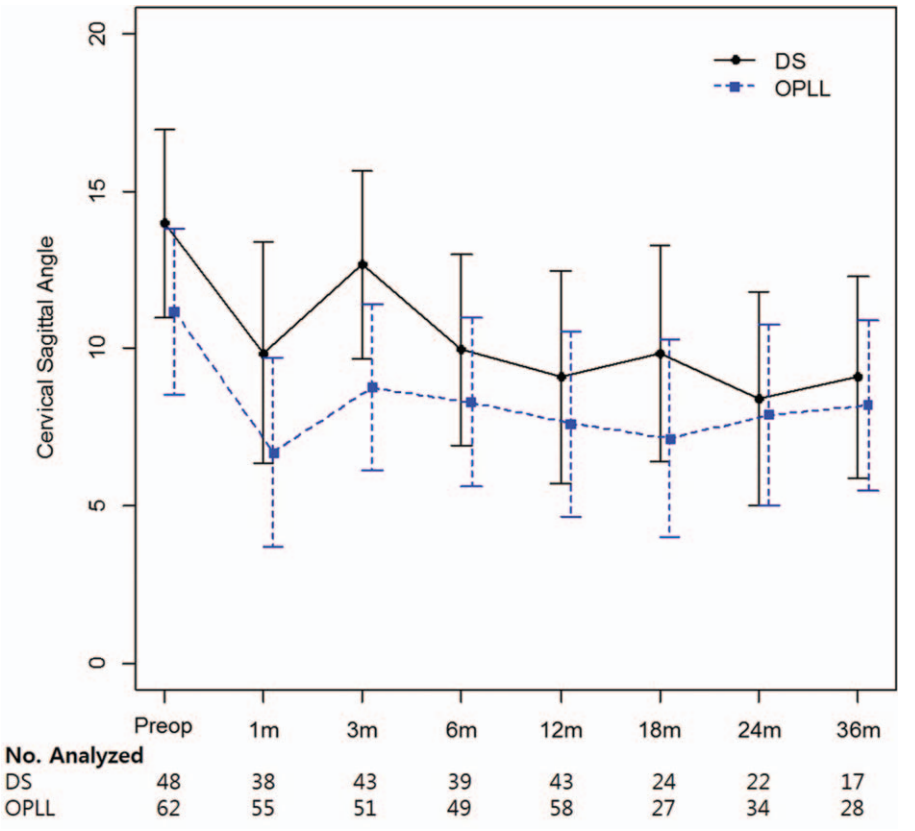

Figure 4. The alignment angle change according to preoperative diagnosis dividing into DS and OPLL. (linear mixed model was applied. and each observation point represent mean ± standard deviation). DS = Degenerative spondylosis, OPLL = ossification of posterior longitudinal ligament.

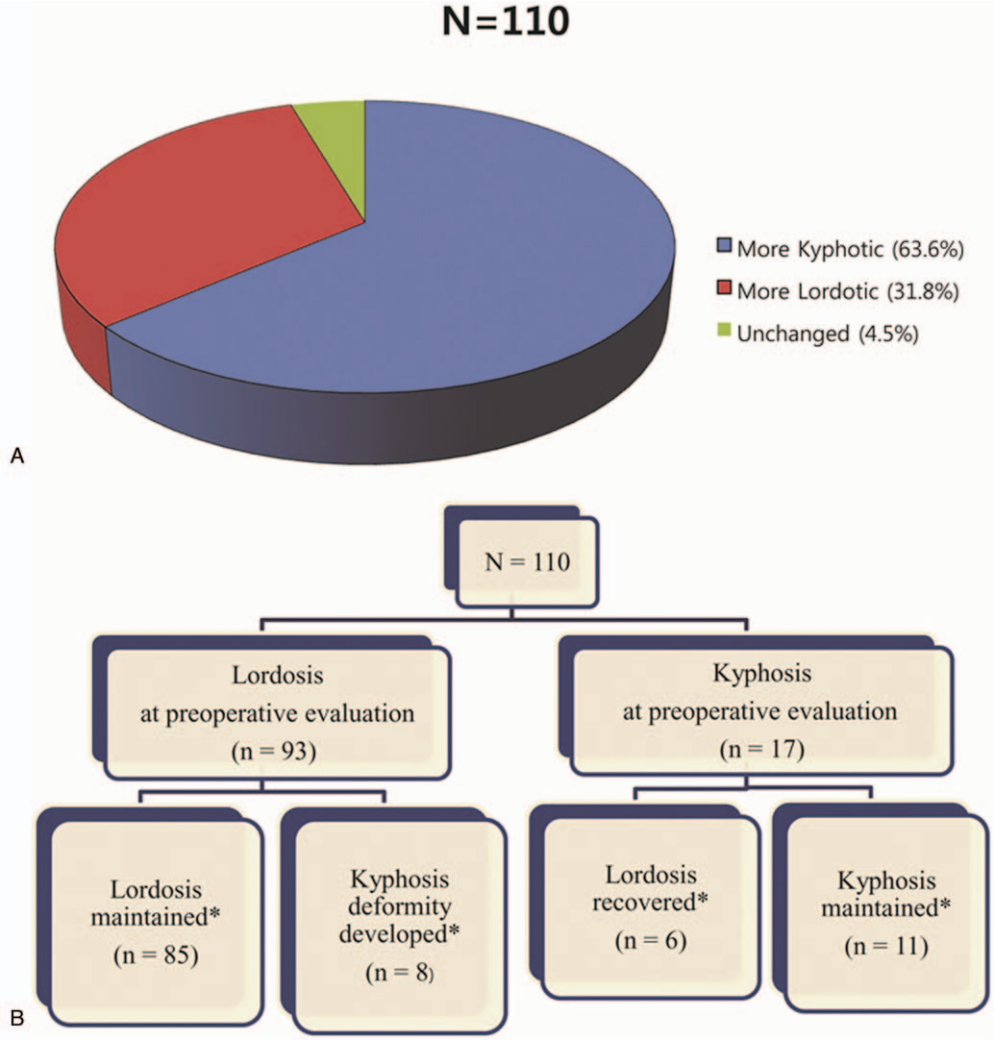

Figure 5. Cervical alignment change after cervical expansive laminoplasty: (a) the change in the C2–7 sagittal alignment before and after CEL, and (b) angle conversion of alignments. CEL = cervical expansive laminoplasty.

group and $11.2 \pm 10.3 \rightarrow 5.9 \pm 11.6$, $P = .00$ in OPLL) and recovered to the lordotic orientation in the 3rd month (13.0 ± 10.5, $P = .02$ in DS and 8.6 ± 9.5, $P = .04$ in OPLL). After 3 months, the alignment angle in OPLL group showed the plateau (8.6 ± 9.8, $P = .61$), but in DS group, the kyphotic angle slightly developed (9.8 ± 10.3, $P = .01$) and reached to the plateau (9.0 ± 13.1, $P = .36$) at 6 month (Fig. 4).

The functional outcomes based on JOA score were not significantly different between the kyphosis (12.42 ± 3.77 at the preoperative evaluation; 14.56 ± 2.57 at the last follow-up) and lordosis (13.10 ± 3.14, $P = .41$ at the preoperative evaluation; 14.98 ± 2.38, $P = .51$ at the last follow-up) groups. There was no revision due to the progression of kyphosis.

When we analyzed the cervical sagittal alignment angle between the preoperative evaluation and the 6-month follow-up (when the angle change reached a plateau), 70 of 110 patients (63.6%) were found to have a more kyphotic angle, 35 patients (31.8%) had a more lordotic angle, and 5 patients (4.5%) were unchanged. Lordosis was maintained in 85 of 93 patients who showed preoperative lordosis, whereas 8 patients converted to kyphosis after CEL. In contrast, 6 out of 17 patients who showed preoperative kyphosis were restored to lordosis, whereas 11 patients maintained kyphosis, after CEL (Fig. 5).

3.3. Risk factors for kyphosis development of cervical alignment

The clinical characteristics and surgical factors of the 2 groups according to cervical alignment (kyphosis and lordosis at the 6-month follow-up) are compared in Table 2. Overall, both cohorts were similar and showed no statistically significant differences. The only risk factor for kyphosis after CEL was the preoperative cervical alignment angle. The mean angle of the kyphosis group was $2.2 \pm 9.69°$ compared with $14.5 \pm 9.36°$ in the postoperative lordosis group ($P = .00$).

3.4. Cut-off value for angle change

We performed ROC analysis to identify the preoperative cervical alignment angle that predicted postoperative kyphosis at 6 months when the kyphotic angulation stabilized. Figure 6 shows the ROC curve that defined the cut-off angle for predicting

Table 2

Univariate analysis showing the individual effects of study variables on cervical alignment at 6 postoperative months (unpaired Student *t* test or Mann–Whitney test for continuous variables and chi-square test or Fisher exact test for categorical variables were conducted).

	Kyphosis Group (n = 19)	Lordosis Group (n = 91)	*P* value
Men	16 (84.2%)	69 (75.8%)	.555
Age	59.89 (± 8.26)	56.89 (± 10.58)	.247
Diagnosis at operation			
OPLL	12 (63.2%)	50 (54.9%)	.431
Degenerative spondylosis	7 (36.8%)	41 (45.1%)	
Weakness of extremities	9 (47.4%)	54 (59.3%)	.337
Preoperative cause			
Trauma	3 (15.8%)	16 (17.6%)	1.000
Spontaneously	16 (84.2%)	75 (82.4%)	
Ambulatory, ambulatory status	18 (94.7%)	86 (94.5%)	1.000
Signal change at spinal cord	5 (26.3%)	19 (20.9%)	.558
Number of laminoplasties	3.68 (0.75)	3.66 (1.09)	.925
Method of laminoplasty			
Open door laminoplasty	10 (52.6%)	64 (70.3%)	.135
Midline splinting	9 (47.4%)	27 (29.7%)	
C2 involvement (laminectomy or -plasty)	0 (0%)	6 (6.6%)	.587
C7 involvement (laminectomy or -plasty)	4 (21.1%)	17 (18.7%)	.757
T1 involvement (laminectomy or -plasty)	0 (0%)	3 (3–3%)	1.000
Cervical alignment angle at baseline preoperative evaluation	2.16 (± 9.69)	14.53 (± 9.36)	.00000
JOA score at preoperative evaluation	12.42 (± 3.77)	13.10 (± 3.14)	.41
JOA score at last follow-up	14.56 (± 2.57)	14.98 (± 2.38)	.51

JOA = Japanese Orthopaedic Association, OPLL = ossification of posterior longitudinal ligament.

cervical kyphosis. The optimal cut-off value for postoperative kyphosis was 8.5° (sensitivity, 70%; specificity, 77%; area under curve, 0.77; 95% confidence interval, 0.64–0.90). Figure 7 demonstrates the distributions of the preoperative cervical Cobb angle by cervical alignment group.

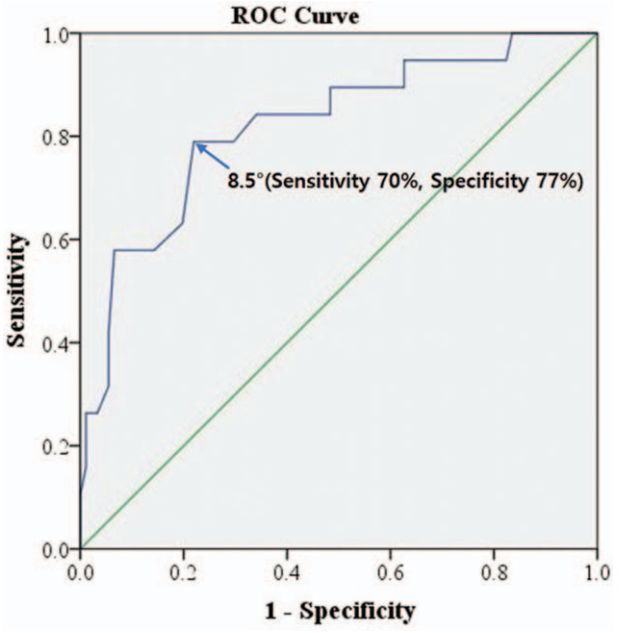

Figure 6. A ROC curve of the cervical alignment angle for predicting postoperative kyphosis at 6 postoperative months when the cervical angle change stabilized. ROC = receiver operating characteristic.

4. Discussion

We found in our present study that the kyphotic angulation after CEL developed in the 1st postoperative month, recovered to lordotic alignment at the 3rd and 6th months, and then reached a plateau after the 6th month. We believe that the kyphotic change in the 1st month can be considered to be the result of acute anatomical destruction of posterior elements, such as the yellow ligament, semispinalis muscle, and nuchal ligament of the neck, due to the surgical approach.[7] Lordotic angle recovery after acute kyphotic progression is suggested to be due to restoration of the destroyed posterior elements as well as recovery from acute surgical pain. Several studies demonstrated cervical alignment changes during the follow-up period.[3,8–10] Generally, in these studies, the cervical alignment after CEL showed a kyphotic change at the last follow-up evaluation.

Various risk factors were found to be associated with kyphotic change after CEL. Laminoplasty involving C2, C7, and/or T1 is a known risk factor for postoperative kyphosis.[1,2,10] Moreover, diagnosis of myelopathy associated with cervical spondylosis has been reported to affect postoperative kyphosis.[3] In our present study, procedures involving C2, C7, and/or T1 and the diagnosis of myelopathy associated with cervical spondylosis did not affect the development of kyphosis after CEL. The lordotic curvature of the preoperative alignment has been closely associated with postoperative alignment, with Suk et al[3] reporting that a lordosis angle of <10° affected postoperative kyphosis. In our present analyses, preoperative cervical alignment was found to be a significant risk factor for postoperative kyphosis. We found 8.5° to be the optimal cut-off value for predicting the development of postoperative cervical kyphosis.

In our present study cohort, the rate of kyphosis development after CEL was 8.6% (8 of 93 patients), when those with preoperative kyphosis were excluded. In the literature, the rate of kyphosis reported after CEL ranged from 6% to 8%.[8,11] The

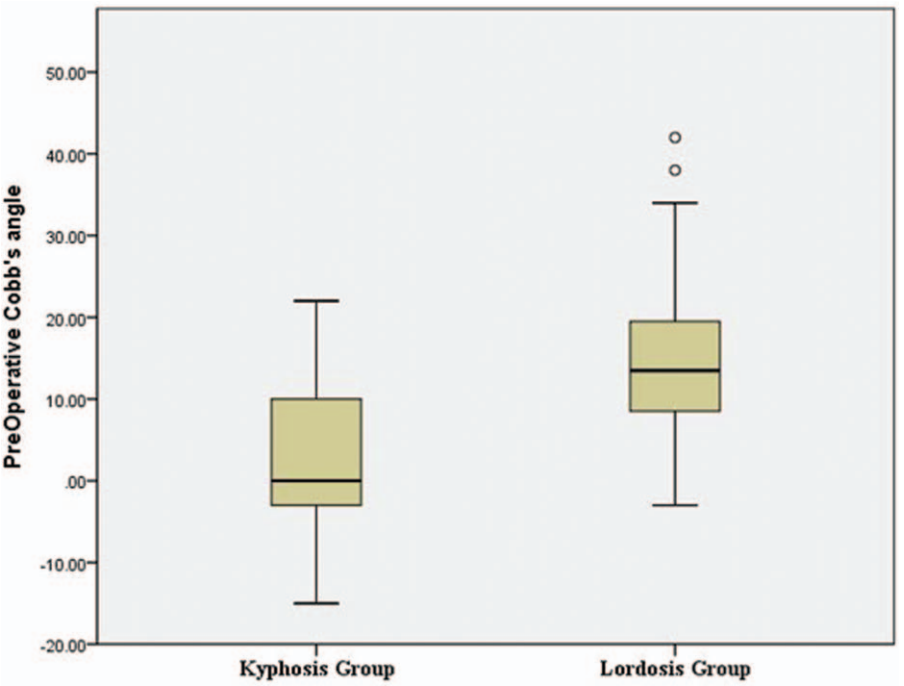

Figure 7. Distributions of the preoperative cervical Cobb's angle according to cervical alignment between postoperative kyphosis and lordosis group. (Box and whisker plot).

reported prognosis of postoperatively developed kyphosis has varied.[12,13] In neurological outcomes, few reports have documented the potential neurological decline that can accompany a loss of normal cervical lordosis. In our present study, the outcome analysis conducted by using JOA scores did not show significant differences between the lordosis and kyphosis groups. The strength of our present study was that our protocol was consistently applied to a large sample size for a long time. A few studies have reported that lordosis of cervical alignment decreases over time. In these studies, however, the decrease in the cervical lordotic angle was only seen at the last observation or within a limited follow-up time.[3,8–10]

There are several limitations to our study of note. First, we measured the CLA only when the patient was in a neutral position. Dynamic changes, including the range of motion in flexion or the extension view on lateral cervical X-ray imaging, were not measured, although dynamic factors may affect cervical alignment. Second, not all patients were observed for 3 years, although we adjusted the missing data by using a linear mixed statistical model. This limitation is due to the retrospective study design, and a prospective study would overcome this. Third, associated neck pain was not evaluated, although we focused on the serial changes in cervical alignment after CEL. Serial cervical alignment changes and neck pain scores may be closely associated. However, we think the retrospective investigation of clinical outcome according to each observation time would have a risk of recalling bias. Therefore, the correlation between sequential changes of cervical alignment and clinical symptom should be evaluated by a prospective study.

5. Conclusions

The cervical kyphotic angle change after expansive laminoplasty peaked in the 1st month. Some of the lordotic angles were restored in the 3rd and 6th months, before reaching a plateau after the 6th month. The only factor affecting posterative kyphosis was cervical alignment angle at baseline preoperative evaluation. And the optimal cut-off value angle predicting postoperative kyphosis was 8.5°.

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