

Usefulness of K-line in predicting prognosis of laminoplasty for cervical spondylotic myelopathy

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Abstract

Background: K-line is widely recognized as a useful index to evaluate alignment and size of the cervical ossification of the posterior longitudinal ligament (OPLL) in one parameter. The purpose of this study was to investigate that K-line could be a tool to predict the prognosis of LP for cervical spondylotic myelopathy (CSM) as well.

Methods: Sixty-eight patients who underwent LP were enrolled. C2-7 angle, local kyphosis angle, and K-line which is the straight line connecting the midpoints of the spinal canal at C2 and C7 was evaluated on T2-weighted sagittal magnetic resonance imaging (MRI). The JOA score and the recovery rate of the JOA score were evaluated at pre-operation and at follow-up. C2/C7 angle, local kyphosis angle, the JOA score, and the recovery rate were compared between K-line (-) and K-line (+) groups.

Results: The recovery rate of K-line (+) group (50.6%) was significantly better than that of K-line (-) (19.4%). In K-line (-), the disc type in which the protruded disc was absorbed during the follow-up showed statistically better recovery rate (27.6%) at follow-up compared to other K-line (-) in which anterior cord compression due to the osteophyte or the kyphotic beak was not absorbed (osseous type, 5.0%).

Conclusion: The present study has indicated that K-line can be a factor to predict the clinical outcome of LP for CSM. In K-line (-), the disc type showed somewhat better outcomes compared to the osseous type. However, the results were not sufficient.

Background

Laminoplasty (LP) is occasionally indicated for cervical myelopathy caused by a narrow spinal canal due to spondylosis and/or ossification of the posterior longitudinal ligament (OPLL). This procedure enables sufficient decompression in multi-segmental stenotic myelopathy. The effects of decompression with LP are attributed to two mechanisms, i.e., direct posterior decompression and posterior shifting of the spinal cord from anterior compressive lesions [1–3]. However, a large anterior bulge, as with a protruded disc or OPLL, often worsens the postoperative neurological recovery rate after LP [4–6]. Cervical kyphosis may also lead to poor surgical outcomes by interfering with posterior shifting of the spinal cord [3, 8]. Iwasaki et al. [4] reported that the neurologic outcome of LP for cervical OPLL was poor or fair in patients with occupying ratio greater than 60%, hill-shaped ossification, and postoperative kyphotic change in cervical alignment.

Fujiyoshi et al. [7] developed the K-line, a straight line connecting the midpoints of the spinal canal at C2 and C7 on plain lateral radiograph, as a new index to evaluate cervical alignment and OPLL size in one parameter, i.e., OPLL did not exceed the K-line in the K-line (+) group and did exceed the K-line in the K-line (-) group.

With regard to cervical spondylotic myelopathy (CSM), Suda et al. [8] reported that the patients with local kyphosis ≥ 13 degrees exhibited poorer clinical outcomes than those without kyphosis due to the

mechanisms described above. On the other hand, Chiba et al. [9] reported that several patients accompanying by cervical kyphosis obtained an acceptable clinical outcome after LP alone, probably because of the slackening of the spinal cord due to reduced multilevel disc height, which would not be compatible with cervical OPLL. Therefore, usefulness of K-line for CSM was uncertain. The purpose of the present study was to investigate whether K-line can provide a predictor of the clinical outcomes of LP for CSM.

Methods

Participants in the present study comprised Sixty-eight patients who underwent LP as decompression surgery for CSM were involved in the present study. Exclusion criteria were myelopathy caused by single-level disc herniation, OPLL, or a history of cervical spinal surgery, spinal tumor, trauma, and infection.

As the ethics approval, the study protocol was approved by the Institutional Review Board of Kindai University Hospital (Control Cohort Study, No.2020-025). We conducted this study under approval of the institutional review board and informed consent was obtained from all patients.

The operative technique was previously described by Miyazaki and Kirita's method (n = 64) and a modification of Kurokawa's method (n = 4). The method of Miyazaki and Kirita was a procedure in which bilateral gutters were made and the laminae were split in the middle with a high-speed drill. The laminae were kept open with nylon sutures in the deep fascia bilaterally. The modification of Kurokawa's method was the procedure in which mid-splitting of the spinous processes was performed using a T-saw [10]. After spreading the split spinous processes, hydroxyapatite spacers were sutured as necessary between the opened spinous process at each level.

We were able to obtain follow-up results for all 68 patients (50 males and 18 females). Mean age at surgery was 60.3 years (range, 32–92 years). All patients were followed-up for 2 year or longer after surgery. Mean follow-up period was 74.2 months (Table 1). The spinal levels of decompression were from C3 to C7 in 47 patients, C4 to C7 in 4 patients, C3 to C6 in 8 patients, C3 to Th1 and C2 to C7 in 3 patients each, and C4 to C5, C3 to C5 and C4 to Th1 in 1 patient each.

Table 1
Background characteristics of the participants

Characteristic	
Age (years old)	60.3 ± 12.4
Sex (male/female)	50 / 18
Follow-up period (months)	74 ± 43.5
The JOA score at preoperation (points)	9.7 ± 2.9
The JOA score at follow-up (points)	13.0 ± 2.6
The RR (%) of the JOA score	45.5 ± 28.0
C2-7 angle at preoperation (degrees)	4.1 ± 12.5
C2-7 angle at follow-up (degrees)	6.6 ± 14.3
Data are presented as means ± SD.	
JOA: Japanese Orthopaedic Association	
RR: recovery rate	

Clinical Findings

The Japanese Orthopaedic Association (JOA) scoring system was used to evaluate the severity of cervical myelopathy preoperatively and at the final follow-up. The recovery rate (RR) of the JOA score was calculated using the method of Hirabayashi et al. to compare preoperatively and at final follow-up JOA scores. As defined by Hirabayashi et al., RR (%) was calculated as (postoperative JOA score – preoperative JOA score) / (17- preoperative JOA score) × 100.

Radiological Evaluation

C2-7 angle was measured on T2-weighted sagittal images of magnetic resonance imaging (MRI) preoperatively and at the final follow-up. In CSM patients, although C2-7 angle was positive, local kyphosis existed due to the alignment (e.g., sigmoid, reverse sigmoid, and kyphosis) in several patients. In those cases, local kyphosis angle was also measured on T2-weighted sagittal images of MRI at preoperatively and at the follow-up. The K-line was defined as the straight line connecting the midpoints of the spinal canal at C2 and C7 on midsagittal T2-weighted MRI in the present study. The patients were divided into two groups; K-line (-) and K-line (+). In the K-line (-) group, the anterior structural factors (e.g., disc herniation, osteophyte, or kyphotic beak of the vertebra) crossed the K-line with no space between the K-line and the anterior wall of the canal. On the other hand, in the K-line (+) group, the anterior structural factors did not exceed K-line and stayed within the ventral area of K-line.

Clinical parameters such as gender, age, preoperative JOA score, the JOA score at the follow-up, the RR of the JOA score, and radiological parameters such as preoperative C2-7 angle, C2-7 angle at the follow-up, preoperative local kyphosis angle, and the local kyphosis angle at the follow-up were compared between K-line(-) and K-line (+).

Statistical analysis was performed using Student t-test and Mann-Whitney U test, with $P < 0.05$ considered statistically significant. Statistical analyses of data were performed with Stat Flex Ver.6 (Artech Co., Ltd., Osaka, Japan). Results were presented as means \pm SD.

Results

The mean JOA score was 9.7 points (range, 1–14 points) before surgery and 13.1 points (range, 1–17 points) at final follow-up. The Mean RR of the JOA score was 45.5%. The C2-7 angles at preoperatively and at follow-up were 4.1 ± 12.5 and 6.6 ± 14.3 degrees respectively (Table 1). K-line (-) were 11 patients (8 male, 3 females; mean of 57.2 years old), and K-line (+) were 57 patients (42 male, 15 females; mean of 60.9 years old). The JOA score at preoperatively and at follow-up were 10.1 ± 4.1 and 11.6 ± 4.1 in K-line (-) and 9.7 ± 2.6 and 13.3 ± 2.2 in K-line (+). The mean RR of JOA score were 19.4% in K-line (-) and 50.6% in K-line (+) group, representing a significant difference. With respect to radiological findings, preoperative C2-7 angle was significantly smaller in the K-line (-) group (-10.1 ± 9.0 degrees) than in the K-line (+) group (6.8 ± 11.2 degrees). The C2-7 angle at follow-up was significantly smaller in the K-line (-) group (-11.8 ± 10.4 degrees) than in the K-line (+) group (10.2 ± 12.1 degrees). Preoperative local kyphosis angle was significantly larger in the K-line (-) group (16.6 ± 10.0 degrees) than in the K-line (+) group (1.6 ± 3.1 degrees). Local kyphosis angle at follow-up was significantly larger in the K-line (-) group (14.7 ± 7.6 degrees) than in the K-line (+) group (1.3 ± 3.1 degrees) (Table 2).

Table 2
Comparison between K-line (-) and K-line (+)

	K-line(-)	K-line(+)	p
Numbers of the patients	11	57	
Age (years old)	57.2 ± 17.5	60.9 ± 11.0	NS
The JOA score at preoperation (points)	10.1 ± 4.3	9.7 ± 2.6	NS
The JOA score at follow-up (points)	11.6 ± 4.1	13.3 ± 2.2	< 0.01
The RR of the JOA score (%)	19.4 ± 25.2	50.6 ± 25.8	< 0.01
C2-7angle at preoperation (degrees)	-10.1 ± 9.0	6.8 ± 11.2	< 0.01
C2-7angle at follow-up (degrees)	-11.8 ± 10.4	10.2 ± 12.1	< 0.01
Local kyphosis angle at preoperation (degree)	16.6 ± 10.0	1.6 ± 3.1	< 0.01
Local kyphosis angle at follow-up (degree)	14.7 ± 7.6	1.3 ± 3.1	< 0.01
Data are presented as means ± SD.			
JOA: Japanese Orthopaedic Association			
RR: recovery rate			

With follow-up, we found that 7 cases of preoperative K-line (-) changed to K-line (+) because of absorption of the protruded disc (disc type; Fig. 1). On the other hand, 4 cases of preoperative K-line (-) due to the osteophyte or the beak of local kyphosis still stayed as K-line (-) at follow-up (osseous type; Fig. 2). We compared the clinical data between disc type (Fig. 3) and osseous type as shown in Table 3. Mean RR in the K-line (-) group classified as disc type was 27.6% at follow-up (Fig. 3). On the other hand, mean RR in the K-line (-) group classified as osseous type was only 5.0% (Fig. 2). This difference was statistically significant.

Table 3
Characteristics of K-line (-) patients by types

	Disc type	Osseous type	p
Number	7	4	
Age (yr)	57.4 ± 15.1	56.8 ± 23.9	NS
Pre-JOA (points)	11.1 ± 3.1	8.1 ± 5.8	NS
FU-JOA (points)	13.4 ± 1.6	8.6 ± 5.8	NS
RR of JOA (%)	27.6 ± 28.1	5.0 ± 10.0	< 0.05
Pre-MRI C2-7angle (degrees)	-6.0 ± 7.4	-17.3 ± 7.1	< 0.05
Fu-MRI C2-7angle (degrees)	-6.7 ± 4.5	-20.8 ± 12.3	< 0.05
Data are presented as means ± SD.			
JOA: Japanese Orthopaedic Association			
RR: recovery rate			

Discussion

Surgical outcomes for CSM accompanying local kyphosis have generally been reported as less than acceptable. Baba et al. [11] reported that patients with preoperative kyphosis (mean angle of 11.7°) show significantly poorer neurological improvement.

Suda et al. [8] also reported that outcomes of LP for CSM accompanying local kyphosis with an angle exceeding 13 degrees (when coexisted with myelomalacia) and 5 degrees (without myelomalacia) were poorer than those for CSM without local kyphosis in their multivariate logistic regression analysis. In contrast, Kaptain et al. [12] and Uchida et al. [13] have shown that surgical outcomes were not correlated with preoperative cervical kyphosis. We speculated that their conclusion might have been due to the kyphosis in their patients being mild. Kasai and Uchida reported that the presence or absence of anterior or posterior subarachnoid space of the spinal cord in postoperative MRI correlated significantly with clinical outcome of LP [14]. The present study has indicated that K-line can be a factor to predict the clinical outcome of LP for CSM. That is, cases preoperatively defined as K-line (-) displayed poorer clinical outcome after LP compared to those defined K-line (+). In particular, this is the first report to show that the disc type for preoperative K-line (-), in which disc was absorbed during the follow-up and the classification changed into K-line (+) at follow-up, achieved better clinical outcomes compared to patients showing the osseous type. However, outcome for disc type were worse than those of K-line (+). Moreover, predicting whether the bulging disc will be resorbed after surgery is not currently possible. Miyamoto et al. [15] reported that posterior correction surgery for patients with CSM accompanied by local kyphosis resulted

in a better clinical outcome than LP alone. Therefore, posterior correction surgery combined with LP should thus be considered for CSM in K-line (-) patients.

Conclusion

The present study has indicated that K-line can be a factor to predict the clinical outcome of LP for CSM. In K-line (-), the disc type showed somewhat better outcomes compared to the osseous type. However, the results were not sufficient. Therefore, posterior correction surgery combined with LP should be considered for CSM with K-line(-).

Abbreviations

LP: Laminoplasty; OPLL: posterior longitudinal ligament; CSM: cervical spondylotic myelopathy; JOA: The Japanese Orthopaedic Association; RR: recovery rate

Declarations

Availability of data and materials

The study was analyzed using data obtained from patients who provided informed consent.

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Kindai University Hospital (Control Cohort Study, No.2020-025). We conducted this study under approval of the institutional review board and informed consent was obtained from all patients. This study does not include patients under 18 years of age.

Consent for publication

Not applicable

Competing interests

The Authors declare that they have no competing interests.

Funding

The authors declare no potential conflict of interest concerning this study.

Authors' contributions

TI collected the data and interpreted, and wrote the manuscript. HM,MA contributed to design of the work and revised the manuscript critically for important content. All authors read and approved the final

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Figures

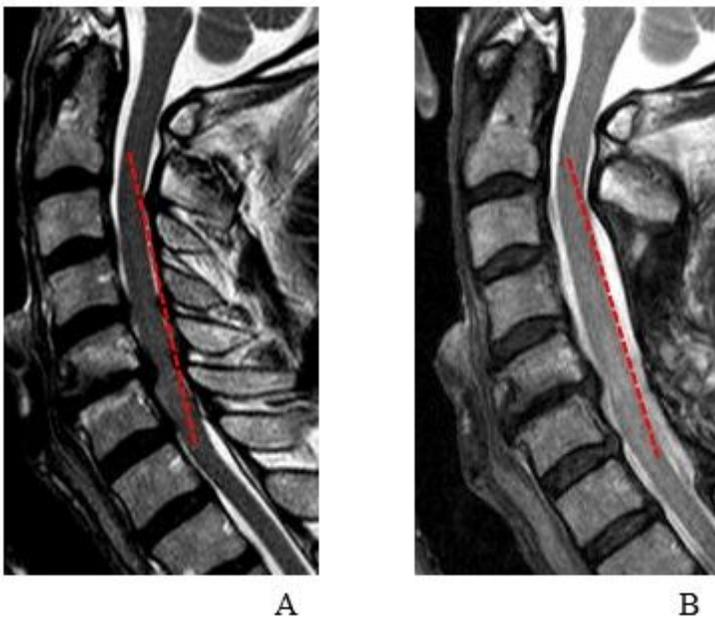


Figure 1

69-year-old male with K-line (+). Laminoplasty was performed from C3 to C7. C2/C7 angle was 29° at preoperation (A) and 28° at follow-up (B). The JOA score improved from 13 points to 15.5 points. The recovery rate of the JOA score was 62.5%.



Figure 2

44-year-old male with K-line (-). Laminoplasty was performed from C3 to C7. C2/C7 angle was -39° at preoperation (A) and -39° at follow-up (B). The JOA score improved from 7 points to 9 points. The recovery rate of the JOA was 20%.

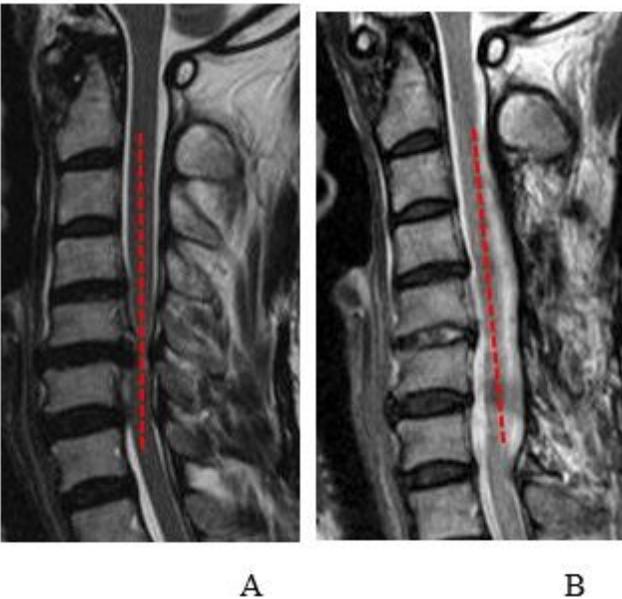


Figure 3

50-year-old female with K-line (-). Laminoplasty was performed from C3 to C7. C2/C7 angle was -1° at preoperation (A) and -16° at follow-up (B). The JOA improved from 11 points to 13.5 points. The recovery

rate of the JOA score was 41.7%. The protruded disc at C5/6 had a contact with K-line at preoperation (A). However, at the follow-up (B), the disc was absorbed, and the classification was changed to K-line (+).