Different standing postures are the influencing factors for the efficacy of laminoplasty in the treatment of K-Line (−) patients with ossification of the posterior longitudinal ligament

Rui Xue1 · Dai Liu2 · Yao Li1 · Di Zhang1

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Abstract

Objective To investigate the relationship between different standing postures and surgical outcomes of K-Line (−) ossification of the posterior longitudinal ligament (OPLL) patients after laminoplasty with a titanium basket.

Summary of Background Data There is a lack of data evaluating the relationship between the postoperative satisfaction of K-Line (−) patients and their standing postures.

Methods OPLL patients enrolled in the study were divided into a K-Line (+) group (Group A) and a K-Line (−) group (Group B) in natural and relaxed standing positions. We compared the postoperative outcomes after cervical laminoplasty with titanium basket surgery using the Japanese Orthopaedic Association score (JOA), recovery rate and the degree of improvement in the six JOA score items. The degree of satisfaction with the outcome was assessed at the 1-year follow-up using a 7-point numerical rating scale.

Results A total of 34 K-Line (+) patients with OPLL (age 61.9 ± 2.9 years) in Group A and 40 K-Line (−) patients with OPLL (age 60.4 ± 3.5 years) in Group B in natural and relaxed standing positions were recruited. In Group A, the mean preoperative and postoperative JOA scores were 10.1 ± 1.4 and 13.1 ± 0.8 points, respectively, and in Group B, the mean preoperative and postoperative JOA scores were 9.7 ± 1.3 and 11.1 ± 0.9 points, respectively. A significant improvement in the JOA score was seen in both groups postoperatively, but the recovery rate of the patients’ JOA scores was significantly lower in Group B. In Group A, significant improvements were seen in all JOA score items, but in Group B, improvements were seen only in upper- and lower-extremity sensory functions.

Conclusion Different standing postures are risk factors in the treatment of K-Line (−) patients, and therefore, natural and relaxed standing positions should be given more attention before devising the surgical plan.

Keywords Standing postures · K-Line · OPLL

Introduction

Ossification of the posterior longitudinal ligament (OPLL) is a degenerative disorder of the cervical spine that may lead to neurologic impairment. Many clinical studies have demonstrated satisfactory neurologic recovery following cervical laminoplasty [1–3]. However, the poor outcomes after surgery for patients are due to (1) the alignment of the cervical spine being kyphotic and (2) the large size of the OPLL [4, 5]. In 2008, an index named K-Line was proposed by Fujiyoshiet [6]. K-Line, a straight line joining the midpoints of the spinal canal at C2 and C7 on a lateral radiograph, is an index used for judging the severity of OPLL. The K-Line (+) OPLL was defined as the ossified mass not exceeding the K-Line, whereas the K-Line (−) OPLL was defined as the OPLL mass growing beyond the K-Line. Posterior decompression was recommended as a better approach for patients...
with K-Line (+) OPLL, and posterior decompression with instrumented fusion (PDF) was reported as a surgical option for K-Line (−) patients [7].

In our clinical practice, the satisfaction of K-Line (−) patients with OPLL was not the same after posterior approach surgery. Based on the different postures the patients assumed under evaluation by X-ray and in daily life, we speculated that the clinical outcome of K-Line (−) patients with OPLL may have some relationship with the standing posture. To our knowledge, there are few reports on the K-Line in different standing postures. Therefore, this retrospective study tried to investigate whether the standing position is related to the different postoperative outcomes in K-Line (−) patients with OPLL.

**Methods**

Informed consent was obtained from all patients. All methods were carried out in accordance with relevant guidelines and regulations.

In total, 74 K-Line (−) OPLL patients who underwent laminoplasty operations at our institution were included in this study from January 2017 to December 2018. Patients with acute traumatic cord injuries; patients with other confirmed neurologic disorders, such as Parkinson’s disease, multiple sclerosis and polio; and patients with ossification of the yellow ligament or a history of cervical spine surgery were excluded. The K-Line was defined as positive(+) when the OPLL peak did not exceed the K-Line and negative(−) when the OPLL peak exceeded the K-Line. OPLL patients with a negative K-Line in the upright standing position but a positive K-Line in the natural and relaxed standing positions were assigned to Group A. OPLL patients with a negative K-Line both in the upright standing position and in the natural and relaxed standing positions were assigned to Group B.

All the patients were asked to undergo an X-ray in two different standing positions: First, they were asked to learn how to keep the upright position first through pictorial charts and were requested to “stand as straight as possible and do not lean forwards, backwards or to the sides before taking the X-ray.” Next, all the patients were told to stand in a comfortable upright position that made them feel comfortable and relaxed just as in daily life and then to maintain this position during imaging.

All 74 patients who finished the 1-year follow-up were divided into 2 groups according to the K-Line in different standing positions. Thirty-four patients were placed into Group A due to a negative K-Line in the upright standing position and a positive K-Line in the comfortable standing position, and the remaining forty patients were arranged into Group B with a negative K-Line in both the upright standing position and the comfortable standing position.

An open-door laminoplasty operation was performed in both groups as follows. A posterior midline incision was made according to the required level of laminoplasty. High-speed blur was used to create a complete laminotomy on one side and an incomplete laminotomy on the contralateral side after C3-C6 (or C7) were fully exposed. The elevation of the lamina at the open side provided sufficient spinal cord decompression. The open side was stabilized with laminoplasty baskets and screws. In each case, appropriate basket sizes were chosen for adequate enlargement of the spinal canal. Philadelphia collars were applied for 2 months postoperatively. The patients were followed up at 1, 3, 6 and 12 months postoperatively. Pre- and postoperative JOA scores for cervical myelopathy and recovery rates at 1, 3, 6 and 12 months were collected.

Data were analyzed using SPSS software (version 24.0; SPSS, Chicago, IL). Continuous variables were expressed as the mean ± standard deviation (SD), and categorical variables were expressed as frequencies or percentages. An independent t test was used to analyze the difference in continuous variables between the 2 groups. A Chi-square analysis and Fisher’s exact test were used to examine the differences among categorical variables. P < 0.01 was considered statistically significant.

**Results**

The mean age was 61.9 ± 2.9 years in Group A and 60.4 ± 3.5 years in Group B. There were no statistically significant differences among the demographic data between the groups in terms of sex, social drug use (smoking and alcohol drinking), axial neck pain, myelopathy, or the clinical findings for the Hoffman sign, the Spurling test, dyskinesia and paresthesia. Patient characteristics and baseline functions are shown in Table 1.

The postoperative outcome during the entire follow-up period was assessed by the JOA score, as demonstrated...
Fig. 1 Comparison of JOA scores in the K-Line (−) (+) and K-Line (−) (−) groups. "*" Means statistical significance
The average Hirabayashi recovery rates (%) for patients in the 2 groups were 58.6 ± 10.1% in Group A and 31.5 ± 9.9% in Group B (p < 0.001). There was a significant difference between the groups.

**Discussion**

In 2008, a concept named K-Line was proposed by Fujiyoshi, who recommended anterior decompression surgery as the
first choice for K-Line (−) patients because sufficient posteri- 

tor shift of the spinal cord and neurologic improvement 

were not obtained after posterior decompression surgery [6]. In 2013 and 2014, Taniyama considered the modified K-Line in magnetic resonance imaging to predict insufficient decompression and clinical outcome [8, 9] because it was a better predictor of the space for the spinal cord. In the process of selecting surgical methods for ossification of the longitudinal ligament, the key factor for posterior surgery was enough space for the spinal cord. Sufficient space for the spinal cord to ward off ventral compression could be achieved in two different ways: enough posterior space or sufficient cervical lordosis.

Laminoplasty was developed in Japan and is now used in patients worldwide. Laminoplasty has been recognized as an effective method to obtain posterior space, and motor function can be maintained to the greatest extent. However, sometimes this does not bring about enough indirect decompression, resulting in unfavorable outcomes [10]. To solve these problems, Matsuoka et al. concluded that titanium basket implantation is a safe procedure with satisfactory clinical results that has the potential to promote bone union between the spacer and both laminae, as well as lateral mass, just as we observed in our clinical practice. Laminoplasty with a titanium basket is a useful alternative as an improved method compared with the conventional procedure [11].

It has been reported that cervical local kyphosis is a predi c tive factor for poor outcomes after laminoplasty [12]. Therefore, some methods need to be taken to increase the lordotic nature of the cervical spine. Based on its better clinical outcome, PDF was regarded as a proper surgical option for OPLL with the effects of increasing the recovery rate, improving the recovery effect and significantly reducing the JOA score [13–15]. However, posterior cervical fusion surgery also has its own complications, such as acute blood loss anemia, surgical site infection, C5 palsy, incidental durotomy, adjacent segment degeneration, junctional kyphosis and pseudoarthrosis [16]. Ha et al. reported that, compared to posterior fusion, laminoplasty was recommended for the treatment of multilevel cervical OPLL because it could maintain lordosis and reduce the risk of kyphosis due to minimal damage to the musculo-ligamentous complex [17].

To our knowledge, there has been no study investigating the relationship between a patient's recovery and standing posture after laminoplasty with a titanium basket. Different standing postures showed different spine profiles, and compared to upright standing postures, a more lordotic global cervical angle (GCA), a more kyphotic global thoracic angle (GTA) and a less kyphotic global lumbar angle (GLA) could be obtained during natural and relaxed standing positions [18]. In other words, cervical lordosis could be increased during natural and relaxed standing postures, which provides enough space for the spinal cord. Hey et al. reported an approximately 10° increase in lordosis in the GCA angle in natural and relaxed standing positions compared with upright standing positions in a study of sixty young and healthy adults. The natural and relaxed standing position was a better choice than the upright standing position in order for postoperative patients returning to their daily activities to maintain their balance with minimal effort [19, 20]. Although better cervical lordosis could be attained after posterior fusion surgery, it was not necessary to restore the cervical curvature intentionally. In a study of cervical alignment variations in different postures, Hey et al. found that lordotic correction of the cervical spine is not always physiological and may not prove beneficial in certain patients [21]. We believe that the normal cervical spine has a wide morphology and varies according to the posture assumed by an individual, and the optimal cervical curvature should be determined by individualized postures in daily life rather than by a standard.

The limitations of the present study are as follows. First, the sample size was relatively small, which could have led to false positives in the statistics. Second, there was a short follow-up period of 1 year, which may have been too short for changes in OPLL after cervical laminoplasty to appear, and this may have affected the surgical outcomes. Despite these limitations, to our knowledge, this is the first study to investigate the relationship between the K-Line (−) OPLL patients’ recovery and standing posture after laminoplasty with a titanium basket.

**Conclusion**

Different standing postures are the influencing factors for the efficacy of laminoplasty in the treatment of K-Line (−) patients with OPLL. Natural and relaxed standing postures should also be focused on before devising a surgical plan for OPLL patients.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s00586-022-07300-0.

**Declaration**

**Conflict of interest** The authors declare that they have no conflict of interest.

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References

1. Seichi A, Takeshita K, Ohishi I et al (2001) Long-term results of double-door laminoplasty for cervical stenosis myelopathy. Spine 26:479–487
2. Kawaguchi Y, Kanamori M, Ishihara H et al (2003) Minimum 10-year follow-up after en bloc cervical laminoplasty. Clin Orthop 411:129–139
3. Ogawa Y, Toyama Y, Chiba K et al (2004) Long-term results of expansive open-door laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine. J Neurosurg Spine 1:168–174
4. Iwasaki M, Okuda S, Miyauchi A et al (2007) Surgical strategy for cervical myelopathy due to ossification of the posterior longitudinal ligament: part 1: clinical results and limitations of laminoplasty. Spine 32:647–653
5. Lee CK, Shin DA, Yi S et al (2016) Correlation between cervical spine sagittal alignment and clinical outcome after cervical laminoplasty for ossification of the posterior longitudinal ligament[J]. J Neurosurg Spine 24(1):100–107
6. Takayuki F, Masashi Y, Junko K et al (2008) A New Concept for Making Decisions Regarding the Surgical Approach for Cervical Ossification of the Posterior Longitudinal Ligament. Spine 26(33):E990–E993
7. Junya S, Satoshi M, Koshiro K et al (2016) Outcome of posterior decompression with instrumented fusion surgery for K-line (−) cervical ossification of the longitudinal ligament. J Clin Neurosci 32:57–60
8. Taniyama T, Hirai T, Yamada T, et al. Modified K-line in magnetic resonance imaging predicts insufficient decompression of cervical laminoplasty. Spine (Phila Pa 1976). 2013; 38:496–501.
9. Taniyama T, Hirai T, Yoshii T, et al. Modified K-line in magnetic resonance imaging predicts clinical outcome in patients with nonlordotic alignment after laminoplasty for cervical spondylotic myelopathy. Spine (Phila Pa 1976). 2014;39: E1261–E1268.
10. Ma L, Liu F Y, Huo J S, et al. Comparison of laminoplasty versus laminectomy and fusion in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: A systematic review and meta-analysis[J]. Medicine, 2018, 97(29).
11. Hidenori M, Yukoh O, Takaoki K et al (2020) Clinical outcome and radiological findings after cervical open door laminoplasty with titanium basket. J Clin Neurosci 73:140–143
12. Suda K, Abumi K, Ito M, et al. Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy. Spine (Phila Pa 1976). 2003; 28:1258–1262.
13. Tani T, Ushida T, Ishida K, et al. Relative safety of anterior micro-surgical decompression versus laminoplasty for cervical myelopathy with a massive ossified posterior longitudinal ligament. Spine (Phila Pa 1976) 2002; 27:2491–8.
14. Iwasaki M, Okuda S, Miyauchi A, et al. Surgical strategy for cervical myelopathy due to ossification of the posterior longitudinal ligament: Part 2: Advantages of anterior decompression and fusion over laminoplasty. Spine (Phila Pa 1976) 2007; 32:654–60.
15. Sakai K, Okawa A, Takahashi M, et al. Five-year follow-up evaluation of surgical treatment for cervical myelopathy caused by ossification of the posterior longitudinal ligament. Spine (Phila Pa 1976) 2012; 37:367–76.
16. Ryan KB, Rory M, Brenton P et al (2020) Complications following posterior cervical decompression and fusion: a review of incidence, risk factors, and prevention strategies. J Spine Surg 6(1):323–333
17. Ha Y, Shin J J. Comparison of clinical and radiological outcomes in cervical laminoplasty versus laminectomy with fusion in patients with ossification of the posterior longitudinal ligament[J]. Neurosurgical Review, 2019: 1–13.
18. Hwee WDH, Tan KA, Liu G et al (2019) Comparison of whole-body sagittal alignment during directed vs natural, relaxed standing postures in young, healthy adults. Spine J 19:1832–1839
19. Schwab F, Patel A, Ungar B et al (2010) Adult spinal deformity—postoperative standing imbalance. Spine 35:2224–2231
20. Douboisset J. Three-dimensional analysis of the scoliotic deformity. In: Weinstein S, editor. Pediatric spine: principles and practice. New York, NY: Raven Press; 1994.
21. Hwee WDH, Eugene TCL, Tan KA et al (2017) Cervical Alignment Variations in Different Postures and Predictors of Normal Cervical Kyphosis. Spine J 21(42):1614–1621

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