


RESEARCH ARTICLE

Open Access



Segmental motion at the peak of the ossification foci is independent risk factor except for mal-alignment and thick ossification foci for poor outcome after laminoplasty for cervical ossification of the posterior longitudinal ligament: analyses in patients with positive K-line, lordotic alignment, and lower canal occupying ratio

Junya Saito¹, Masao Koda^{2*} , Takeo Furuya¹, Satoshi Maki¹, Yasushi Ijima¹, Mitsuhiro Kitamura¹, Takuya Miyamoto¹, Sumihisa Orita¹, Kazuhide Inage¹, Fumio Hasue³, Takayuki Fujiyoshi³, Koshiro Kamiya³, Yoshikazu Ikeda⁴, Fumitake Nakajima⁴, Mitsuhiro Hashimoto⁴, Hiroshi Noguchi², Hiroshi Takahashi⁵, Masashi Yamazaki² and Seiji Ohtori¹

Abstract

Purpose: To elucidate the independent preoperative factors that have a significant impact on poor surgical outcome after laminoplasty for K-line (+) ossification of the posterior longitudinal ligament (OPLL). Analyses in K-line (+) patient population can exclude the influence by mal-alignment and thick OPLL, both of which are well known two major factors that have significant impact on clinical outcome.

Methods: The present study included 72 patients (50 male and 22 female) who underwent laminoplasty for K-line (+) cervical OPLL and were followed-up for at least 1 year. Recovery of Japanese Orthopedic Association score (JOA score) for cervical myelopathy was used as the measure of clinical outcome. For radiographic assessment, the type of OPLL, the maximum OPLL occupation ratio, the C2-C7 angle, and the segmental range of motion at the peak of OPLL (segmental ROM) were assessed. To elucidate the factors that are significantly associated with a poor clinical outcome after laminoplasty for K-line (+) OPLL, statistical analyses were conducted.

(Continued on next page)

* Correspondence: masaokod@gmail.com

²Department of Orthopedic Surgery, University of Tsukuba, Tennodai, Tsukuba, Ibaraki 305-8575, Japan

Full list of author information is available at the end of the article



© The Author(s). 2020 **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

(Continued from previous page)

Results: The mean preoperative JOA score was 8.9 points and improved to 12.8 points after surgery. The recovery of JOA score was $47 \pm 35\%$. Stepwise logistic regression following univariate analyses revealed that preoperative segmental ROM at the peak of OPLL is an independent factor associated with a poor outcome ($p = 0.04$, odds ratio = 1.15).

Conclusions: Large preoperative segmental ROM at the peak of the OPLL is an independent factor that has significant impact on poor surgical outcome after laminoplasty for K-line (+) OPLL.

Keywords: Ossification of the posterior longitudinal ligament, K-line, Laminoplasty, Risk factor, Segmental range of motion

Introduction

In Japan, expansive laminoplasty is widely applied to ossification of the posterior longitudinal ligament (OPLL) of the cervical spine, because it can achieve simultaneous multilevel spinal cord decompression, and does not need any special procedures or techniques. The rationale for spinal cord decompression by laminoplasty for anteriorly located OPLL is a bow-stringing effect, which achieves posterior shift of the spinal cord by removal of the posterior element of the spinal canal based on lordosis of the cervical spine [1]. Therefore, OPLL patients with kyphosis and/or thick ossification foci may have an unfavorable outcome because the bow-stringing effect cannot work sufficiently in such patients [2, 3]. To predict sufficient decompression by laminoplasty preoperatively, the K-line was conceived [4]. The K-line is defined as an imaginary line between the midpoints of the spinal canal at C2 and C7. If the peak of the OPLL does not exceed the K-line, which means lordosis and/or ossification foci are not so extensive, the patient will be categorized as K-line (+), and sufficient spinal cord decompression can be obtained by laminoplasty alone. By contrast, in patients with the peak of OPLL exceeding the K-line, which means kyphosis and/or ossification foci are extensive, then the patient will be categorized as K-line (–), and insufficient decompression by laminoplasty alone is predicted. K-line (–) OPLL patients show poor surgical outcome after laminoplasty alone [5]. Therefore, anterior decompression and fusion surgery or posterior decompression with instrumented fusion surgery should be applied for K-line (–) OPLL patients.

Analyses in K-line (+) patient population can exclude the influence by mal-alignment and thick OPLL, both of which are two major factors that have significant impact on clinical outcome. The primary aim of the present study was to elucidate the independent preoperative factors that have a significant impact on poor surgical outcome after laminoplasty for K-line (+) OPLL, omitting the possible influence by mal-alignment and thick OPLL.

Methods

The present study included 72 patients (50 male and 22 female) who underwent laminoplasty alone for K-line

(+) cervical OPLL and were followed-up for at least 1 year. Therefore, the present study excluded K-line (–) patients with kyphosis and/or thick ossification foci, both of which are the major known risk factors for insufficient decompression by laminoplasty alone. The average age at surgery was 66.5 years (range 31–86 years) and the mean follow-up period was 52.6 months (range 12–194 months). The demographic data of the patients is shown in Table 1.

Recovery of Japanese Orthopedic Association score (JOA score) for cervical myelopathy [6] was used as the measure of clinical outcome. The recovery of JOA score was calculated using the following formula: percentage recovery = $((\text{postoperative JOA score} - \text{preoperative JOA score}) / (17 - \text{preoperative JOA score})) \times 100$ [7].

Radiographic assessments were performed as follows: the type of OPLL was classified into continuous, segmental, and mixed type according to the classification described by Tsuyama et al. [8]. The maximum OPLL occupation ratio was defined as the thickness of the peak of OPLL divided by the anteroposterior diameter of the bony spinal canal on lateral plain X-ray images of the cervical spine (Fig. 1). The C2–C7 angle was measured by the angle between the C2 and C7 inferior endplates in pre- and postoperative lateral radiographs of the cervical spine, and was expressed as positive values for lordosis and negative values for kyphosis. Preoperative segmental range of motion (segmental ROM) was expressed as an increase in the angle between the inferior endplates of the vertebrae at the peak of OPLL in the flexion–extension lateral radiograph.

Table 1 Patient demographics

Patient demographics	(n = 72)
Male: Female	50: 22
Age at surgery (years old)	66.5 (31–86)
Follow-up period (month)	52.6 (12–194)
Japanese Orthopedic Association (JOA) score (points)	
Pre-op.	8.9 (2–15)
Post-op.	12.8 (5.5–17)
Recovery rate	$46.6 \pm 35.0\%$

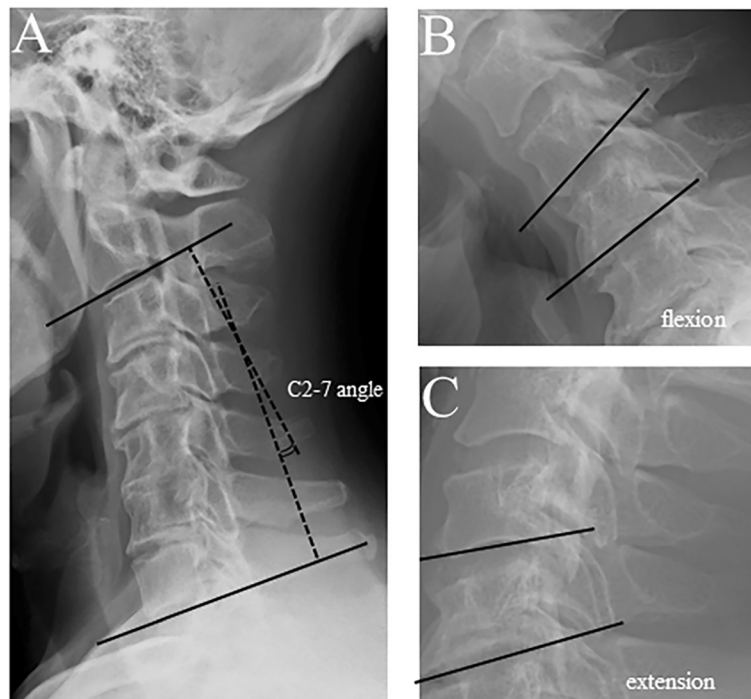


Fig. 1 Measurement of C2-7 angle and range of motion. C2-7 angle was measured as angle between C2 and C7 lower endplates in lateral cervical spine X-ray in neutral position (a). Range of motion was measured as change in angle between corresponding spinal segment in cervical spine X-ray in flexion and extension position (b)(c)

To elucidate the factors that are significantly associated with a poor clinical outcome after laminoplasty for K-line (+) OPLL, statistical analyses were conducted as follows. Patients who showed JOA score recovery less than the average of all the patients were considered to have poor surgical outcome. Correlation between a poor surgical outcome and all patient factors (including age, sex, and preoperative JOA score) and imaging assessments described above (including type of OPLL, maximum OPLL occupation ratio, preoperative C2–C7 angle, preoperative segmental ROM) were analyzed using univariate analysis. Factors that showed a $p < 0.1$ were selected for further analyses. Next, the selected factors were subjected to logistic regression analyses using a stepwise method to determine which independent factors were significantly associated with a poor surgical outcome after laminoplasty for K-line (+) OPLL. Receiver-operator characteristic (ROC) curve analyses were performed to determine the cutoff value predicting a poor outcome. Values are expressed as mean \pm SD. All the analyses were conducted using JMP (version 10.0.2; SAS Institute, Cary, NC, USA).

Results

The mean preoperative JOA score was 8.9 points (range 2 to 15) and improved to 12.8 points (range 5.5 to 17)

after surgery. The recovery of the JOA score was $47 \pm 35\%$ (Table 1).

The types of OPLL were classified into continuous (1 case), mixed (39 cases), segmental (27 cases), and local (5 cases) types. The average maximum occupation ratio of the OPLL was $44.7 \pm 11.8\%$. The average preoperative segmental ROM at the peak of the OPLL was $5.2 \pm 3.9^\circ$. The average preoperative C2–C7 angle was $11.5 \pm 8.8^\circ$ (Table 2).

By univariate analyses, the maximum occupation ratio of the OPLL and preoperative segmental ROM at the peak of OPLL showed a significant correlation with poor surgical outcome after laminoplasty alone for K-line (+)

Table 2 Imaging analyses

Imaging analyses	
Type of ossification of the posterior longitudinal ligament (OPLL)	
Continuous	1 case
Mixed	39 cases
Segmental	27 cases
Local	5 cases
Maximum occupation ratio (%)	44.7 ± 11.8
Pre-op. C2-7 angle (degree)	11.5 ± 8.8
Pre-op. segmental range of motion (ROM) at peak of OPLL (degree)	5.2 ± 3.9

OPLL. Stepwise logistic regression revealed that preoperative segmental ROM at the peak of OPLL is an independent factor associated with a poor outcome ($p = 0.04$, odds ratio = 1.15), whereas the other factor we examined, maximum occupation ratio of the OPLL ($p = 0.07$), was not significant. ROC analyses showed that the cut-off value of preoperative segmental ROM at the peak of the OPLL to predict poor surgical outcome was 4.2° , and the area under the curve value was 0.67, showing a moderate predictability (Table 3). Thus, if the preoperative segmental ROM is greater than 4.2° , poor surgical outcome after laminoplasty is expected.

Discussion

We found that a large preoperative segmental ROM at the peak of the OPLL is an independent factor having a significant impact on poor surgical outcome after laminoplasty for K-line (+) OPLL.

In the present study, we only included patients with K-line (+), excluding K-line (-) patients who have kyphosis and/or thick ossification foci, both of which are well known major deteriorative factors after laminoplasty. Kyphosis and thick ossification foci inhibit sufficient posterior spinal cord shift caused by bow-stringing effect, resulting in insufficient decompression after laminoplasty. This suggested that the present series of patients would obtain sufficient spinal cord decompression by laminoplasty alone. A large preoperative segmental ROM at the peak of OPLL can impede neurological recovery even though sufficient decompression is obtained by laminoplasty.

There are several previous reports describing this impediment. Masaki et al. reported that patients showing a

poor surgical outcome had a significantly greater preoperative segmental ROM at the peak of OPLL. They concluded that anterior decompression and fusion surgery is suitable for such patients [9]. Maruo et al. reported that the C2-C7 ROM of patients with a poor surgical outcome after laminoplasty for OPLL was significantly greater than that in patients with a better outcome [10, 11]. These lines of evidence suggest that a large ROM at the peak of the OPLL can impede neurological recovery after laminoplasty. However, definitive conclusion cannot be drawn from those previous reports because those reports include heterogenic patient population, mal-alignment, and thick OPLL, both of which are the major confounding factors on clinical outcome after decompression surgery for OPLL. Possible advantages of the present study is the homogeneity of the patients population by enrolling only K-line (+) patients, which means good lordotic alignment and relatively lower canal occupying ratio, contributing to exclude the confounding factors.

Possible mechanisms underlying the impact of a large segmental ROM on poor neurological recovery are as follows. First, the spinal cord can be impinged at the peak of OPLL, because the peak of OPLL could be an apex during cervical spine flexion, even after sufficient posterior decompression achieved by laminoplasty. Next, there is a possibility that preoperative spinal cord impingement because of large preoperative segmental ROM could induce repetitive minor trauma to the spinal cord, which might result in irreversible spinal cord tissue damage. We cannot distinguish between these two mechanisms. Further investigation is needed to elucidate this issue. We are now applying short segmental fusion to laminoplasty if the preoperative segmental ROM is relatively large. Future comparison between laminoplasty alone and laminoplasty with short segmental posterior fusion for K-line (+) OPLL with large segmental ROM at the peak of the OPLL will elucidate the mechanisms underlying the impact of large segmental ROM on neurological recovery after laminoplasty.

Conclusions

Large preoperative segmental ROM at the peak of the OPLL is an independent factor that has a significant impact on poor surgical outcome after laminoplasty alone for K-line (+) OPLL. Therefore, conversion to anterior surgery or addition of instrumented fusion to laminoplasty should be considered for such patients.

Abbreviations

OPLL: Ossification of the posterior longitudinal ligament; JOA: Japanese Orthopedic Association; ROM: Range of motion; ROC: Receiver-operator characteristic; SD: Standard deviation

Code availability

Not applicable.

Table 3 Univariate analysis and stepwise logistic regression

	p value
Univariate analysis	
Age	0.24
Sex	0.21
Follow-up period	0.36
Pre-op. JOA score	0.24
Type of OPLL	0.68
Maximum occupation ratio	0.09 [#]
Pre-op. C2-7 angle	0.29
Pre-op. segmental ROM at peak of OPLL	0.03 [#]
Stepwise logistic regression	
Pre-op. segmental ROM at peak of OPLL	0.04 [*]
Maximum occupation ratio	0.07

JOA Japanese Orthopedic Association, OPLL ossification of the posterior longitudinal ligament, ROM range of motion

[#] $p < 0.1$

^{*} $p < 0.05$

Authors' contributions

JS and MK conceived and designed the study. TF, SM, YI, MK, TM, SO, KI, FH, TF, KK, YI, FN, MH, HN, and HT gathered and analyzed the data. JS, MK, and TF drafted the paper. MY and SO significantly revised the drafted paper. All the authors gave final approval of the version to be published.

Funding

None.

Availability of data and materials

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

Ethics approval and consent to participate

All procedures used in this research were approved by the institutional review board. Written informed consents were obtained from all patients to participate in this study.

Consent for publication

Written informed consents were obtained from all patients for publication of this study.

Competing interests

The authors declare that there are no relevant conflicts of interest related to the present study.

Author details

¹Department of Orthopedic Surgery, Chiba University School of Medicine, 1-8-1 Inohana Chuo-ku Chiba City, Chiba 260-8670, Japan. ²Department of Orthopedic Surgery, University of Tsukuba, Tennodai, Tsukuba, Ibaraki 305-8575, Japan. ³Department of Orthopedic Surgery, Kimitsu Chuo Hospital, 1010, Sakurai, Kisarazu, Chiba 292-8535, Japan. ⁴Department of Orthopedic Surgery, Chiba Rosai Hospital, 2-16, Tatsumidaihigashi, Ichihara, Chiba 290-0003, Japan. ⁵Department of Orthopedic Surgery, Toho University Chiba Medical Center, 564-1, Shimoshizu, Sakura, Chiba 285-8741, Japan.

Received: 10 May 2020 Accepted: 20 August 2020

Published online: 14 September 2020

References

1. Aita I, Hayashi K, Wadano Y, Yabuki T. Posterior movement and enlargement of the spinal cord after cervical laminoplasty. *J Bone Joint Surg Br.* 1998;80:33–7.
2. Sakai K, Okawa A, Takahashi M, Arai Y, Kawabata S, Enomoto M, et al. Five-year follow-up evaluation of surgical treatment for cervical myelopathy caused by ossification of the posterior longitudinal ligament: a prospective comparative study of anterior decompression and fusion with floating method versus laminoplasty. *Spine.* 2012;37:367–76.
3. Fujimori T, Iwasaki M, Okuda S, Takenaka S, Kashii M, Kaito T, et al. Long-term results of cervical myelopathy due to ossification of the posterior longitudinal ligament with an occupying ratio of 60% or more. *Spine.* 2014;39:58–67.
4. Fujiyoshi T, Yamazaki M, Kawabe J, Endo T, Furuya T, Koda M, et al. (2008) A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. *Spine.* 2008;33:E990–3.
5. Koda M, Mochizuki M, Konishi H, Aiba A, Kadota R, Inada T, et al. (2016) Comparison of clinical outcomes between laminoplasty, posterior decompression with instrumented fusion, and anterior decompression with fusion for K-line (-) cervical ossification of the posterior longitudinal ligament. *Eur Spine J.* 2016;25:2294–301.
6. Japanese Orthopaedic Association. Scoring system for cervical myelopathy. *Nippon Seikeigeka Gakkai Zasshi.* 1994;68:490–503 [in Japanese].
7. Hirabayashi K, Toyama Y. Choice of surgical procedure for cervical ossification of the posterior longitudinal ligaments. In: Yonenobu K, Sakou T, Ono K, eds. *Ossification of the posterior longitudinal ligament.* Springer-Verlag, Tokyo, 1997;pp135–42.
8. Tsuyama N. Ossification of the posterior longitudinal ligament of the spine. *Clin Orthop Rel Res.* 1984;184:71–84.
9. Masaki Y, Yamazaki M, Okawa A, Aramomi M, Hashimoto M, Koda M, et al. An analysis of factors causing poor surgical outcome in patients with

cervical myelopathy due to ossification of the posterior longitudinal ligament: anterior decompression with spinal fusion versus laminoplasty. *J Spinal Disord Tech.* 2007;20:7–13.

10. Maruo K, Moriyama T, Tachibana T, Inoue S, Arizumi F, Daimon T, et al. The impact of dynamic factors on surgical outcomes after double-door laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine. *J Neurosurg Spine.* 2014;21:938–43.
11. Chen Y, Chen D, Wang X, Yang H, Liu X, Miao J, et al. Significance of segmental instability in cervical ossification of the posterior longitudinal ligament and treated by a posterior hybrid technique. *Arch Orthop Trauma Surg.* 2013;133:171–7.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

