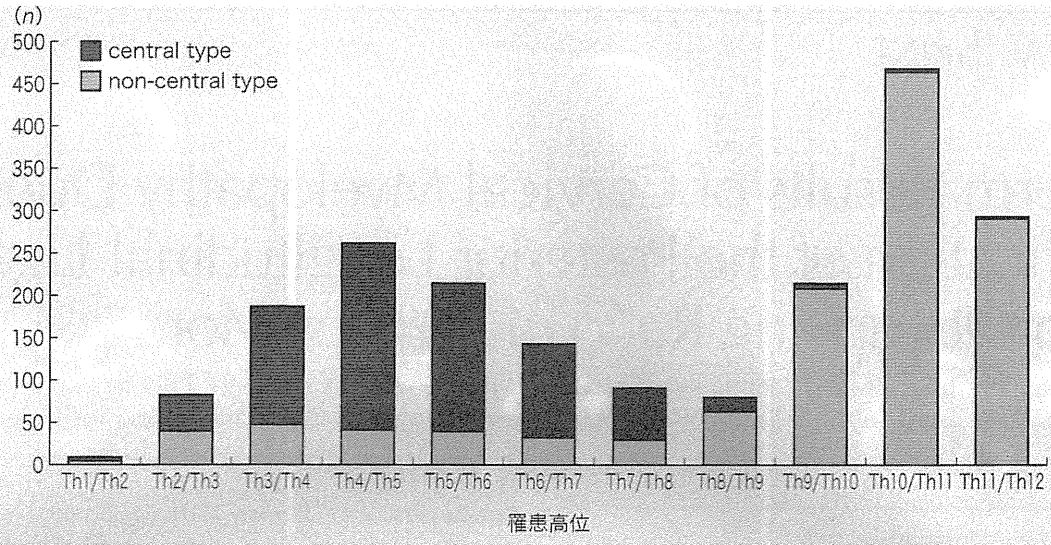

図 2. 胸椎黄色靱帯骨化症の罹患高位分布

OYL の大きさ別では，non-central type は small 37%，medium 40%，large 16%，extralarge 7%であった．Central type は small 26%，medium 46%，large 19%，extralarge 9%であった．単椎間罹患は 532 例（49%），多椎間罹患は 562 例（51%）であり，OYL は合計 2,051 椎間に認められた．罹患高位分布は，もっとも高いピークを Th10/Th11 に，次に高いピークを Th4/Th5 にもつ二峰性分布を示した（図 2）．年代別の検討では，30 歳代以降はほぼ一定の罹患率を示した．

❹ 考　察

われわれの渉猟した限りでは，OYL の有病率に関する 4 編の英文報告[1-7]があるが，いずれも対象年齢や調査方法などに限界がある．直接比較はむずかしいが，本研究での OYL の有病率は既存の報告と比較して高率であり，CT の高描出力のもたらした結果と考えられる．

本研究での central type については，過去にもその存在が指摘されている[5,8]が，OYL としての分類に言及した詳細な報告は本報告がはじめてである．本研究の限界としては，対象が胸部疾患またはその疑いのある患者であることである．われわれの渉猟しえた限りでは，胸部疾患と脊柱靱帯骨化との関連性を示す報告は見出せなかったが，関連性を完全否定するものではない．一方，本研究の一番の利点は，調査対象者に新たな放射線被曝を課すことなく CT による骨化病変の調査が可能であったことである．

❺ おわりに

胸部 CT からみた日本人胸椎 OYL の有病率は 36%であった．椎弓の谷に存在するキノコ型骨化病変も OYL である．臨床症状と脊柱管占拠率や形態などとの関連についての調査が今後の課題である．

文　献

1) Mori K, Kasahara T, Mimura T et al：Prevalence, distribution, and morphology of thoracic ossification of the yellow ligament in Japanese；results of CT-based cross-sectional study. Spine **38**：E1216-E1222, 2013
2) Polgar F：Uber interakuelle wirbelverkalkung. Fortschr Geb Rongenstr Nuklearmed Erganzungsband **40**：292-298, 1920
3) Yonenobu K, Ebara S, Fujiwara K et al：Thoracic myelopathy secondary to ossification of the spinal ligament. J Neurosurg **66**：511-518, 1987
4) Kudo S, Ono M, Russell WJ. Ossification of thoracic ligament flava. AJR **141**：117-121, 1983
5) Williams DM, Gabrielsen TO, Latack JT et al：Ossification in the cephalic attachment of the ligamentum flavum；an anatomical and CT study. Radiology **150**：423-426, 1984
6) Ohtsuka K, Terayama K, Yanagihara M et al：An epidemiological survey on ossification of ligaments in the cervical and thoracic spine in individuals over 50 years of age. Nihon Seikeigeka Gakkai Zasshi **60**：1087-1098, 1986
7) Guo JJ, Luk KD, Karppinen J, et al：Prevalence, distribution, and morphology of ossification of the ligamentum flavum；a population study of one thousand seven hundred thirty-six magnetic resonance imaging scans. Spine **35**：51-56, 2010
8) 柳　　務，内藤明子，安田武司ほか：黄色靱帯骨化の形態—病理学的所見と CT スキャン像．整形外科 **38**：297-307，1987

Spine

SPINE Volume 39, Number 1, pp 58-67
©2013, Lippincott Williams & Wilkins

CERVICAL SPINE

Long-Term Results of Cervical Myelopathy Due to Ossification of the Posterior Longitudinal Ligament With an Occupying Ratio of 60% or More

Takahito Fujimori, MD, DMSc,* Motoki Iwasaki, MD, DMSc,* Shinya Okuda, MD, PhD,† Shota Takenaka, MD,‡ Masafumi Kashii, MD, PhD,* Takashi Kaito, MD, PhD,* and Hideki Yoshikawa, MD, PhD*

Study Design. Retrospective study.

Objective. We sought to determine the long-term outcomes of laminoplasty *versus* anterior decompression and fusion in the treatment of cervical myelopathy caused by ossification of the posterior longitudinal ligament (OPLL) and to ascertain what factors should be considered in selecting appropriate surgical procedure.

Summary of Background Data. There are little data about long-term results of cervical myelopathy due to OPLL with an occupying ratio 60% or more.

Methods. We retrospectively studied 27 patients having OPLL with an occupying ratio 60% or more and a follow-up period of at least 2 years. Clinical outcome was evaluated using Japanese Orthopaedic Association scores and recovery rates (≥75%, excellent; 50%–74%, good; 25%–50%, fair; and <25%, poor).

Results. The mean age and the mean duration of follow-up were 57 years and 10.2 years. The mean Japanese Orthopaedic Association score was 9.3 before surgery and 12.4 at the final follow-up examination. There were 15 patients in the laminoplasty group (LAM group) and 12 patients in the anterior decompression and fusion group (ADF group). The ADF group had a significantly better recovery rate at final evaluation (53% *vs.* 30%; $P = 0.04$), a longer duration of surgery (314 *vs.* 128 min; $P < 0.01$), and greater blood loss (600 *vs.* 240 mL; $P < 0.01$) than did the LAM group. In the LAM group, 4 patients with excellent or good results had a significantly larger degree of cervical lordosis (30° *vs.* 10°; $P = 0.002$) than others.

Conclusion. The ADF group had a significantly better recovery rate than the LAM group, although the degree of surgical invasiveness was high. ADF is generally recommended for OPLL with an occupying ratio 60% or more.

Key words: ossification of the posterior longitudinal ligament, occupying ratio, laminoplasty, anterior decompression and fusion.

Level of Evidence: 3

Spine 2014;39:58–67

Although ossification of the posterior longitudinal ligament (OPLL) has been recognized as one of clinical entities that cause cervical myelopathy, OPLL with an occupying ratio 60% or more is still rare, and surgical treatment of such OPLL is challenging.[1–3] Although anterior decompression and fusion (ADF) enables direct decompression, removal of OPLL close to the dural membrane is still a technically demanding procedure.[4–6] On the contrary, laminoplasty is a relatively safer procedure and can provide extensive decompression of segments more easily than ADF.[2,7,8]

There have been no reports about long-term surgical outcomes in OPLL with an occupying ratio of 60% or more. The purpose of this study was to compare long-term surgical outcomes between ADF and laminoplasty. Our hypotheses were that ADF would have better outcomes, but be associated with more complications.

MATERIALS AND METHODS

Patient Selection

Between 1986 and 2010, a total of 175 patients with cervical myelopathy due to OPLL were treated in our 2 affiliated institutions with our university medical center. We retrospectively reviewed clinical data for 27 patients who met the after inclusion criteria; an occupying ratio of OPLL in the canal diameter of 60% or more and a minimum follow-up period of 2 years. Radiographs of all patients were obtained, and the patients had symptoms of myelopathy, such as a spastic gait and/or clumsiness of the hands. Between 1986 and 1996, laminoplasty was the only procedure used to treat cervical myelopathy.[1,8,9] Since 1996, we have recommended ADF

From the *Department of Orthopedic Surgery, Osaka University Graduate School of Medicine, Osaka, Japan; †Department of Orthopedic Surgery, Osaka Rosai Hospital, Osaka, Japan; and ‡Department of Orthopedic Surgery, Osaka Koseinenkin Hospital, Osaka, Japan.

Acknowledgment date: May 28, 2013. First revision date: August 14, 2013. Second revision date: September 12, 2013. Acceptance date: September 16, 2013.

The manuscript submitted does not contain information about medical device(s)/drug(s).

The Investigation Committee on the Ossification of the Spinal Ligaments of the Japanese Ministry of Health, Labor, and Welfare funds were received in support of this work.

No relevant financial activities outside the submitted work.

Address correspondence and reprint requests to Takahito Fujimori, MD, DMSc, Department of Orthopedic Surgery, Osaka University Graduate School of Medicine, 2-2 Yamadaoka, Suita, Osaka 565-0871, Japan; E-mail: takahito-f@hotmail.co.jp

DOI: 10.1097/BRS.0000000000000054

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

for OPLL in cases in which we expected a poor outcome for laminoplasty because of a large ossification occupying ratio.[1,8,9] However, if patients preferred laminoplasty to ADF after we gave them a full explanation of the risks and benefits of both procedures, we performed laminoplasty.

Clinical and Radiographical Parameters

Japanese Orthopaedic Association (JOA) scores (a maximum possible of 17) and Hirabayashi recovery rates were used to evaluate clinical outcomes.[10,11] A JOA score was recorded before surgery, at a maximum point after surgery, and at final follow-up examination for each participant. The Hirabayashi recovery rate (%) was calculated using the following formula:

(Postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100

Recovery rates at final follow-up examinations were ranked as follows: ≥75% = excellent; 50% to 74% = good; 25% to 50% = fair; and <25% = poor. Postoperative neck pain was evaluated using a visual analogue scale. Patient satisfaction was evaluated on a scale of 1 to 3—"satisfied," "neither satisfied nor dissatisfied," and "dissatisfied"—on the basis of questionnaires completed by participants. Radiographical OPLL type was classified as continuous, segmental, mixed, or localized.[12] OPLL shape was classified as hill or plateau.[1,9] Cervical lordosis (C2–C7 angle), space available for the spinal cord, the occupying ratio of OPLL in the canal diameter, and the K-line slope[13] were used as radiographical parameters (Figure 1). Lordosis was expressed as a positive value. A negative K-line slope meant that the spinal cord was in contact with the ossification. In the laminoplasty group (LAM group), the total range of motion (ROM) from C2 to C7 and segmental ROM at the most occupied level was measured on postoperative flexion-extension radiographs.[14] Radiographical measurements were obtained with a digital viewer (Surgimap Spine, Nemaris Inc., New York, NY; http://www.surgimapspine.com/).

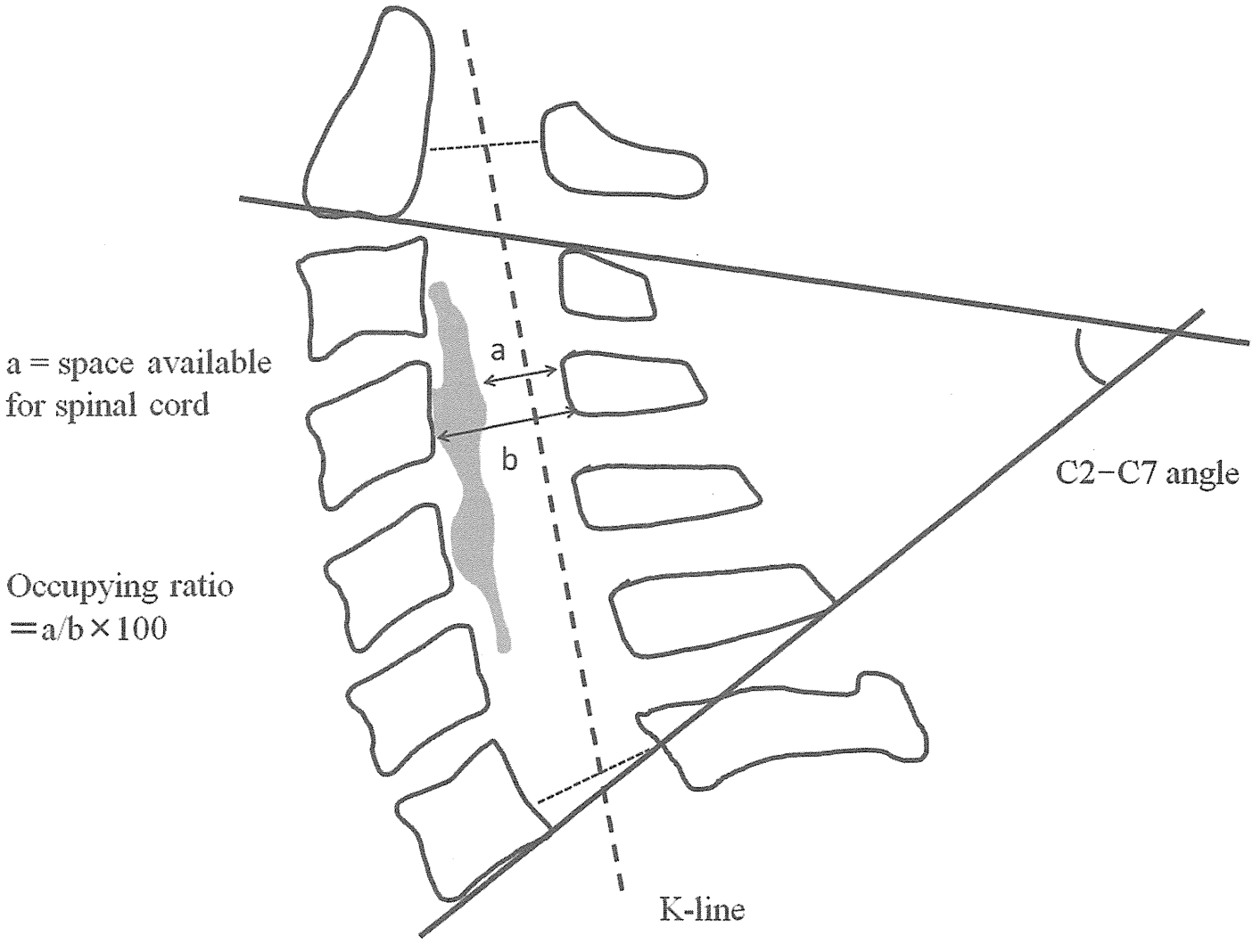

Figure 1. Radiographical parameters. Cervical lordosis was measured between the lower endplates of C2 and C7. When the C7 vertebra was invisible, the lower endplate of C6 was substituted. a indicates space available for the spinal cord; b, canal diameter; occupying ratio, a/b × 100; K-line, straight line connecting the midpoints of the spinal canal at C2 and C7.

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

Surgical Procedures

We performed open-door laminoplasty through a standard posterior straight-incision approach, using 2 spacers as struts to prevent lamina closure.

We performed ADF through a standard left-side Smith-Robinson anterior approach. Subtotal corpectomy and discectomy were performed at the compressed levels. When the OPLL adhered to the dural membrane, we did not attempt to remove all remnants of the OPLL, choosing instead to float the remnant OPLL using the method described by Yamaura *et al.*[15] Iliac crest or fibular strut was used for bone grafts. We generally preferred to use external fixation with the halo-vest system to avoid complications associated with an anterior plate system.

Statistical Analysis

The unpaired *t* test, Mann-Whitney *U* test, and the χ^2 test were used for statistical analysis. *P* values of less than 0.05 were considered to indicate statistical significance with the 2-tailed test. Automatic stepwise regression modeling was performed to identify variables independently associated with the final recovery rate as a dependent variable. SPSS Statistics (version 20; IBM, Armonk, NY) was used for statistical analysis.

RESULTS

Patients' Demographics

Study participants (20 males and 7 females) were a mean age of 57.3 ± 8.6 years (range, 41–76 yr). The mean duration of follow-up was 10.1 years (range, 2–22 yr). The mean occupying ratio was 66.5%. The mean JOA score was 9.3 before surgery, 13.6 at the maximum point, and 12.4 at the final follow-up examination, and the mean recovery rate was 56% at the maximum point and 40% at the final follow-up examination. Among the 27 participants, 10 had continuous OPLL, 16 had mixed types, and 1 had localized OPLL. Ossifications were hill shaped in 15 and plateau shaped in 12 (Table 1).

Questionnaire results showed that 18 patients (67%) were satisfied with the treatment, 4 patients (15%) were dissatisfied, and 1 (4%) was neither satisfied nor dissatisfied. Four patients' answers were not available.

Laminoplasty was performed in 15 patients (the LAM group), and ADF was performed in 12 patients (the ADF group).

Comparison of Clinical Outcomes Between the LAM Group and the ADF Group

Laminoplasty was performed for a significantly larger number of intervertebral segments than ADF was (5.4 *vs.* 3.3; $P < 0.01$). The ADF group had significantly less space for the spinal cord than the LAM group did (4.0 *vs.* 5.4 mm; $P < 0.01$). There was no significant difference in other demographic parameters between the 2 groups (Table 2).

In the LAM group, the mean JOA score improved from 9.1 before surgery to 11.7 afterward. The LAM group included 10 mixed types, 4 continuous types, and 1 localized type. The recovery rate for the group was a mean of 49% (range, 0%–81%) at the maximum point and 30% (range, −21% to 81%) at the final follow-up examination. The mean decline of the recovery rate was 18.9 ± 22.9%. The mean preoperative and postoperative cervical lordosis was 15.5° ± 12.1° and 8.3° ± 11.7°. The LAM group lost an average of 7.2° of cervical lordosis. The mean preoperative ROM in the cervical spine was 20.9° ± 10.9°. Final recovery rates showed 1 excellent result, 3 good results, 5 fair results, and 6 poor results in the LAM group.

In the ADF group, the mean JOA score improved from 9.5 before surgery to 13.3 afterward. The ADF group included 6 continuous types, 5 mixed types, and one localized type. The mean recovery rate for the group was 65% (range, 33%–92%) at the maximum point and 53% (range, 30%–92%) at the final follow-up examination. The mean decline of the recovery rate was 12.3 ± 18.6%. There were 2 excellent results, 4 good results, and 6 fair results in the group. The ADF group had a significantly better recovery rate at the final follow-up examination than the LAM group did ($P = 0.04$), although the ADF group had a significantly longer duration of surgery and greater blood loss ($P < 0.01$). The mean preoperative and postoperative cervical lordosis was 11.0° ± 10.7° and 12.3° ± 8.7°. ADF increased cervical lordosis by an average of 1.2°.

Influencing Parameters for Surgical Results

In the LAM group, those patients with excellent or good results had significantly larger preoperative cervical lordosis than did those with fair or poor results (30° *vs.* 10°; $P = 0.002$). Although patients with excellent or good results had a significantly larger ROM than the others (30° *vs.* 17.6°; $P < 0.05$), segmental ROM tended to be smaller in patients with excellent or good results. Those with excellent or good results tended to have a better preoperative JOA score and were less likely to have comorbid diabetes mellitus, although these were not significant tendencies (Table 3).

In the ADF group, patients with excellent or good results had a significantly smaller ossification occupying ratio than did those with fair results (63% *vs.* 72%; $P = 0.03$). Those with excellent or good results tended to have better preoperative JOA scores, a larger space available for the spinal cord ($P = 0.07$), and a greater degree of preoperative cervical lordosis, although they were not significant tendencies.

Surgical Complications

In the LAM group, there were 2 cases of dural tear and 1 case of hematoma. In the latter case, immediate revision and posterior decompression were necessary. In another case, a C2 laminectomy for recompression was necessary because of progression of OPLL. The complication rate for the LAM group was 20%, and the revision rate was 13%.

In the ADF group, 1 patient had a dural tear, 1 had C5 palsy, and 1 had pseudarthorosis. The patient with C5 palsy underwent additional ADF, and the patient with pseudarthrosis required additional posterior fusion. In the late phase of follow-up, 2 patients required laminoplasty for further decompression. For the ADF group, the complication rate

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

was 25% and the revision rate was 33%, neither of which was significantly different from the rate for the LAM group.

Regression Analysis

Stepwise linear regression modeling was performed using the recovery rate at the final follow-up evaluation as a dependent variable. Age, OPLL type, OPLL shape, occupying ratio, space for the spinal cord, surgical procedure (ADF *vs.* laminoplasty), the presence of diabetes mellitus (+ or −), the K-line slope (+ or −), the preoperative JOA score, and the degree of precervical lordosis were considered independent variables. For the regression model, we used surgical procedure (ADF; $P = 0.005$) and preoperative cervical lordosis (larger cervical lordosis; $P = 0.007$) as independent variables ($r^2 = 0.34$; $P = 0.003$).

DISCUSSION

To the best of our knowledge, there are only a few reports about the results of surgery for the treatment of OPLL with a high occupying ratio.[3,7,9] In our study, we considered the overall result of a 40% recovery rate at final follow-up evaluation to be acceptable for OPLL with an occupying ratio of 60% or more. However, more improvement is desirable, especially in comparison with surgery results for ordinary OPLL.[16]

Previous studies reported that recovery rates of OPLL with a high occupying ratio for ADF and laminoplasty are 54% to 73% and 13% to 41%, respectively[3,7,9] (Table 4). However, after we had good results from laminoplasty, we chose laminoplasty for some patients who did not want to face severe surgical complications and for those who did not think, after thorough discussion of the risks and benefits of surgery, that they could tolerate complications related to anterior surgery.

Detailed comparison of cases with excellent or good results *versus* those with fair or poor results from laminoplasty and a review of previous reports suggest some parameters that may affect the outcome of laminoplasty for the treatment of OPLL with a high occupying ratio. Because laminoplasty relies strongly on the decompression effect for indirect decompression through a posterior shift of the spinal cord, cervical lordosis plays an important role in preventing static compression. In our study, the fact that patients in the LAM group with excellent or good outcomes had a significantly greater degree of lordosis despite a larger ossification occupying ratio emphasizes just how important cervical lordosis is in laminoplasty for OPLL with an occupying ratio 60% or more. Yamazaki *et al*[17] reported that cervical lordosis of less than 10° and/or OPLL thickness of more than 7 mm are risk factors for spinal cord contact with ossification. Fujiyoshi *et al*[13] advocated the used of an interesting parameter, the K-line, that enabled evaluation of both cervical alignment and the size of OPLL. According to their report, a negative K-line slope meant that the OPLL touched the spinal cord, and the negative K-line group had a significantly lower recovery rate than the positive K-line group. In our study, the K-line hardly contacted OPLL when cervical lordosis was more than 15° if the OPLL was located anywhere from C3 to C6. In cases in which there was greater lordosis, the K-line passed over even the laminas from C3 to C6. Several authors have reported that loss of cervical lordosis after laminoplasty ranges from 0° to 12°.[18–20] In our study, the mean loss of cervical lordosis after laminoplasty was 7°. Although it was not easy to clearly establish the ideal degree of cervical lordosis for laminoplasty because of the limited number of our participants in our study, we think that at least preoperative cervical lordosis of 20° or more may be necessary if laminoplasty is to successfully treat OPLL with an occupying ratio 60% or more.

Dynamic factors are another parameter affecting laminoplasty. Ogawa *et al*[21] reported that a larger postoperative C2–C7 ROM was related to late deterioration in myelopathy in patients with the segmental type of OPLL. Goto and Kita[22] reported that the spontaneous fusing of vertebrae by the bridging of OPLL and the ossification of the anterior longitudinal ligament were the most important factors protecting against deterioration in myelopathy. Masaki *et al*[23] and Morio *et al*[24] reported that segmental ROM at the cord compression level was a risk factor for a poor outcome in laminoplasty. Fujiyoshi *et al*[14] reported that myelopathy did not worsen if the segmental ROM was highly restricted although static compression was high. Considering these reports, we speculate that total C2–C7 ROM might be less important than segmental ROM at the compression level because in our study, even patients with excellent or good outcomes had more C2–C7 ROM than did patients with fair outcomes. The reason patients with good results had a larger C2–C7 ROM might be that ROM at that level depended on maintenance of cervical lordosis.[25] Because patients with excellent or good outcomes maintained significantly greater cervical lordosis, they had a larger C2–C7 ROM. Additionally, C2–C7 ROM might not be an appropriate substitute for dynamic factors in OPLL with a high occupying ratio because OPLL with an occupying ratio 60% or more was never the segmental type. However, another reason that segmental ROM was not a perfect parameter was that it was difficult to measure a small amount of segmental ROM accurately on radiographs. Especially pertinent is that segmental ROM tended to decrease as the size of OPLL increased.[14] Fujimori *et al*[26] reported that segmental ROM could be differentiated by the 3-dimensional shape of the OPLL on reconstructed sagittal CT images. Three-dimensionally seamless, continuous-type OPLL and bridging-type OPLL highly restricted the segmental ROM at the vertebrae where they were located. In our study, 3 of the 4 patients in the LAM group with excellent or good outcomes (cases 13, 14, and 15) had bridging or 3-dimensionally seamless, continuous OPLL, which helped restrict segmental ROM at the compression level. Although CT was not available in all cases in our study, dynamic factors should be evaluated by multiple modalities.

The decline of recovery rate was greater in the LAM group (18.9%) than in the ADF (12.3%), although it did not reach statistical level. Postoperative progression, residual dynamic factor might be related to this deterioration.[27]

Considering these limitations of laminoplasty, ADF would be the more reasonable surgical procedure, especially for OPLL with a high occupying ratio. ADF does have disadvantages,

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 1. Demographic Data for 27 Patients

No.	Age (yr)	Sex	Type of Surgery	Duration of Follow-up Period (yr)	Level	Type of OPLL	Shape	Compression Level	OR (%)	SAC (mm)	DM	JOA		
												Pre	Max	Final
1	60	M	LAM	10	C3–C7	Mix	Hill	C4–C5	65	6	1	6	11	10
2	55	M	LAM	15	C3–C7	Mix	Plateau	C4	62	5	1	10	12	8.5
3	46	M	LAM	22	C3–C7	Mix	Plateau	C4–C5	71	4	1	7	15	11.5
4	63	M	LAM	11	C3–C7	Mix	Plateau	C3–C4	60	6	1	11.5	12	12
5	47	M	LAM	17	C3–C7	Con	Hill	C5–C6	70	5	0	10	10	10
6	57	M	LAM	16	C2–C7	Con	Hill	C4	67	5	0	12	14	12
7	64	M	LAM	14	C2–C6	Mix	Plateau	C2–C3	67	6.5	0	12	16	12.5
8	65	M	LAM	8	C3–T1	Mix	Hill	C6–C7	85	4	0	9.5	14.5	14.5
9	56	F	LAM	5	C3–C6	Con	Plateau	C4–C5	64	5	0	14	15	15
10	55	M	LAM	8	C3–C7	Mix	Hill	C4–C5	60	6	0	5	11.5	9.5
11	74	M	LAM	9	C2–C6	Mix	Hill	C3–C4	61	5.	0	7.5	12.5	12
12	54	F	LAM	8	C3–C7	Loc	Hill	C4–C5	60	7	1	6.5	10	5.5
13	46	M	LAM	6	C3–C6	Mix	Hill	C5–C6	63	4	0	10.5	15	14
14	76	F	LAM	2	C3–T2	Mix	Plateau	C2–C3	65	8.5	0	9	15.5	15.5
15	63	M	LAM	2	C2–T1	Con	Plateau	C5–C6	70	3	1	6.5	13	13
16	58	M	ADF	10	C2–C7	Con	Plateau	C3–C4	69	4	0	11	13	13
17	48	M	ADF	17	C3–C7	Con	Plateau	C5–C6	62	5	1	12	16.5	13.5
18	60	F	ADF	12	C4–C7	Con	Hill	C5–C6	63	4	0	11	16.5	16.5
19	56	M	ADF	16	C2–C5	Mix	Hill	C3–C4	60	6	0	9	15.5	13.5
20	58	F	ADF	10	C3–C6	Con	Plateau	C4–C5	75	3	0	7.5	12.5	11.5
21	41	M	ADF	10	C4–C7	Mix	Hill	C5–C6	80	3	0	7	12	11
22	52	F	ADF	13	C3–C6	Con	Plateau	C5–C6	67	4	1	10.5	14	14
23	51	M	ADF	8	C2–C5	Con	Plateau	C3–C4	64	5	1	11	14.5	14
24	74	F	ADF	8	C3–C5	Loc	Hill	C3–C4	75	3	0	9.5	15.5	13
25	56	F	ADF	5	C3–C7	Mix	Hill	C5–C6	70	3	0	4.5	10	10
26	57	M	ADF	5	C4–C6	Mix	Hill	C4–C5	61	3.5	0	11.5	16	16
27	56	M	ADF	5	C4–C6	Mix	Hill	C4–C5	64	5	0	9.5	14	14

ADF indicates anterior decompression and fusion; Con, continuous type; Dis, dissatisfied; DM, diabetes mellitus; LAM, laminoplasty; Loc, localized type; Max, ossification of ligamentum flavum; Pre, preoperative; Post, postoperative; PSF, posterior spinal fusion; SAC, space available for the spinal cord; Sat, satisfied;

however: it requires more time, there are more complications with it. In our study, 4 patients (33%) in the ADF group required revision surgery. According to previous reports, the neurological deterioration rate after ADF for OPLL ranges from 0% to 13.3%[2,3,9] and the overall surgical complication rate ranges from 23% to 29%.[7,9,28] In a multicenter study of ADF for 150 patients with OPLL, Kimura *et al*[2] reported that the rate of motor deterioration after ADF was 13.3% in the upper extremities and 2% in the lower extremities. Yet in a study of laminoplasty for 581 patients with OPLL, Seichi *et al*[29] reported that the motor deterioration rate was 4% in the upper extremities and 3.1% in the lower extremities. A 600 mL blood loss of the ADF group was greater than blood loss in standard anterior cervical discectomy and fusion. However, the reason for the great blood loss was that subtotal corpectomy was usually necessary to achieve extensive decompression. It also takes

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

Recovery Rate (%)		Final Outcome	VAS Neck	Satisfaction	Cervical Lordosis (°)		K-line	Surgical Complication	Reoperation	Reason for Reoperation
Max	Final				Pre	Post				
45	36	Fair	NA	NA	14	14	+			
29	−21	Poor	NA	NA	10	17	−			
80	45	Fair	4	Sat	2	4	−			
9	9	Poor	1	Sat	11	−1	−	Hematoma	Decompression	Hematoma
0	0	Poor	7	Dis	−2	−8	−	Dural tear		
40	0	Poor	0	Sat	16	6	+			
80	10	Poor	3	Sat	5	−8	−		C2 laminectomy	Recompression
67	67	Good	3	Sat	30	22	−			
33	33	Fair	8	Sat	10	10	−			
54	38	Fair	1	Dis	26	18	+	Dural tear		
53	47	Fair	3	Sat	3	3	−			
33	−10	Poor	5	Dis	18	10	−			
69	54	Good	1	Sat	20	4	+			
81	81	Excellent	8	Sat	42	35	+			
62	62	Good	7.5	NA	28	7	+			
33	33	Fair	NA	NA	13	10	+			
90	30	Fair	10	Sat	−3	11	−		LAM	Traffic accident
92	92	Excellent	0	Sat	32	16	+			
81	56	Good	8	Sat	16	7	+	Pseudarthorosis	PSF	Pseudarthorosis
53	42	Fair	5	Dis	1	13	−		LAM	C2–C3 OLF
50	40	Fair	9	Sat	7	7	−			
54	54	Good	4	Sat	3.5	8	−	C5 palsy	ADF	C5 palsy
58	50	Good	7	Sat	16	29	+			
80	47	Fair	4	Neither	26	30	+			
44	44	Fair	10	Sat	16	6	−	Dural tear		
82	82	Excellent	0	Sat	3	5	−			
60	60	Good	7	Sat	2	5	−			

maximum; Mix, mixed type; NA, data not available; ND, neurological deterioration; Neither, neither satisfied nor dissatisfied; OR, occupying ratio; OLF, VAS, visual analogue scale; JOA, Japanese Orthopaedic Association; OPLL, ossification of the posterior longitudinal ligament.

a time to shave ossified ligament with a diamond bur. Epidural venous plexus is also highly developed in OPLL.

To cover the shortcomings of both surgical procedures, combined anterior and posterior procedures might be a future option. Long continuous-type OPLL extending upward from the C3 or C4 vertebra to behind the C2 vertebra is a typical pattern of continuous-type OPLL.[12] However, it is really difficult to remove long ossifications such as this totally by ADF. Laminoplasty could be a good option for this continuous-type OPLL because there is little motion at these segments.[26] ADF for the severe occupying mobile segment, typically at middle to lower levels, and combined laminoplasty for continuous-type OPLL could be safe and effective choices. Another possible option for posterior surgery might be posterior decompression and an additional fusion with instrumentation to restore cervical alignment.[30] Houten and

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 2. Comparison Between Laminoplasty and Anterior Decompression and Fusion

Parameter	Laminoplasty (Mean ± SD)	ADF (Mean ± SD)	*P*
No. of cases	15	12	
Age at surgery (yr)	58.7 ± 9.1	55.6 ± 7.8	0.6
Duration of follow-up (yr)	10.2 ± 5.7	9.9 ± 4.1	0.9
Sex (M/F)	13/2	7/5	0.3
Surgical level (intervertebral segment)	5.4 ± 1.2	3.3 ± 0.9	<0.01*
Duration of surgery (min)	128 ± 60	314 ± 89.9	<0.01*
Blood loss (mL)	240 ± 153	600 ± 459	<0.01*
OPLL type: continuous/mixed/segmental/localized	4/10/0/1	6/5/0/1	0.3
OPLL shape: hill/plateau	8/7	7/5	0.9
Occupying ratio (%)	66.0 ± 6.5	67.5 ± 6.4	0.4
Space available for cord (mm)	5.4 ± 1.4	4.0 ± 1.0	0.01*
DM	6	3	0.6
JOA score			
Preoperative	9.1 ± 2.6	9.5 ± 2.2	0.8
Maximum	13.1 ± 2.0	14.2 ± 2.0	0.2
Final	11.7 ± 2.7	13.3 ± 1.9	0.1
Recovery rate (%)			
Maximum	49.0 ± 25.2	64.8 ± 19.4	0.09
Final	30.1 ± 30.5	52.5 ± 18.5	0.04*
Decline	18.9 ± 22.9	12.3 ± 18.6	0.4
Final outcome: excellent/good/fair/poor	1/3/5/6	2/4/6/0	0.1
VAS score for neck	3.9 ± 2.8	5.8 ± 3.6	0.2
Satisfaction: satisfied/dis/neither/NA	9/3/0/3	9/1/1/1	0.5
Cervical lordosis (°)			
Preoperative	15.5 ± 12.1	11.0 ± 10.7	0.5
Final	8.3 ± 11.7	12.3 ± 8.7	0.4
Loss†	7.2 ± 7.0	−1.2 ± 9.5	0.01*
K-line: ±	6/9	5/7	0.8
Complications/reoperations	3/2	3/4	0.4/0.2

**P < 0.05.*
†A positive value indicates a decrease in lordosis.
ADF indicates anterior decompression and fusion; Dis, dissatisfied; DM, diabetes mellitus; JOA, Japanese Orthopaedic Association; NA, not available; OPLL, ossification of the posterior longitudinal ligament; VAS, visual analogue scale; SD, standard deviation.

Cooper[31] reported that laminectomy and lateral mass fusion for cervical spondylotic myelopathy and OPLL produced neurological recovery equivalent to that provided by ADF but without serious complications.

Our study had a few limitations. One was that it was not randomized. Another is the possibility that a type 2 error might have occurred because of the comparatively small number of cases involved. Although there was a significant difference in the recovery rate between the 2 groups, postoperative total JOA score was not significantly different. The controversial point of JOA score and the recovery rate is that the minimal clinical important differences of them have not been examined. However, there is an advantage of using the recovery rate that we can compare the treatment result of this study to the previous reports. Further studies might be necessary to seek the most reliable scale for cervical myelopathy.

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 3. Comparison Between Excellent or Good Outcomes *Versus* Fair or Poor Outcomes by Surgical Group

Surgical Group	Parameter	Outcome		*P*
		Excellent or Good (Recovery Rate ≥50%; Mean ± SD)	Fair or Poor (Recovery Rate <50%; Mean ± SD)	
Laminoplasty	No. of cases	4	11	
	Age at surgery (yr)	62.5 ± 12.4	57.4 ± 7.9	0.5
	Surgical level (intervertebral segment)	5.5 ± 1.3	5.0 ± 0.4	0.3
	OPLL shape: hill/plateau	2/2	6/5	0.7
	Occupying ratio (%)	69.8 ± 10.2	64.3 ± 4.1	0.1
	Space available for the cord (mm)	5.4 ± 2.2	5.5 ± 0.9	0.9
	DM	1	5	0.5
	Preoperative JOA score	8.9 ± 1.7	9.2 ± 2.9	0.8
	Lordosis (°)			
	Preoperative	30.0 ± 9.9	10.3 ± 8.1	0.002*
	Final	17.0 ± 14.4	5.2 ± 9.5	0.08
	Loss	13.0 ± 6.6	5.1 ± 6.1	0.05
	K-line: ±	3/1	3/8	0.1
	C2–C7 ROM (°)	30.0 ± 0.8	17.6 ± 11.0	0.047*
	Segmental ROM (°)	1.5 ± 1.7	3.1 ± 3.0	0.3
ADF	No. of cases	6	6	
	Age at surgery (yr)	55.3 ± 3.3	55.8 ± 11.1	0.9
	Surgical level (intervertebral segment)	3.0 ± 0.6	3.5 ± 1.0	0.3
	OPLL shape: hill/plateau	3/3	4/2	0.6
	Occupying ratio (%)	63.2 ± 2.5	71.8 ± 6.2	0.03*
	Space available for the cord (mm)	4.5 ± 0.9	3.5 ± 0.8	0.07
	DM	2	1	0.5
	Preoperative JOA score	10.4 ± 1.0	8.6 ± 2.8	0.3
	Lordosis (°)			
	Preoperative	12.1 ± 11.7	10.0 ± 10.6	0.8
	Final	11.7 ± 9.4	12.8 ± 8.8	0.8
	Loss	0.4 ± 10.4	−2.8 ± 9.1	0.6
	K-line: ±	3/3	2/4	0.6

**P < 0.05.*
ADF indicates anterior decompression and fusion; DM, diabetes mellitus; JOA, Japanese Orthopaedic Association; OPLL, ossification of the posterior longitudinal ligament; ROM, range of motion; SD, standard deviation.

There has been debate about which approach, anterior or posterior, is better for OPLL. Full consideration of the advantages and disadvantages of each surgical procedure enables an appropriate choice, to the benefit of patients with this intractable disease.

CONCLUSION

We reviewed data for 27 patients with cervical myelopathy caused by OPLL with an occupying ratio of more than 60%. Those in our ADF group had a significantly better recovery rate at final follow-up evaluation than those in the LAM

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 4. Surgery Results for Cervical Myelopathy Caused by Massive OPLL

Author and Year	Occupying Ratio (%)	N	Mean Duration of Follow-up (yr)	Recovery Rate (%)	
				ADF	LAM
Tani *et al*[3] (2002)	≥50	26	4	58	13
Iwasaki *et al*[1,9] (2007)	≥60	16	8	54	14
Sakai *et al*[7] (2012)	≥50	18	5	73	41
Present study	≥60	27	10	53	30

ADF indicates anterior decompression and fusion; LAM, laminoplasty; OPLL, ossification of the posterior longitudinal ligament.

group (53% *vs.* 30%). Generally ADF, rather than laminoplasty, is recommended for OPLL with an occupying ratio 60% or more.

➢ Key Points

- ❑ Long-term outcomes of 27 patients with OPLL with an occupying ratio of 60% or more were studied.
- ❑ The ADF group had a significantly better recovery rate at final evaluation than the LAM group (53% *vs.* 30%; $P = 0.04$).
- ❑ In the LAM group, patients with excellent or good results had a significantly larger degree of cervical lordosis (30° *vs.* 10°; $P = 0.002$) than the others.

Acknowledgments

The authors thank the Investigation Committee on the Ossification of the Spinal Ligaments of the Japanese Ministry of Health, Labor, and Welfare. Medical editor Katharine O'Moore-Klopf, ELS (East Setauket, NY) provided professional English-language editing of this article.

References

1. Iwasaki M, Okuda S, Miyauchi A, et al. Surgical strategy for cervical myelopathy due to ossification of the posterior longitudinal ligament: Part 1: clinical results and limitations of laminoplasty. *Spine (Phila Pa 1976)* 2007;32:647–53.
2. Kimura A, Seichi A, Hoshino Y, et al. Perioperative complications of anterior cervical decompression with fusion in patients with ossification of the posterior longitudinal ligament: a retrospective, multi-institutional study. *J Orthop Sci* 2012;17:667–72.
3. Tani T, Ushida T, Ishida K, et al. Relative safety of anterior microsurgical decompression versus laminoplasty for cervical myelopathy with a massive ossified posterior longitudinal ligament. *Spine (Phila Pa 1976)* 2002;27:2491–8.
4. Cardoso MJ, Koski TR, Ganju A, et al. Approach-related complications after decompression for cervical ossification of the posterior longitudinal ligament. *Neurosurg Focus* 2011;30:E12.
5. Mazur M, Jost GF, Schmidt MH, et al. Management of cerebrospinal fluid leaks after anterior decompression for ossification of the posterior longitudinal ligament: a review of the literature. *Neurosurg Focus* 2011;30:E13.
6. Mizuno J, Nakagawa H, Matsuo N, et al. Dural ossification associated with cervical ossification of the posterior longitudinal ligament: frequency of dural ossification and comparison of neuroimaging modalities in ability to identify the disease. *J Neurosurg Spine* 2005;2:425–30.
7. 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: a prospective comparative study of anterior decompression and fusion with floating method versus laminoplasty. *Spine (Phila Pa 1976)* 2012;37:367–76.
8. Iwasaki M, Kawaguchi Y, Kimura T, et al. Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up. *J Neurosurg* 2002;96:180–9.
9. 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.
10. Hirabayashi K, Miyakawa J, Satomi K, et al. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine (Phila Pa 1976)* 1981;6:354–64.
11. Yonenobu K, Abumi K, Nagata K, et al. Interobserver and intraobserver reliability of the Japanese Orthopaedic Association scoring system for evaluation of cervical compression myelopathy. *Spine (Phila Pa 1976)* 2001;26:1890–4; discussion 5.
12. Tsuyama N. Ossification of the posterior longitudinal ligament of the spine. *Clin Orthop Relat Res* 1984:71–84.
13. Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. *Spine (Phila Pa 1976)* 2008;33:E990–3.
14. Fujiyoshi T, Yamazaki M, Okawa A, et al. Static versus dynamic factors for the development of myelopathy in patients with cervical ossification of the posterior longitudinal ligament. *J Clin Neurosci* 2010;17:320–4.
15. Yamaura I, Kurosa Y, Matuoka T, et al. Anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Clin Orthop Relat Res* 1999:27–34.
16. Fujimori T, Iwasaki M, Okuda S, et al. Patient satisfaction with surgery for cervical myelopathy due to ossification of the posterior longitudinal ligament. *J Neurosurg Spine* 2011;14:726–33.
17. Yamazaki A, Homma T, Uchiyama S, et al. Morphologic limitations of posterior decompression by midsagittal splitting method for myelopathy caused by ossification of the posterior longitudinal ligament in the cervical spine. *Spine (Phila Pa 1976)* 1999;24:32–4.
18. Aita I, Wadano Y, Yabuki T. Curvature and range of motion of the cervical spine after laminaplasty. *J Bone Joint Surg Am* 2000;82-A:1743–8.
19. Machino M, Yukawa Y, Hida T, et al. Cervical alignment and range of motion after laminoplasty: radiographical data from more than 500 cases with cervical spondylotic myelopathy and a review of the literature. *Spine (Phila Pa 1976)* 2012;37:E1243–50.
20. Suk KS, Kim KT, Lee JH, et al. Sagittal alignment of the cervical spine after the laminoplasty. *Spine (Phila Pa 1976)* 2007;32:E656–60.
21. Ogawa Y, Chiba K, Matsumoto M, et al. Long-term results after expansive open-door laminoplasty for the segmental-type of

Copyright © 2013 Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.