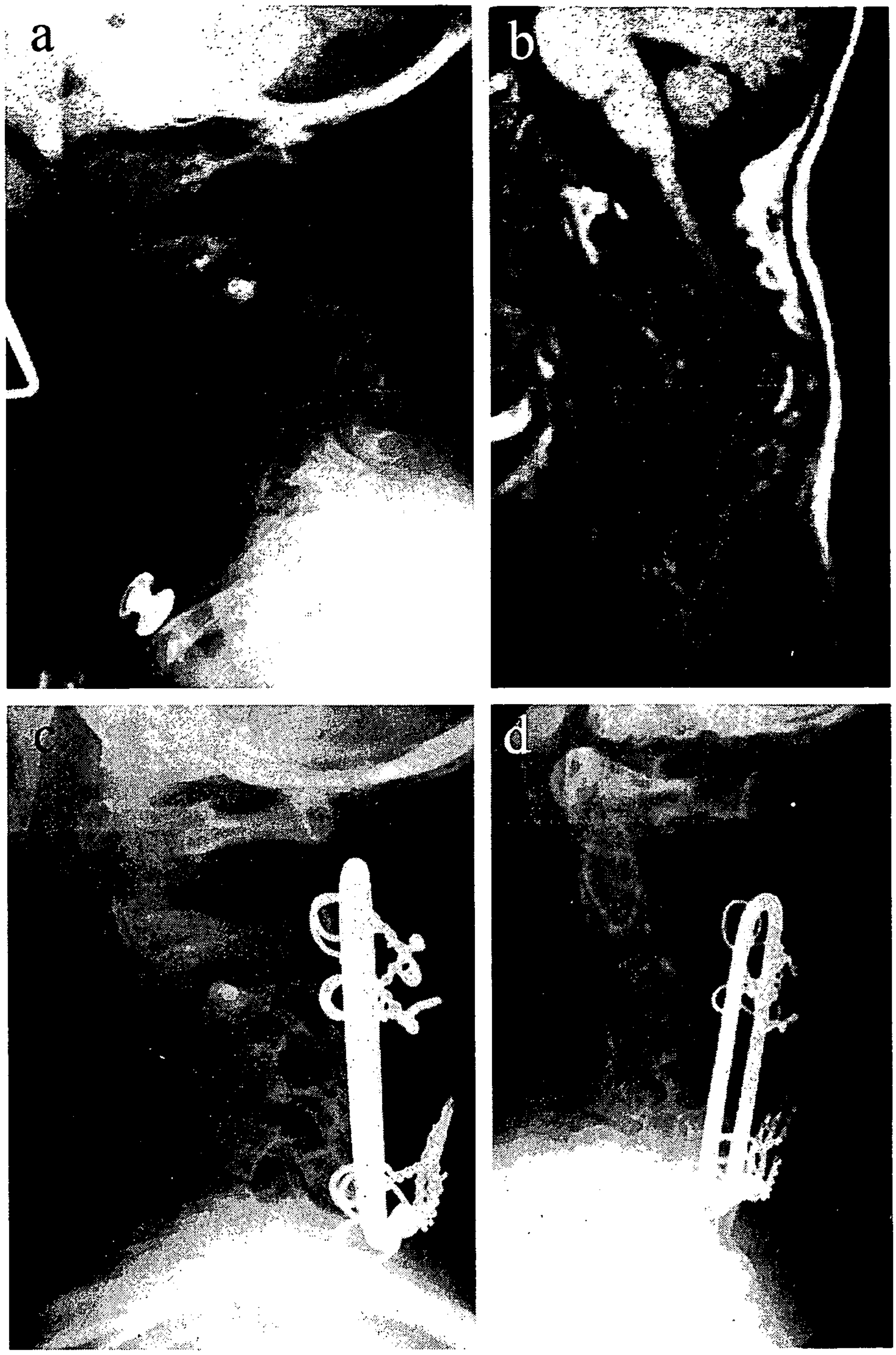

Figure 1. Case 1. (**a**) Before surgery, severe cervical kyphosis measured 110°. (**b**) Magnetic resonance imaging showed severe impingement of the spinal cord at the apex of the kyphosis. (**c**) Kyphosis was corrected to 70° after repeated anterior fusion followed by posterior fusion. (**d**) At 13 years after surgery, surgical correction of the kyphosis was well maintained.

cervical kyphosis in this syndrome and emphasized its potential hazards.[1] Surgical stabilization of the kyphosis thus plays an important role in the overall management of the patients. However, little information has been reported regarding surgical treatments for this challenging condition. To the best of our knowledge, only 9 reports of surgical treatment for cervical kyphosis in Larsen syndrome have been described, with PSF in 5 cases, ASF combined with PSF in 3, and ASF alone in 1 (Table 2).[1,3–7]

Johnston *et al*[7] reported successful PSF in 3 patients with mild and flexible cervical kyphosis (Cobb angle, 35° to 37° in neutral position, 26° to −25° in extended position). However, they also reported 1 failed PSF case with 65° kyphosis that was reduced to only 48° in the extended position before surgery. Kyphotic deformity of this patient had progressed to 110° after attempted PSF and required repeated anterior surgeries (Table 2).[7] In the present series, PSF provided similar results to those reported by Johnston *et al.*[7] One patient with 60° kyphosis reduced to 27° in extension was successfully treated using PSF (Case 2). Conversely, in the patient with 93° cervical kyphosis, kyphotic deformity progressed to 146° over a brief 18-month period due to pseudarthrosis (Case 3) (Table 1). Our 2 patients with severe and rigid kyphotic defor-

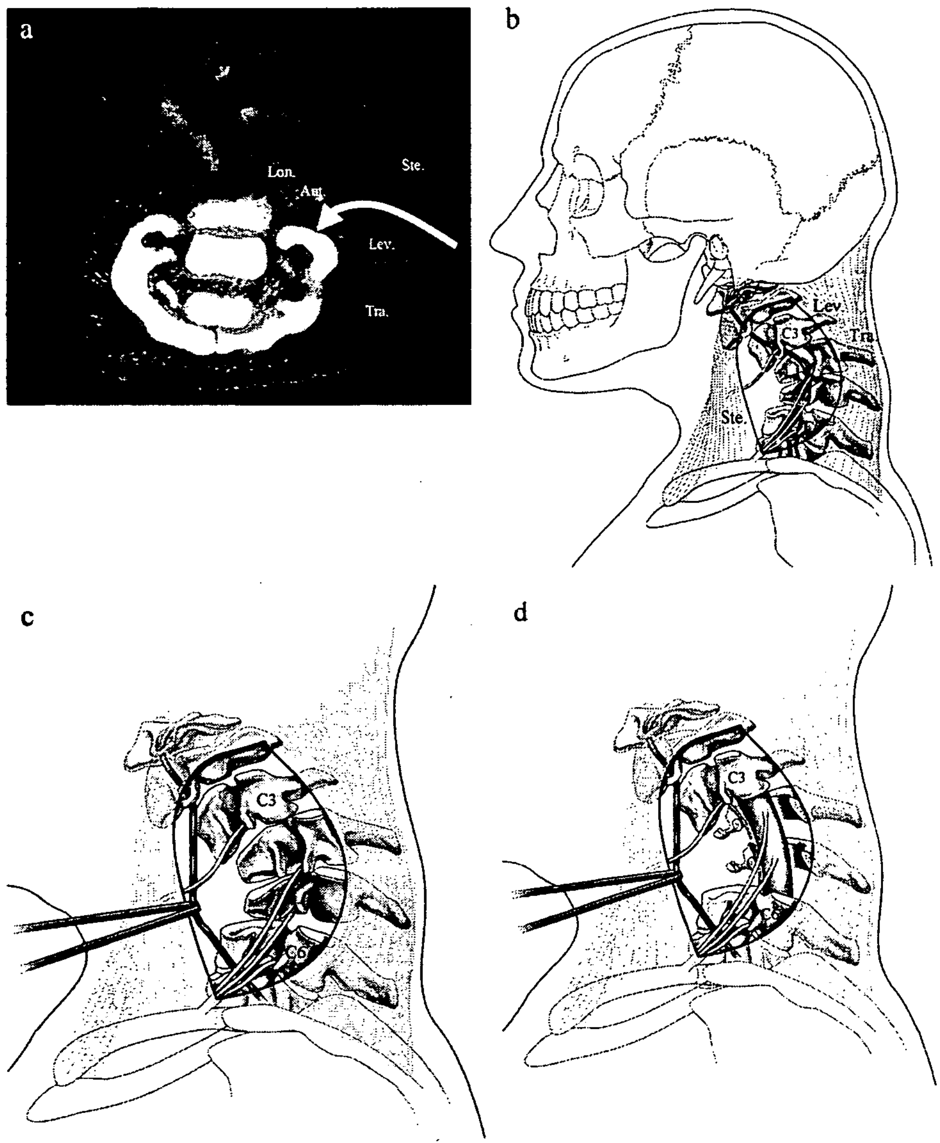

Figure 2. Anterior decompression and fusion *via* a lateral approach. **(a)** Axial image of lateral approach to the cervical spine. Tra., trapezius muscle; Ste., sternocleidomastoid muscle; Lev., levator scapulas muscle; Ant., anterior scalene muscle; Lon., longus colli muscle. **(b)** Lateral view. The vertebral artery and the C4–C6 nerve roots lying posterior to the vertebral artery were identified. **(c)** The vertebral artery was anteriorly dislocated by resecting the transverse processes from C3–C6. **(d)** After subtotal removal of the C4 and C5 bodies and cutting the PLL, the vertebrae became mobile slightly and the dura shifted ventrally.

mity (Cases 1 and 3) actually developed serious myelopathy and required release of tight cartilaginous tissue ventral to the cervical vertebrae, followed by corpectomies and fusion. Francis and Noble also noted that anterior release of tight cartilaginous tissue and vertebrectomy was effective in the treatment of a patient with 168° cervical kyphosis.[4] Given these findings, PSF is indicated only for patients with mild and flexible cervical kyphosis, with anterior decom-

Figure 3. Case 2. **(a)** Before surgery, cervical kyphosis measured 60°. **(b)** Kyphosis was corrected to 27° in extension. **(c)** Magnetic resonance imaging showed impingement of the spinal cord at the apex of the kyphosis. **(d)** Kyphosis was corrected to 32° just after posterior arthrodesis. **(e)** At 8 years after surgery, anterior growth after solid posterior fusion resulted in spontaneous correction of the kyphosis to 16°.

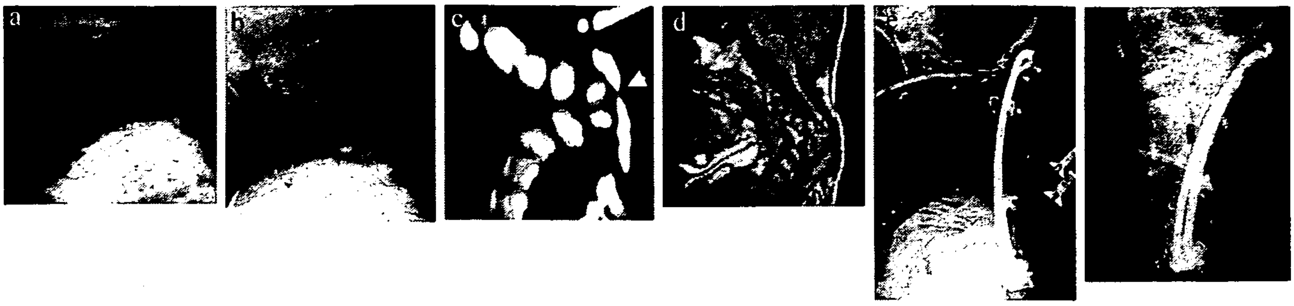

Figure 4. Case 3. (**a**) At 10 months of age, cervical kyphosis measured 93°. (**b**) Kyphosis was corrected to 60° after attempted posterior fusion at another institute. (**c**) At the age of 2 years and 5 months, sagittal reconstructed images of computed tomography showed failed posterior fusion (arrow) and kyphosis had progressed to 146°. (**d**) Magnetic resonance imaging demonstrated severe impingement of the spinal cord at the apex of the kyphosis. (**e**) Kyphosis was corrected to 117° after 2-stage circumferential surgery. (**f**) At 6 years after surgery, surgical correction of the kyphosis was well maintained.

pression and circumferential fusion required for patients displaying severe and/or rigid kyphotic deformity, who usually have myelopathic symptoms.

Regarding PSF for infantile kyphosis, anterior vertebral growth with a mature posterior fusion mass could additionally decrease the magnitude of kyphotic deformity. In a very young patient with congenital kyphosis of the thoracolumbar spine, Winter *et al* suggested that continued growth in the anterior parts of the segments would result in gradual spontaneous correction of the thoracolumbar kyphosis in the presence of solid posterior fusion.[11] As for cervical kyphosis of Larsen syndrome, Johnston *et al* reported that the kyphosis had gradually been reversed to lordosis due to anterior growth with a solid posterior fusion in 2 of 3 patients (Table 2).[7] In our patient with 32° kyphosis just after PSF, anterior growth provided additional correction to 16° over the course of 8 years after posterior fusion (Case 2). However, in 1 of the cases described by Johnston et al,[7] cervical kyphosis was overcorrected to 68° lordosis due to anterior growth by 92 months after surgery (Table 2).[7] Overcorrection of kyphosis after posterior surgery might thus result in hyperlordosis due to anterior growth, although prediction of this growth would be difficult.

ASF involves some important issues, particularly: 1) much higher risk of spinal cord injury during decompression maneuvers and 2) difficulty in stabilization of the reconstructed cervical spine. Patients with cervical kyphosis of Larsen syndrome are very small infants. Furthermore, candidates for ASF usually have extremely severe kyphotic deformities with hypoplastic vertebrae. Francis and Noble described that, *via* a conventional anterior approach, excision of the apical vertebral body posterior to the adjacent vertebrae and encroaching on the cord was technically demanding and quite dangerous.[4] In patients with severe thoracolumbar kyphosis, such as congenital or tuberculous kyphosis, a lateral transthoracic approach is preferred to decompress the spinal cord in safety under much better visualization. Anterior surgery was thus performed *via* a lateral approach in 2 patients of the current series with extremely severe cervical kyphosis (Cases 1 and 2), allowing safer decompression of the cord under direct visualization of the association between vertebrae and spinal cord. This approach would be useful for patients with very severe kyphotic deformity, although retraction of the carotid sheath and release of the vertebral artery might carry considerable risk. As for another problem, difficulty in stabilization of

Table 2. Summary of Data on the 9 Patients Previously Reported

				Cervical Kyphosis			
Case No.	Sex/Age	Surgical Procedure (instrumentation + immobilization)	Follow-up (yr)	Preoperative (level) (°)	Preoperative Correction (manipulation) (°)	Postoperative (°)	Latest Follow-up (°)
1[7]	M/16 mo	PSF (no instrumentation + halo)	6.3	35 (C3–C6)	0 (passive extension)	4	−21
2[7]	M/16 mo	PSF (no instrumentation + orthosis)	6.0	37 (C3–C6)	26 (passive extension)	31	18
3[7]	M/14 mo	PSF (no instrumentation + orthosis)	7.7	35 (C3–C6)	−25 (passive extension)	35	−68
4[7]	M/10 mo	1st: PSF (no instrumentation + orthosis)	1.3	65 (C3–C6)	48 (passive extension)	39	110
		2nd: ASF (no instrumentation + halo)	1.1	110	NA	NA	(145)
		3rd: ASF (no instrumentation + halo)	1.0	145	NA	NA	20
5[5]	M/14 yr	ASF + PSF (wiring + orthosis)	2.7	40 (C3–C7)	NA	3°	3
6[4]	M/5 yr	ASF (no instrumentation + halo)	NA	168 (C4–C7)	NA	NA	NA
7[1]	M/10 mo	PSF (no instrumentation + orthosis)	NA	NA (C3–C7)	NA	NA	NA
8[6]	M/5 yr	ASF + PSF (NA)	5.0	NA (C3–C6)	NA	NA	NA
9[3]	M/6 yr	PSF (no instrumentation + orthosis → halo)	NA	NA (C2–C4)	NA	NA	NA

Age, age at the operation; ASF, anterior spinal fusion; PSF, posterior spinal fusion; halo, halo vest; NA, not available.

the reconstructed cervical spine, extremely severe kyphotic deformities with hypoplastic vertebrae would lead to posterior dislodgement of strut grafts after anterior surgery in spite of halo immobilization (Case 1). In hope of obtaining as much stability of the reconstructed cervical spine as possible, we performed posterior arthrodesis with SSI following ASF, although sublaminar wiring has inherent risk for neurologic deterioration. In the present series, posterior arthrodesis using SSI combined with ASF resulted in acceptable stability for the reconstructed cervical spine without any sequelae. As the most advantageous instrumentation in the correction and stabilization of cervical kyphosis, Abumi *et al* advocate cervical pedicle screw fixation.[12] However, no useful instrumentations such as pedicle screw fixation are available for very small Larsen patients other than SSI, although SSI cannot provide as much stabilization as more rigid pedicle screw systems. The cervical spine should therefore be immobilized in a halo vest even after circumferential arthrodesis using SSI. Regarding halo techniques for small children, in the present series, we used multiple pins (*e.g.*, 6 pins for the frontal and occipital bone, respectively in Case 3) inserted by the lower torque (1–2 lb) before surgery, and added extra pins for occipital bone after surgery. However, sufficient care must be used given the much greater risk of halo complications in children than in adults.[13] Given these difficult problems associated with anterior surgery for such a small patient with severe cervical kyphosis, all patients with Larsen syndrome should be screened with radiographs at the first visit to detect cervical kyphosis early so that posterior alone fusion is possible.

■ Key Points

- Posterior spinal fusion is only indicated for patients with mild and flexible cervical kyphosis, and anterior decompression and circumferential arthrodesis is required for patients with severe kyphotic deformity, who usually develop myelopathic symptoms.
- The lateral approach would be useful for patients with very severe kyphotic deformity, although retraction of the carotid sheath and release of the vertebral artery might carry considerable risk.
- The cervical spine should be immobilized in a halo vest even after circumferential arthrodesis using spinal instrumentations.

Acknowledgments

The authors thank Mr. Tomohiko Nakano for his fine work in medical illustrations.

References

1. Micheli LJ, Hall JE, Watts HG. Spinal instability in Larsen's syndrome: report of three cases. *J Bone Joint Surg Am* 1976;58:562–5.
2. Muzumdar AS, Lowry RB, Robinson CE. Quadriplegia in Larsen syndrome. *Birth Defects Orig Artic Ser* 1977;13:202–11.
3. Bellon JM, Filipe G. Spinal complications encountered in Larsen's syndrome: apropos of 3 cases [in French]. *Rev Chir Orthop Reparatrice Appar Mot* 1987;73:57–62.
4. Francis WR, Noble DP. Treatment of cervical kyphosis in children. *Spine* 1988;13:883–7.
5. Kaneda K, Kurakami C, Minami A. Free vascularized fibular strut graft in the treatment of kyphosis. *Spine* 1988;13:1273–7.
6. Forese LL, Berdon WE, Harcke HT, et al. Severe mid-cervical kyphosis with cord compression in Larsen's syndrome and diastrophic dysplasia; unrelated syndromes with similar radiologic findings and neurosurgical implications. *Pediatr Radiol* 1995;25:136–9.
7. Johnston CE 2nd, Birch JG, Daniels JL. Cervical kyphosis in patients who have Larsen syndrome. *J Bone Joint Surg Am* 1996;78:538–45.
8. Larsen LJ, Schottstaedt ER, Bost FC. Multiple congenital dislocations associated with characteristic facial abnormality. *J Pediatr* 1950;37:574–81.
9. Bowen JR, Ortega K, Ray S, et al. Spinal deformities in Larsen's syndrome. *Clin Orthop* 1985;197:159–63.
10. Tachdjian MD. *Pediatric Orthopedics*. Philadelphia: Thieme, 1990.
11. Winter RB, Moe JH, Wang JF. Congenital kyphosis: its natural history and treatment as observed in a study of one hundred and thirty patients. *J Bone Joint Surg Am* 1973;55:223–56.
12. Abumi K, Shono Y, Taneichi H, et al. Correction of cervical kyphosis using pedicle screw fixation systems. *Spine* 1999;24:2389–96.
13. Baum JA, Hanley EN Jr, Pullekines J. Comparison of halo complications in adults and children. *Spine* 1989;14:251–2.

SPINE Volume 32, Number 6, pp 647–653
©2007, Lippincott Williams & Wilkins, Inc.

Surgical Strategy for Cervical Myelopathy due to Ossification of the Posterior Longitudinal Ligament

Part 1: Clinical Results and Limitations of Laminoplasty

Motoki Iwasaki, MD, PhD,* Shin'ya Okuda, MD, PhD,† Akira Miyauchi, MD, PhD,§
Hironobu Sakaura, MD,* Yoshihiro Mukai, MD,¶ Kazuo Yonenobu, MD, PhD,‡
and Hideki Yoshikawa, MD, PhD*

Study Design. Retrospective study of 66 patients who underwent laminoplasty for treatment of cervical myelopathy due to ossification of the posterior longitudinal ligament (OPLL).

Objectives. The present study describes surgical results of laminoplasty for treatment of cervical myelopathy due to OPLL and aims to clarify 1) factors predicting outcome and 2) limitations of laminoplasty.

Summary of Background Data. During the period 1986 and 1996, laminoplasty was the only surgical treatment selected for cervical myelopathy at our institutions.

Methods. We reviewed data obtained in 66 patients who underwent laminoplasty for treatment of cervical myelopathy due to OPLL. Mean duration of follow-up was 10.2 years (range, 5–20 years). Surgical outcomes were assessed using the Japanese Orthopaedic Association (JOA) scoring system for cervical myelopathy.

Results. Surgical outcome was significantly poorer in patients with occupying ratio greater than 60%. Multiple regression analysis showed that the most significant predictor of poor outcome after laminoplasty was hill-shaped ossification, followed by lower preoperative JOA score, postoperative change in cervical alignment, and older age at surgery.

Conclusions. Laminoplasty is effective and safe for most patients with occupying ratio of OPLL less than 60% and plateau-shaped ossification. However, neurologic outcome of laminoplasty for cervical OPLL was poor or fair in patients with occupying ratio greater than 60% and/or hill-shaped ossification.

Key words: cervical myelopathy, ossification of the posterior longitudinal ligament, laminoplasty. **Spine 2007; 32:647–653**

From the *Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, Osaka, Japan; †Department of Orthopaedic Surgery, Osaka Rosai Hospital, Osaka, Japan; ‡National Hospital Organization, Osaka Minami Medical Center, Osaka, Japan; §Miyauchi Orthopaedic Clinic, Osaka, Japan; and ¶Sumitomo Hospital, Osaka, Japan.
Acknowledgment date: June 7, 2006. First revision date: August 2, 2006. Acceptance date: August 2, 2006.
Presented in part at the 35th Annual Meeting of the Japanese Spine Research Society, Tokyo, Japan, April 2006.
Supported by a grant-in-aid from the Investigation Committee on Ossification of the Spinal Ligaments, Japanese Ministry of Public Health, Labor, and Welfare.
The manuscript submitted does not contain information about medical device(s)/drug(s).
No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
Address correspondence and reprint requests to Motoki Iwasaki, MD, PhD, Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, 2-2, Yamadaoka, Suita, Osaka 565-0871, Japan; E-mail: iwasaki@ort.med.osaka-u.ac.jp

Ossification of the posterior longitudinal ligament (OPLL) has been recognized as a common clinical entity that causes compression myelopathy of the cervical spine. One of the authors (M.I.) reported the superiority of laminoplasty in terms of long-term results and when taking into consideration the incidence of surgery-related complications and the high possibility of postoperative progression of the ossified lesion,[1] although similar neurologic recovery can be achieved with any of these procedures.[1–3] However, several studies have focused on the occupying ratio of OPLL and reported the superiority of anterior decompression for massive ossified lesions.[2,4–6] To determine whether only occupying ratio of OPLL or any other factor is related to surgical outcome of posterior decompression, clinical review was made in 66 patients who underwent laminoplasty for OPLL. Since laminoplasty was the only surgical procedure selected for cervical myelopathy due to OPLL at our institutions during the period 1986 and 1996, the authors think that the follow-up data presented in this report can provide unbiased information about surgical strategy for cervical myelopathy due to OPLL.

Materials and Methods

Patient Population. During the period 1986 and 1996, 82 patients underwent laminoplasty for treatment of cervical myelopathy due to OPLL at Osaka University Hospital and Osaka Rosai Hospital. During this decade, laminoplasty was the only procedure selected for compression myelopathy due to any etiology including OPLL.[1,7] Thirteen patients who could not be followed for a minimum of 5 years and 3 patients in whom neurologic status could not be clearly evaluated due to associated comorbidity such as brain infarction or arteriosclerosis obliterans of the lower extremities were excluded from the present study. Therefore, data were available for 66 patients: 51 men and 15 women. Mean age at surgery was 57 years (range, 41–75 years). Mean duration of follow-up was 10.2 years (range, 5–20 years). All patients included in the present study were of Asian descent.

Radiographic Assessment. Based on preoperative findings of standard lateral radiographs and/or tomograms, OPLL of the cervical spine was classified into 4 types: continuous-type, segmental-type, mixed-type, or circumscribed-type (localized or others).[8] In addition to this conventional typing, sagittal shape of the ossified lesion was classified into plateau- or hill-shaped.[9] Plateau-shaped ossification, which is found in segmental-type OPLL and most cases of continuous- and mixed-type OPLL, is

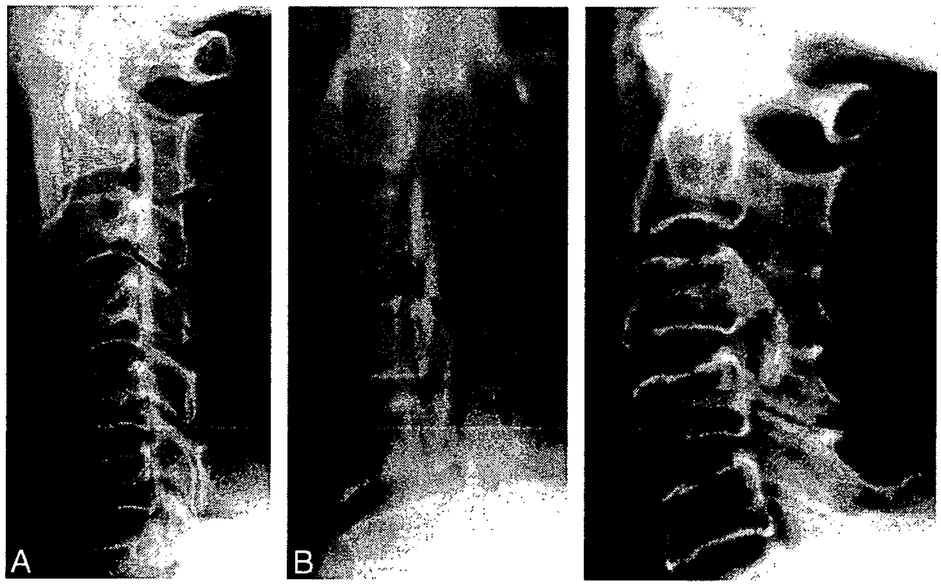

Figure 1. Sagittal-shape of ossification. **A**, Lateral radiograph image demonstrating plateau-shaped ossification: relatively narrow spinal canal without any localized massive ossification. **B**, Tomogram demonstrating a hill-shaped ossification located from C2–C3 to C5–C6 in the shape of a beak (left) and another hill-shaped ossification that is circumscribed-type OPLL localized from C3–C4 (right).

characterized by a relatively narrow spinal canal without any localized massive ossification (Figure 1A). On the other hand, hill-shaped ossification, which is found in circumscribed-type OPLL and some cases of continuous- or mixed-type OPLL, demonstrates massive beak-shaped ossification localized to certain levels (Figure 1B).

Before surgery, extent of ossification and space available for the cord (SAC) were measured. The occupying ratio of OPLL was calculated as the ratio of the maximum anteroposterior thickness of OPLL to the anteroposterior diameter of the spinal canal at the corresponding level on a lateral radiograph or tomogram.[8,10]

Progression of OPLL was defined as the following[11]: an increase of ≥2 mm in existing lesions, appearance of a new ossified lesion measuring ≥2 mm, and bridging between separate lesions to form a continuous lesion.

Neurologic Assessment. All patients presented with long tract signs such as spastic gait disturbance and clumsiness of the hands, with the exception of 1 patient with segmental-type myelopathy. This patient exhibited severe weakness of the deltoid muscle and muscular atrophy of the shoulder girdle, a presentation similar to so-called cervical spondylotic amyotrophy.[12] The neurologic status of each patient was evaluated according to a scoring system proposed by the Japanese Orthopaedic Association (JOA), and recovery rate was used to reflect the degree of postoperative recovery of normal function.[1,3,9,10,13] Recovery rates were graded as follows: >75%, excellent; 50% to 74%, good; 25% to 50%, fair; and <25%, poor.

Surgical Technique. The procedure of cervical laminoplasty has been described in detail elsewhere.[14–16] Decompression was extended up to C2 and/or down to the thoracic spine as indicated when ossified lesions extended to these levels. When decompression at C2 was necessary, laminoplasty or dome-shaped undercutting of the axis was performed. If the decompression needed to be extended to C1, laminectomy of the posterior arch of the atlas was performed. Mean number of opened laminae was 5.7 (range, 5–11): C3–C7, n = 41; C2–C7, n = 13; C3–T (T1–T6), n = 7; C2–T1 or T2, n = 3; C1–C7, n = 2. After surgery, patients wore a soft cervical collar and were allowed to mobilize within a week. Mean operation time was 177 minutes (range, 90–395 minutes), and mean estimated blood loss during laminoplasty was 464 g (range, 50–1800 g).

Statistical Analysis. Multiple regression analysis was performed using JMP (SAS Institute Inc., Cary, NC) to assess factors predicting the surgical outcome of laminoplasty. To determine the factors affecting surgery-related outcomes, the JOA score and recovery rate at final follow-up or at time of maximum recovery were used as dependent variables, respectively. In model fitting, variables were selected by stepwise procedure to determine the best model, with the probability value for entering or staying in the model being ≤0.20. Of the total of 66 patients undergoing laminoplasty, 6 patients who had developed neurologic symptoms of thoracic myelopathy or lumbar spinal canal stenosis were excluded from the multiple regression analysis in order to clarify factors predictive of surgical outcomes. Comparisons of data between 2 groups were assessed using the Mann-Whitney *U* test.

■ Results

Patient Demographics

In the 66 patients, mean preoperative JOA score was 9.2 (range, 0–15). Mean occupying ratio of OPLL was 44.4% (range, 15%–71%) and mean SAC was 7.6 mm (range, 4–11 mm). Type of OPLL was distributed as follows: mixed-type, n = 36 (55%); continuous-type, n = 20 (30%); segmental-type, n = 7 (11%); and circumscribed-type, n = 3 (5%). Plateau-shaped ossification was apparent in 54 patients (82%) and hill-shaped ossification was found in 12 (18%). Preoperative sagittal alignment of the cervical spine was lordotic in 32 patients (48%), straight in 29 (44%), and kyphotic or S-shaped in 5 (8%). Analysis of serial radiographic data revealed progression of OPLL in 27 (52%) of the 52 patients who underwent periodic follow-up radiographic examination for more than 5 years after surgery.

Table 1. Surgical Outcome of Laminoplasty With Respect to Occupying Ratio of OPLL

			JOA Score		Recovery Rate	
Occupying Ratio	No.	SAC (mm)	Preoperative	Final Follow-up	Final Follow-up (%)	Maximum (%)
<60%	60	7.8	9.2	14.1	58	67
≥60%	6	5.2†	9.4	11.0*	14*	34†

*$P < 0.03$.
†$P < 0.01$.
SAC indicates space available for the spinal cord; JOA, Japanese Orthopaedic Association.

Surgery-Related Results of Laminoplasty

Mean JOA score improved from 9.2 (range, 0–15) before surgery to 13.7 (range, 8–17) at final follow-up. Mean recovery rate was 63% (range, 0%–100%) at time of maximum recovery and 55% (range, −21% to 100%) at final follow-up. When surgical outcomes were compared with respect to occupying ratio of OPLL, mean JOA score improved from 9.2 (range, 0–15) before surgery to 14.1 (range, 8–17) at final follow-up in 60 patients in whom occupying ratio was less than 60% (Table 1). Mean recovery rate of these 60 patients was 58% (range, −10% to 100%) at final follow-up and 67% (range, 0%–100%) at time of maximum recovery. In contrast, mean JOA score improved from 9.4 (range, 6–12) before surgery to 11.0 (range, 8.5–14.5) at final follow-up in 6 patients in whom occupying ratio was greater than 60%. Mean recovery rate of these 6 patients with greater occupying ratio was only 14% (range, −21% to 75%) at final follow-up and 34% (range, 0%–80%) at time of maximum recovery. Surgical outcome of laminoplasty in patients with occupying ratio ≥60% was significantly poorer than those with occupying ratio <60% (Table 1).

Characteristics of Patients With Fair and Poor Results After Laminoplasty

For 22 patients (33%), recovery rate at final follow-up or at time of maximum recovery was less than 50%. Of these, 6 patients were excluded from this study due to either thoracic myelopathy caused by OPLL and/or ligamentum flavum, or lumbar spinal canal stenosis. In the remaining 16 patients with fair or poor outcome after laminoplasty, 7 had hill-shaped ossification, 7 exhibited postoperative change in cervical alignment (including 3 with deterioration to kyphosis), 6 showed postoperative progression of OPLL, 4 had an occupying ratio ≥60%, 3 exhibited abnormal preoperative alignment (*i.e.*, S-shaped or kyphotic), and 1 had amyotrophic-type myelopathy associated with muscular atrophy of the shoulder girdle (Table 2).

Looking at these results from the opposite point of view, surgical outcome was fair or poor in 5 (83%) of the 6 patients with occupying ratio greater than 60%, 9 (75%) of the 12 patients with hill-shaped ossification, 8 (67%) of the 12 patients with postoperative change in cervical alignment, and 3 (60%) of the 5 patients with preoperative abnormal alignment of the cervical spine, respectively (Table 3).

With regard to sagittal shape of ossification, surgical outcome of patients with hill-shaped ossification was significantly poorer than that of those with plateau-shaped ossification, although there was no significant difference in occupying ratio of OPLL between these groups (Table 4). Mean recovery rate of the 12 patients with hill-shaped ossification was 32% at final follow-up and 40% at time of maximum recovery; these recovery rates were

Table 2. Characteristics of 16 Patients With Fair and Poor Results After Laminoplasty

		JOA Score		Recovery Rate (%)			Cervical Alignment			
Case No./ Age (yr)/ Sex	Occupying Ratio (%)	Preoperative	Final Follow-up	Maximum	Final Follow-up	Shape of OPLL	Preoperative	Postoperative Change	OPLL Progression (mm)	Others
1/63/M	31	15	15	0	0	Plateau	Straight	No	0	Amyotrophic type
2/48/M	31	11	11.5	58	8	Plateau	Lordotic	No	3	
3/63/M	33	14	14.5	33	17	Plateau	Lordotic	Straight	0	
4/61/F	36	11	12.5	33	25	Plateau	Straight	Kyphotic	0	
5/41/M	36	10	12.5	36	36	Hill	S-shaped	No	0	
6/61/M	40	12	11.5	20	−10	Plateau	S-shaped	Kyphotic	0	
7/56/M	50	10	12	43	29	Plateau	Straight	No	3	
8/72/M	50	10	10.5	21	7	Hill	Straight	No	5	Arm pain
9/54/M	50	8	8.5	11	6	Hill	Lordotic	Straight	0	
10/56/F	54	10	11	29	14	Plateau	Straight	No	8	
11/63/M	57	6	10.5	64	41	Hill	Lordotic	No	0	
12/73/M	58	10	12	43	29	Plateau	Lordotic	No	2	
13/55/M	62	10	8.5	29	−21	Plateau	Straight	No	5	Arm pain
14/60/M	65	6	10	46	36	Hill	Lordotic	Straight	0	
15/57/M	67	12	12	20	0	Hill	Lordotic	Straight	0	
16/47/M	70	10	9	0	−14	Hill	Kyphotic	Kyphotic	0	Arm pain

JOA indicates Japanese Orthopaedic Association.

Table 3. Overall Surgical Outcome of Laminoplasty With Respect to Predictive Factors

	Excellent/Good [no. (%)]	Fair [no. (%)]	Poor [no. (%)]
Occupying ratio 60% (N = 6)	1 (17)	3 (50)	2 (33)
Hill-shaped ossification (N = 12)	3 (25)	4 (33)	5 (42)
Postoperative change in cervical alignment (N = 12)	4 (33)	2 (17)	6 (50)
Preoperative abnormal alignment (N = 5)	2 (40)	1(20)	2 (40)
Postoperative progression of OPLL (N = 27)	20 (74)	2 (7)	5 (19)

Surgical outcome was evaluated from recovery rate: excellent, >75%; good, 50%–74%; fair, 25%–50%; poor, <25%.

Table 5. Cervical Alignment After Laminoplasty in 66 Patients With OPLL

	Postoperative Alignment [no. (%)]			
Preoperative Alignment	Lordotic	Straight	Kyphotic or S-Shaped	Total
Lordotic	24	8	0	32 (48)
Straight		27	2	29 (44)
Kyphotic or S-shaped			5*	5 (8)
Total	24 (36)	35 (53)	7 (11)	66

*Cervical alignment deteriorated postoperatively in 2 of 5 patients whose preoperative alignment was kyphotic or S-shaped.

significantly poorer than those in patients with plateau-shaped ossification ($P < 0.01$).

Postoperative change in cervical alignment was observed in 12 (18%) of 66 patients at final follow-up (Table 5): deterioration from lordotic to straight in 8 patients and deterioration to kyphotic in 4 patients. Eight (67%) of these 12 patients had poor or fair surgical outcomes (Table 3). Mean recovery rate at final follow-up in these 12 patients was 32% (range, −14% to 83%); significantly lower than that observed in other patients whose cervical alignment did not change ($P < 0.03$).

Postoperative progression of OPLL was observed in 27 (52%) of the 52 patients who underwent periodic follow-up radiographic examination for more than 5 years after surgery. Surgical outcome was fair or poor in 7 (26%) of these patients (Table 3). Late deterioration of cervical myelopathy was defined as a decrease of JOA scores of more than 2 points.[17] According to this definition, late-onset neurologic deterioration was observed in 3 patients of the 16 patients with fair or poor outcome after laminoplasty, in whom postoperative progression of OPLL was the considerable cause of the neurologic deterioration (Cases 2, 10, and 13 in Table 2).

Table 4. Clinical Characteristics of Patients With Hill- and Plateau-Shaped Ossification

	Hill-Shaped	Plateau-Shaped	*P*
No. of patients	12	54	
Occupying ratio (%)			
Mean	50.8	43.0	NS
Range	36 to 76	15 to 71	
SAC (mm)			
Mean	6.9	7.7	NS
Range	5 to 10	4 to 11	
Preoperative JOA score			
Mean	9.1	9.3	NS
Range	6 to 13	0 to 15	
Postoperative JOA score			
Mean	11.7	14.1	<0.01
Range	8.5 to 16	8 to 17	
Recovery rate (%)			
Mean	30.0	59.9	<0.01
Range	−14.3 to 85.7	−21.0 to 100	

SAC indicates space available for the spinal cord; JOA, Japanese Orthopaedic Association; NS, not statistically significant.

Factors Predictive of Surgery-Related Outcome of Laminoplasty

Age at operation, preoperative JOA score, occupying ratio of OPLL, SAC, shape of ossification (plateau- or hill-shaped), preoperative abnormal alignment of the cervical spine (kyphotic/S-shaped or lordotic/straight), and postoperative change in cervical alignment (deterioration or none) were chosen as independent variables in all cases. Based on the results of multiple regression analysis, the following factors correlated with surgical outcome of laminoplasty (JOA score at time of maximum recovery): 1) shape of ossification (F = 33.0; $P < 0.0001$); 2) preoperative JOA score ($F = 15.1$; $P = 0.0003$); 3) postoperative change in cervical alignment ($F = 3.0$; $P = 0.091$); and 4) age at surgery ($F = 1.8$; $P = 0.1866$) (Table 6). On this multiple regression analysis, the most significant predictor of poor outcome after laminoplasty was hill-shaped ossification followed by lower preoperative JOA score, whereas occupying ratio of OPLL, SAC, and preoperative abnormal alignment of the cervical spine (kyphosis or S-shaped) were not statistically related to surgical outcome of laminoplasty.

Surgery-Related Complications

After laminoplasty, transient motor paresis in the upper extremity occurred in 6 cases (9%) and persistent neuropathic arm pain in 5 cases (8%). Regarding reoperations, additional spine surgeries such as lumbar laminotomy for spinal canal stenosis and/or thoracic laminectomy for thoracic OPLL or ossification of ligamentum flavum were required in 4 patients (6%) during the follow-up period, but additional surgery related to the cervical spine was required in only 1 patient (1.5%): transient deterioration of myelopathy immediately after surgery was observed in this patient who developed epidural hematoma and recovered completely after emergent surgical reexploration. There was no case that required reoperation for transient arm paresis or postoperative progression of OPLL at the surgically treated level.

■ Cases Reports

Case 8

This 72-year-old man with circumscribed-type OPLL underwent C3–C7 laminoplasty. JOA scores were 10 be-

Table 6. Predictive Factors for the Surgical Results of Laminoplasty Using Multiple Regression Analysis

	Shape of OPLL (hill-shaped)	Postoperative Change in Cervical Alignment	Preoperative JOA Score	Age at Surgery
JOA score (final follow-up)	$F = 21.5$ $P < 0.0001$	$F = 2.1$ $P = 0.1485$	$F = 11.2$ $P = 0.0015$	— —
JOA score (maximum)	$F = 33.0$ $P < 0.0001$	$F = 3.0$ $P = 0.0910$	$F = 15.1$ $P = 0.0003$	$F = 1.8$ $P = 0.1866$
Recovery rate (final follow-up)	$F = 13.7$ $P = 0.0005$	$F = 3.6$ $P = 0.0625$	— —	— —
Recovery rate (maximum)	$F = 19.2$ $P < 0.0001$	$F = 8.1$ $P = 0.0063$	— —	— —

JOA indicates Japanese Orthopaedic Association.

fore surgery and 10.5 at the 7-year follow-up. OPLL occupied 50% of the spinal canal with hill-shaped ossification (Figure 2A). Transient arm palsy was observed in this patient. Although the spinal cord was decompressed adequately after open-door laminoplasty (Figure 2B), he continued to complain of neuropathic pain in his upper extremities and surgical outcome was poor. Recovery rate was 20% and 7% at time of maximum recovery and final follow-up, respectively.

Case 16

This 47-year-old man with continuous-type OPLL underwent C3–C7 laminoplasty. JOA scores were 10 before surgery, 10 at time of maximum recovery, and 9 at final follow-up. Recovery rate at final follow-up was −14% (poor outcome). OPLL occupied 70% of the spinal canal with hill-shaped ossification and preoperative alignment of the cervical spine was kyphotic (Figure 3). Although the spinal cord was decompressed adequately after open-door laminoplasty (Figure 3B, C), the patient developed neuropathic arm pain after surgery and the kyphotic deformity worsened.

■ Discussion

Although Tani *et al* reported that anterior decompression and fusion was safer than laminoplasty for massive OPLL with an occupying ratio greater than 50%,[5] our results in the present study indicated no significant difference in surgical outcome of laminoplasty between patients with occupying ratio <50% and those with occupying ratio between 50% and 60% (data not shown). However, surgical outcome was significantly poorer in patients with occupying ratio ≥60%.

Multiple regression analysis in the present study revealed that the most significant predictor of poor neurologic outcome after laminoplasty was hill-shaped ossification, followed by lower preoperative JOA score (more severe neurologic symptoms), postoperative change in cervical alignment, and older age at surgery. With regard to preoperative JOA score and age at surgery, the present study demonstrated similar results to those published in our previous reports.[1,10] Although MR images were not available in all cases, hill-shaped ossification might reflect severe compression of the spinal cord at localized levels with sharp angulation of the spinal cord, while plateau-shaped ossification might instead reflect a relatively narrow canal in the entire area of the ossified lesion.

Postoperative change in cervical alignment was observed in 12 (18%) of 66 patients. Laminoplasty extended from C2 to C7 in 6 of these 12 patients and extended further in 3 of 4 patients in whom cervical alignment deteriorated to kyphosis. Therefore, the possibility exists that postoperative deterioration to kyphosis is related to extension of decompression up to C2.[18]

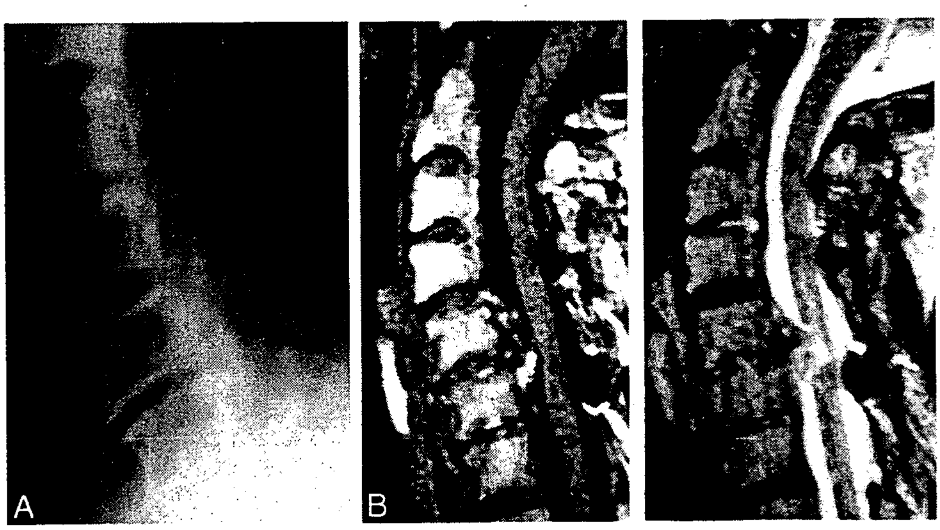

Figure 2. Case 8. **A**, Preoperative tomogram demonstrating hill-shaped ossification at C5–C6. **B**, T1-weighted MR image (left) and T2-weighted MR image (right) taken 5 years after laminoplasty demonstrating posterior decompression but remaining hill-shaped ossification in front of the spinal cord.

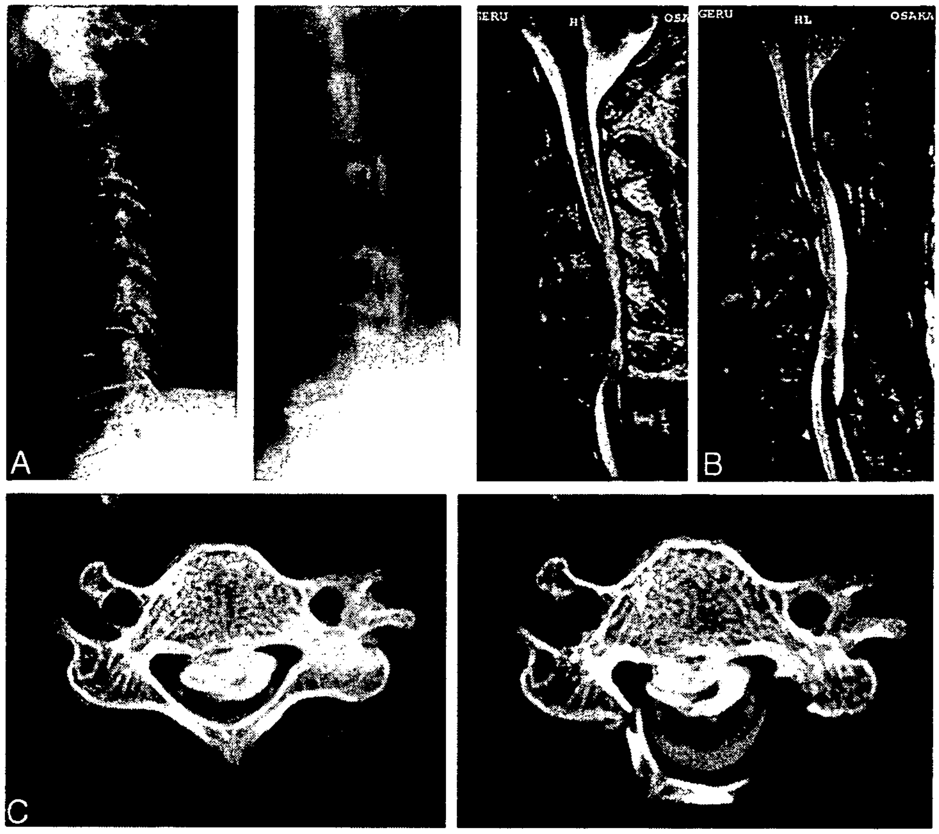

Figure 3. Case 16. **A**, Preoperative radiograph image (left), tomogram (middle), and T2-weighted MR image (right) demonstrating massive ossification from C3–C4–C6–C7. **B**, T2-weighted MR image taken 18 months after laminoplasty demonstrating posterior decompression but remaining angulation of the spinal cord. **C**, CT myelogram. Preoperative CT myelogram (left) demonstrating severe compression of the spinal cord with massive OPLL; occupying ratio was 70%. Postoperative CT myelogram (right) demonstrating adequate posterior decompression after open-door laminoplasty.

Furthermore, the authors consider that postoperative change in cervical alignment might reflect dynamic instability. This could play a crucial role in the development of myelopathy as Matsunaga *et al* pointed out in a study of the natural history of OPLL.[19,20] Poor surgical outcome was evident in 3 of 4 patients with cervical kyphosis newly developed after laminoplasty (mean recovery rate of these 4 patients: 21%). Moreover, fair or poor surgical outcomes were found in 5 of 8 patients in whom postoperative cervical alignment changed from lordotic to straight (mean recovery rate of these 8 patients, 38%). Although none of the patients who underwent laminoplasty exhibited obvious spinal instability, these results of postoperative cervical alignment suggest that laminoplasty has limitations in terms of spinal stabilization.

Conclusion

Laminoplasty is effective and safe for most patients with occupying ratio of OPLL <60% and plateau-shaped ossification. However, surgical outcome of laminoplasty would be poor when occupying ratio of OPLL is greater than 60% and/or when the ossified lesion is hill-shaped with sharp angulation of the spinal cord.

Key Points

- We retrospectively studied 66 patients who underwent laminoplasty for treatment of cervical OPLL to clarify factors predicting outcome and limitations of laminoplasty.
- Neurologic outcomes of patients with occupying ratio ≥60% were poorer than those with occupying ratio <60%.
- Multiple regression analysis showed that the most significant predictor of poor outcome after laminoplasty was hill-shaped ossification, followed by lower preoperative JOA score, postoperative change in cervical alignment, and older age at surgery.

Acknowledgments

The authors thank Masao Yarita and Hidekuni Susaki for assistance with statistical analysis.

References

1. 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.
2. Belanger TA, Roh JS, Hanks SE, et al. Ossification of the posterior longitudinal ligament: results of anterior cervical decompression and arthrodesis in sixty-one North American patients. *J Bone Joint Surg Am* 2005;87:610–5.
3. Matsuoka T, Yamaura I, Kurosa Y, et al. Long-term results of the anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Spine* 2001;26:241–8.
4. Sodeyama T, Goto S, Mochizuki M, et al. Effect of decompression enlargement laminoplasty for posterior shifting of the spinal cord. *Spine* 1999;24:1527–31.
5. 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* 2002;27:2491–8.
6. 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* 1999;24:32–4.

7. Iwasaki M, Ebara S, Miyamoto S, et al. Expansive laminoplasty for cervical radiculomyelopathy due to soft disc herniation. *Spine* 1996;21:32–8.
8. Tsuyama N. Ossification of the posterior longitudinal ligament of the spine. *Clin Orthop* 1984;71–84.
9. Iwasaki M, Yonenobu K. Ossification of the posterior longitudinal ligament. In: *The Spine*, 5th ed. Philadelphia: Elsevier, 2006:896–912.
10. Kato Y, Iwasaki M, Fuji T, et al. Long-term follow-up results of laminectomy for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *J Neurosurg* 1998;89:217–23.
11. Chiba K, Yamamoto I, Hirabayashi H, et al. Multicenter study investigating the postoperative progression of ossification of the posterior longitudinal ligament in the cervical spine: a new computer-assisted measurement. *J Neurosurg Spine* 2005;3:17–23.
12. Kameyama T, Ando T, Yanagi T, et al. Cervical spondylotic amyotrophy: magnetic resonance imaging demonstration of intrinsic cord pathology. *Spine* 1998;23:448–52.
13. 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* 2001;26:1890–4.
14. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine* 1983;8:693–9.
15. Itoh T, Tsuji H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine* 1985;10:729–36.
16. Yonenobu K, Wada E, Ono K. Part B: Laminoplasty. In: Cervical Spine Research Society Editorial Committee, ed. *The Cervical Spine*, 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2005:1057–71.
17. Ogawa Y, Toyama Y, Chiba K, et al. Long-term results of expansive open-door laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine. *J Neurosurg Spine* 2004;1:168–74.
18. Takeshita K, Seichi A, Akune T, et al. Can laminoplasty maintain the cervical alignment even when the C2 lamina is contained? *Spine* 2005;30:1294–8.
19. Matsunaga S, Kukita M, Hayashi K, et al. Pathogenesis of myelopathy in patients with ossification of the posterior longitudinal ligament. *J Neurosurg* 2002;96:168–72.
20. Matsunaga S, Sakou T, Taketomi E, et al. The natural course of myelopathy caused by ossification of the posterior longitudinal ligament in the cervical spine. *Clin Orthop* 1994:168–77.

SPINE Volume 32, Number 6, pp 654–660

Surgical Strategy for Cervical Myelopathy due to Ossification of the Posterior Longitudinal Ligament

Part 2: Advantages of Anterior Decompression and Fusion Over Laminoplasty

Motoki Iwasaki, MD, PhD,* Shin'ya Okuda, MD, PhD,† Akira Miyauchi, MD, PhD,§ Hironobu Sakaura, MD,* Yoshihiro Mukai, MD,¶ Kazuo Yonenobu, MD, PhD,‡ and Hideki Yoshikawa, MD, PhD*

Study Design. Retrospective study of 27 patients who underwent anterior decompression and fusion (ADF) for treatment of cervical myelopathy due to ossification of the posterior longitudinal ligament (OPLL).

Objectives. To compare surgical outcome of ADF with that of laminoplasty.

Summary of Background Data. During the period 1986 and 1996, laminoplasty was the only surgical treatment selected for cervical myelopathy at our institutions. According to surgical results of laminoplasty performed during this period, we have performed either laminoplasty or ADF for patients with OPLL since 1996.

Methods. We reviewed clinical data obtained in 27 patients who underwent ADF between 1996 and 2003. Mean duration of follow-up was 6.0 years (range, 2–10 years). Surgical outcomes were assessed using the Japanese Orthopedic Association (JOA) scoring system for cervical myelopathy. Surgical results of ADF were compared with those of laminoplasty, which was performed in 66 patients during the period 1986 and 1996.

Results. ADF yielded a better neurologic outcome at final follow-up than laminoplasty in patients with occupying ratio ≥60%, although graft complications occurred in 15% and additional surgical intervention was required in 26%. Neither occupying ratio of OPLL, sagittal shape of ossification, nor cervical alignment was found to be related to surgical outcome of ADF.

Conclusions. Although ADF is technically demanding and has a higher incidence of surgery-related complications, it is preferable to laminoplasty for patients with occupying ratio of OPLL ≥60%.

Key words: cervical myelopathy, ossification of the posterior longitudinal ligament, laminoplasty, anterior decompression and fusion. **Spine 2007;32:654–660**

Part 1 of our articles detailed surgical results of laminoplasty and indicated that occupying ratio greater than 60% and hill-shaped ossification were associated relatively poor outcome.[1] Since anterior decompression and fusion (ADF) would accordingly be the procedure of choice to obtain appropriate decompression and stabilization in patients with these predisposing factors, the authors have performed either laminoplasty or ADF for patients with OPLL since 1996. The purpose of the present study was to compare neurologic outcomes between the 2 procedures for the surgical treatment of cervical myelopathy associated with a massive ossified lesion on the basis of the results in Part 1 of our investigations.

Materials and Methods

The authors have selected either laminoplasty or ADF since 1996, and 27 selected patients with OPLL were managed with ADF at Osaka University Hospital and Osaka Rosai Hospital between 1996 and 2003. These patients had undergone no previous cervical surgery with the exception of one patient in whom cervical kyphosis had developed after laminoplasty, requiring ADF 4 months later. Although no definitive selection criteria were applied in the selection of either laminoplasty or ADF, ADF was chosen on the basis of the following characteristics, which were considered factors predicting poor outcome of laminoplasty: massive ossified lesions, hill-shaped ossification, and sharp angulation of the spinal cord. Data for ADF were available for all 27 patients (15 men and 12 women). Mean age at surgery was 58 years (range, 41–74 years) and mean duration of follow-up was 6.0 years (range, 2–10 years). All patients included in the present study were of Asian descent. Surgical results of ADF were compared with those of laminoplasty, which was performed in 66 patients during the period 1986 and 1996.

Radiographic and neurologic assessment was described in detail in Part 1 of our investigation.[1]

Surgical Technique. The procedures of ADF as well as cervical laminoplasty have been described in detail elsewhere.[2–6]

Anterior procedures of the cervical spine were performed through a standard left-sided Robinson-Smith anterior approach. The base of the uncinate process or lateral border of

From the *Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, Osaka, Japan; †Department of Orthopaedic Surgery, Osaka Rosai Hospital, Osaka, Japan; ‡National Hospital Organization, Osaka Minami Medical Center, Osaka, Japan; §Miyauchi Orthopaedic Clinic, Osaka, Japan; and ¶Sumitomo Hospital, Osaka, Japan.
Acknowledgment date: June 7, 2006. First revision date: July 3, 2006. Acceptance date: July 18, 2006.
Presented in part at the 35th Annual Meeting of the Japanese Spine Research Society, Tokyo, Japan, April 2006.
Supported by a grant-in-aid from the Investigation Committee on Ossification of the Spinal Ligaments, Japanese Ministry of Public Health, Labor, and Welfare.
The manuscript submitted does not contain information about medical device(s)/drug(s).
Federal funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
Address correspondence and reprint requests to Motoki Iwasaki, MD, PhD, Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, 2-2, Yamadaoka, Suita, Osaka 565-0871, Japan; E-mail: iwasaki@ort.med.osaka-u.ac.jp

the disc was used as a landmark for the width of the vertebral body. Subtotal corpectomy was performed at 2 to 5 levels as determined by the extent of neurologic involvement and CT reconstruction images. This was followed by total discectomy. Transverse decompression was extended at least 20 to 25 mm to ensure sufficient decompression.[5,7] When the posterior cortex of the vertebral body was exposed, the cortex and ossified ligament were shaved with a diamond burr to make their thickness as uniform as possible. After release of the ossified lesion, the remnant of the ossified mass was not shaved but was instead allowed to spontaneously move ventrally. Ossified lesions were removed if they could easily be released, but this was not attempted if lesions were strongly adherent to the dura or if the dura itself was ossified. Autografts were used for arthrodesis in all patients; a tricortical iliac crest graft was used in 9 patients and fibular strut graft was used in 18 patients. The mean number of intervertebral levels fused was 3 (range, 2–5). One patient with myeloradiculopathy caused by segmental-type OPLL was managed with an anterior plate, but anterior instrumentation was not used for any other patients. Immobilization with a halo-vest was maintained after surgery for a mean of 8.2 weeks (range, 4–14 weeks). Mean operation time was 302 minutes (range, 167–470 minutes), and mean estimated blood loss for ADF was 513 g (range, 70–1730 g).

Statistical Analysis. Comparisons of surgical outcomes between anterior and posterior procedures were assessed using the Mann-Whitney *U* test.

Table 1. Preoperative Data in 27 Patients Who Underwent ADF and 66 Patients Who Underwent Laminoplasty

	ADF	Laminoplasty
No. of patients	27	66
Female/male	12:15	15:51
Age (yr) at surgery		
Mean	58	57
Range	41–74	41–75
Follow-up (yr)		
Mean	6.0	10.2
Range	2–10	5–20
Preoperative JOA score		
Mean	9.5	9.2
Range	4.5–14	0–15
Occupying ratio of OPLL (%)		
Mean	56.6	44.4
Range	30–80	15–71
Space available for spinal cord (mm)		
Mean	5.6	7.6
Range	3–10	4–11
Type of OPLL [no. (%)]		
Continuous	14 (52)	20 (30)
Mixed	7 (26)	36 (55)
Segmental	2 (7)	7 (11)
Circumscribed	4 (15)	3 (5)
Shape of ossified lesion [no. (%)]		
Plateau-shaped	16 (59)	54 (82)
Hill-shaped	11 (41)	12 (18)
Operation time (min)		
Mean	302	177
Range	167–470	90–395
Estimated blood loss (g)		
Mean	513	464
Range	70–1730	50–1800

ADF indicates anterior decompression and fusion; JOA, Japanese Orthopaedic Association.

Table 2. Cervical Alignment After ADF in 27 Patients With OPLL

	Postoperative Alignment [no. (%)]			
Preoperative Alignment	Lordotic	Straight	Kyphotic	Total
Lordotic	12	3	0	15 (56)
Straight	3*	4	0	7 (26)
Kyphotic	0	3*	2	5 (19)
Total	15 (56)	10 (37)	2 (7)	27

*Improvement of cervical alignment was observed in 6 patients.
ADF indicates anterior decompression and fusion.

■ Results

Patient Demographics

The details of preoperative data in 27 patients who underwent ADF are listed in Table 1. Mean preoperative JOA score was 9.5 (range, 4.5–14). Mean preoperative occupying ratio of OPLL was 56.6% (range, 30%–80%) and mean space available for the spinal cord (SAC) was 5.6 mm (range, 3–10 mm). Type of OPLL was distributed as follows: continuous-type n = 14; (52%), mixed-type n = 7 (26%); segmental-type, n = 2 (7%); and circumscribed-type, n = 4 (15%). Ossified lesions were plateau-shaped in 16 patients (59%) and hill-shaped in 11 (41%). Preoperative sagittal alignment of the cervical spine was lordotic in 15 patients (56%), straight in 7 (26%), and kyphotic in 5 (19%) (Table 2). After ADF, improvement of cervical alignment was observed in 6 patients and cervical alignment changed from lordotic to straight in 3 patients at final follow-up.

Surgical Results of ADF Compared With Laminoplasty

Overall outcome of ADF was compared with that of laminoplasty in Table 3. Among the 27 patients who underwent ADF, mean JOA score improved from 9.5 (range, 4.5–14) before surgery to 13.2 (range, 9–16.5) at final follow-up. Mean recovery rate was 57% (range, 28%–92%) at time of maximum recovery and 51% (range, 0%–92%) at final follow-up. Neurologic outcome was excellent or good in 56% of patients, fair in 37%, and poor in 7%. Although proportion of excellent or good results was similar between ADF and laminoplasty, poor outcome was more frequent in laminoplasty than in ADF.

Table 3. Summary of Surgical Outcome of ADF and Laminoplasty

Overall Outcome*	ADF [no. (%) of total 27 patients)]	Laminoplasty [no. (%) of total 66 patients)
Excellent/good	15 (56)	43 (65)
Fair	10 (37)	10 (15)
Poor	2 (7)	13 (20)

*Surgical outcome was evaluated from recovery rate: excellent, >75%; good, 50%–74%; fair, 25%–50%; poor, <25%.
ADF indicates anterior decompression and fusion.

Table 4. Surgical Outcomes of ADF and Laminoplasty With Respect to Occupying Ratio of OPLL

Occupying Ratio	No.	Mean Occupying Ratio (%)	JOA Score		Recovery Rate (%)	
			Preoperative	Postoperative	Final Follow-up	Maximum
ADF						
<60%	17	50	9.6	13.1	49	55
≥60%	10	69	9.3	13.4	54*	64*
Laminoplasty						
<60%	60	42	9.2	14.1	58	67
≥60%	6	66	9.4	11.0	14	34

ADF, anterior decompression and fusion; JOA, Japanese Orthopaedic Association.
*Surgical outcome of anterior decompression and fusion was superior to that of laminoplasty in patients with occupying ratio greater than 60% ($P < 0.03$).

When surgical outcomes were compared with respect to occupying ratio of OPLL, mean JOA score improved from 9.6 (range, 6–14) before surgery to 13.1 (range, 9–16.5) at final follow-up in the 17 patients with occupying ratio <60% (Table 4). Mean recovery rate of these patients was 49% (range, 0%–91%) at final follow-up and 55% (range, 28%–91%) at time of maximum recovery. Therefore, there was no significant difference in surgical outcome between ADF and laminoplasty for patients with occupying ratio <60%. On the other hand, in the 10 patients with occupying ratio ≥60%, mean JOA score improved from 9.3 (range, 4.5–12) before surgery to 13.4 (range, 10–16.5) at final follow-up. Mean recovery rate of these 10 patients was 54% (range, 33%–92%) at final follow-up and 64% (range, 33%–92%) at time of maximum recovery. In patients with occupying ratio ≥60%, surgical outcome of ADF was therefore superior to that of laminoplasty ($P < 0.03$) (Table 4). Pre- and postoperative data from patients with occupying ratio ≥60% are detailed in Table 5. Among 10 patients underwent ADF for massive ossification with occupying ratio ≥60%, pseudarthrosis was observed in Case 1, late deterioration was observed in Case 2 after a minor trauma, additional surgery due to inadequate decompression of ossification was needed in Case 5, and laminoplasty was required thereafter in Case 9 (Table 5). With the exception of 1 patient (Case 2) who experienced late neurologic deterioration and neuropathic pain in the left arm due to the traffic accident 99 months after ADF, no patients developed severe postoperative pain after ADF.

With regard to sagittal shape of ossification, surgical outcome of patients with hill-shaped ossification was sig-

Table 5. Characteristics of OPLL Patients With Occupying Ratio 60%

Case/Age (yr)/Sex	Follow-up (yr)	Occupying Ratio (%)	JOA Score		Recovery Rate (%)		Shape/Type of OPLL	Cervical Alignment		Others
			Preoperative	Final Follow-up	Maximum	Final Follow-up		Preoperative	Postoperative Change	
ADF										
1/56/M	9	60	9	13.5	81	56	Hill/mixed	Lordotic	No	Pseudarthrosis
2/48/M	10	62	12	13.5	90	30	Plateau/cont.	Kyphotic	Straight	Trauma
3/60/F	9	63	11	16.5	92	92	Hill/cont.	Lordotic	No	
4/51/M	6	64	11	14	58	50	Plateau/cont.	Lordotic	No	
5/52/F	6	67	10.5	14	54	54	Plateau/cont.	Lordotic	No	Reoperation
6/58/M	10	69	11	13	33	33	Plateau/cont.	Lordotic	No	
7/56/F	3	70	4.5	10	44	44	Hill/mixed	Lordotic	Straight	
8/74/F	5.5	75	9.5	15.5	80	80	Hill/circum.	Lordotic	No	
9/58/F	7	75	7.5	12	53	47	Plateau/cont.	Straight	Lordotic	Laminoplasty
10/41/M	6.5	80	7	12	50	50	Hill/mixed	Straight	No	
Laminoplasty										
1/63/M	5	60	11.5	12	27	9	Plateau/mixed	Straight	No	Axial pain
2/55/M	15	62	10	8.5	29	−21	Plateau/mixed	Straight	No	Arm pain
3/60/M	10	65	6	10	46	36	Hill/mixed	Lordotic	Straight	
4/57/M	9	67	12	12	20	0	Hill/cont.	Lordotic	Straight	
5/47/M	5	70	10	9	0	−14	Hill/cont.	Kyphotic	Kyphotic*	Arm pain
6/46/M	15	71	7	14.5	80	75	Plateau/mixed	Kyphotic	Kyphotic	

*In this case, preoperative kyphosis deteriorated.
ADF indicates anterior decompression and fusion; JOA, Japanese Orthopaedic Association; cont., continuous-type of OPLL; circum., circumscribed-type of OPLL.

Table 6. Surgical Outcomes of ADF and Laminoplasty With Respect to Sagittal Shape of Ossification

Sagittal Shape of Ossification	No.	Mean Occupying Ratio (%)	JOA Score		Recovery Rate (%)	
			Preoperative	Final Follow-up	Final Follow-up	Maximum
ADF						
Plateau	16	53	9.9	13.6	54	59
Hill	11	61	8.9	12.9	51	57
Laminoplasty						
Plateau	54	43	9.3	14.1	60	69
Hill	12	51	9.1	11.7*	30*	40*

*Surgical outcome of patients with hill-shaped ossification was significantly poorer than that of those with plateau-shaped ossification in laminoplasty ($P < 0.01$). ADF indicates anterior decompression and fusion; JOA, Japanese Orthopaedic Association.

nificantly poorer than that of those with plateau-shaped ossification among patients who underwent laminoplasty ($P < 0.01$), although there was no significant difference in surgical outcome among patients who underwent ADF (Table 6).

Surgery-Related Complications After ADF

With regard to surgical complications among 27 patients underwent ADF, neurologic deterioration was observed in 2 patients (7%). One patient demonstrated transient motor weakness in the left lower extremity immediately after surgery; this gradually recovered. The other patient (Case 5) demonstrated C5 segment palsy immediately after surgery, and additional anterior decompression was required because inadequate decompression of ossification was recognized on postoperative CT and MR images. Four patients (15%) developed complications related to grafted bone; graft extrusion occurred in 2 patients and pseudarthrosis in 2 patients. In these 4 patients, with graft-related complications, additional posterior stabilization with instrumentation was performed and resulted in solid fusion. Laminoplasty was added thereafter in 2 patients who exhibited late neurologic deterioration 8 months and 35 months after surgery, respectively. Ultimately, additional surgical interventions were required in 7 (26%) of 27 patients who underwent ADF, whereas additional cervical spine surgery was required for epidural hematoma immediately after laminoplasty in only 1 (2%) of 66 patients who underwent laminoplasty.

Case Reports

Case 7

This 56-year-old woman with OPLL occupying 70% of the spinal canal underwent an anterior floating procedure using fibular strut graft (Figure 1). Preoperative JOA score was 4.5, postoperative JOA score was 10, and recovery rate was 44%. Preoperative radiograph demonstrated mixed-type OPLL but did not clearly show a massive ossified lesion at the lower levels (Figure 1A). Preoperative reconstructed CT and T1-weighted MR imaging clearly demonstrated a massive hill-shaped ossification at C5–C6 (Figure 1B). T1-weighted MR imaging performed 3 months after surgery (Figure 1C) demonstrated sufficient anterior decompression of the spinal cord. Preoperative CT myelography demonstrated massive ossification compressing the spinal cord anteriorly at C5–C6. CT performed 1 week after surgery demonstrated 2 pieces of grafted fibula and the line of residual ossification behind the grafted fibula (Figure 1D). CT image taken 7 weeks after surgery (Figure 1D) and radiograph images taken 2 years after surgery (Figure 1E) demonstrated anterior shift of the residual ossification behind the grafted fibula.

Case 8

This 74-year-old woman with OPLL occupying 75% of the spinal canal underwent an anterior floating procedure using a fibular strut graft (Figure 2). Preoperative JOA score was 9.5, postoperative JOA score was 15.5, and recovery rate was 80%. Preoperative lateral radiograph demonstrated circumscribed-type, hill-shaped OPLL (Figure 2A). Preoperative T2-weighted MR imaging and CT myelography (Figure 2A-B) demonstrated a massive ossification compressing the spinal cord anteriorly. CT image taken 1 week after surgery demonstrated grafted fibula and a line of residual ossification behind the grafted fibula. CT image taken 5 weeks after surgery (Figure 2B) and lateral radiograph images taken 4 years after surgery (Figure 2C) demonstrated anterior shift of the residual ossification behind the grafted fibula.

Discussion

Surgery-Related Considerations

Some controversy exists over the appropriate method of surgery for cervical myelopathy caused by OPLL. In the present study, surgical outcome of ADF was significantly better than that of laminoplasty in patients with occupying ratio ≥60%. In addition to occupying ratio of OPLL, hill-shaped ossification was found to be predictive of poorer outcome after laminoplasty.[1] In the present study, neither occupying ratio of OPLL, nor sagittal shape of ossification, nor cervical alignment were found to be related to surgical outcome of ADF.

The authors have concluded that laminoplasty is effective and safe for most patients with the following characteristics[1,8]: 1) occupying ratio of OPLL <60%; and 2) plateau-shaped ossification. However, one limitation of laminoplasty is that OPLL remains ventral to the spinal cord even after surgery because the dis-

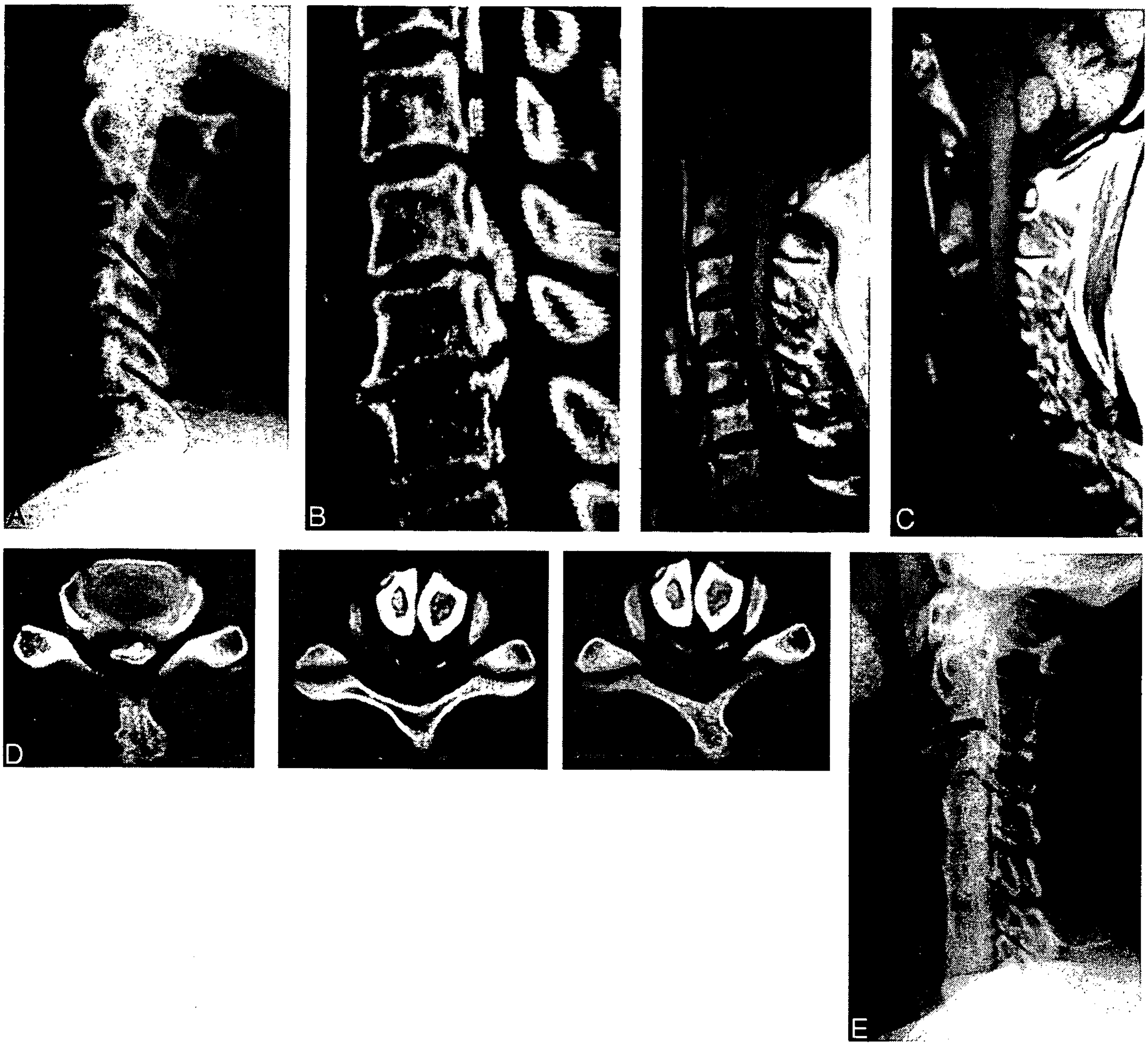

Figure 1. Case 7. **A**, Preoperative lateral radiograph image demonstrating mixed-type OPLL but not clearly showing a massive ossified lesion at C5–C6. **B**, CT reconstruction image (left), T1-weighted MR image (right) demonstrating a massive ossification at C5–C6. **C**, T1-weighted MR image taken 3 months after surgery demonstrating sufficient anterior decompression of the spinal cord. **D**, Preoperative and postoperative CT. Preoperative CT myelogram (left) demonstrating severe compression of the spinal cord with a massive OPLL at C5–C6. CT image taken 1 week after (middle) surgery demonstrating 2 pieces of grafted fibula and the line of residual ossification behind the grafted fibula. CT image taken 7 weeks after surgery (right) demonstrating anterior shift of the residual ossification behind the grafted fibula. **E**, Radiograph image taken 2 years after surgery demonstrating anterior shift of the residual ossification.

order generally continues to progress. Incidence of progression of OPLL after laminoplasty has been reported at 70% to 73%; this risk is reportedly greatest in younger patients (<59 years of age).[8–10] On the other hand, incidence of postoperative progression after the anterior procedure has been found to range from 36% to 64%.[7,11] Since ossification remains ventral to the spinal cord permanently and can progress after surgery, the authors consider that laminoplasty has limitations in terms of maintaining decompression of the spinal cord if patients would have hill-shaped massive ossification or cervical alignment would deteriorate after surgery.

Surgery-Related Complications

Regarding surgery-related complications, several authors have noted a high incidence of complications in ADF.[12,13] Shinomiya *et al* reported that the rate of surgical complications, including CSF leakage and dislocation or pseudarthrosis of the bone graft, was 23% and that reoperation was required in 12.5% of cases.[12] Similarly, Epstein reported that 15% of patients undergoing anterior surgery for cervical OPLL required reoperation due to pseudarthrosis.[14]

Several surgeons have attempted to remove ossified lesions using the anterior approach, however, results of anterior procedures have varied due to insufficient de-

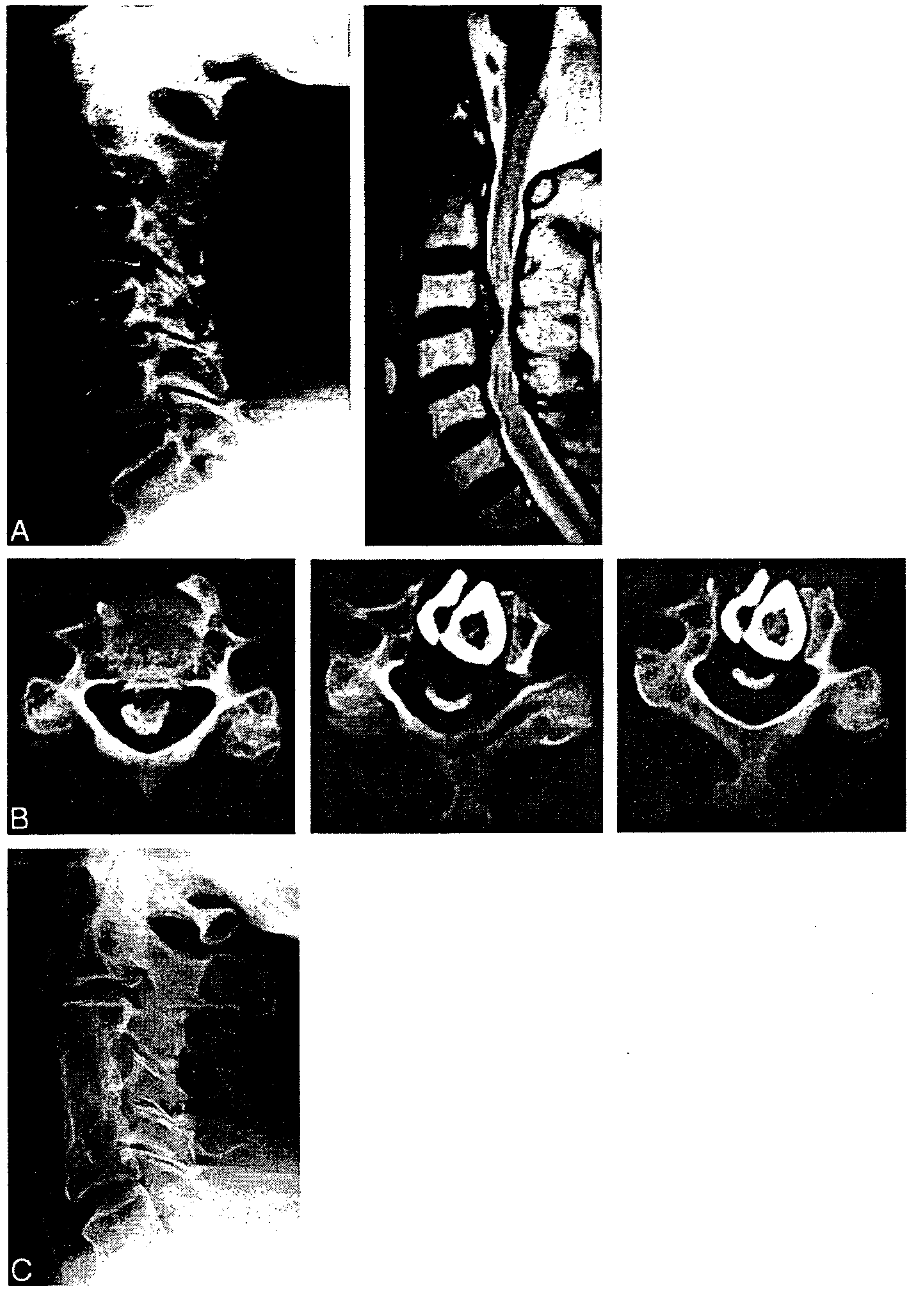

Figure 2. Case 8. **A**, Preoperative lateral radiograph image (left) and T2-weighted MR image (right) demonstrating circumscribed-type OPLL at C3–C4. **B**, Preoperative and postoperative CT. Preoperative CT myelogram (left) demonstrating severe compression of the spinal cord with a massive OPLL at C3–C4. CT image at 1 week (middle), CT image at 5 weeks (right) demonstrating anterior shift of the residual ossification behind the grafted fibula. **C**, Lateral radiograph image at 4 years after anterior floating procedure.

compression resulting from ossification of the dura or massive bleeding from the epidural space. The authors have selected the anterior floating method in which the spinal cord is decompressed without total resection of the ossified lesion.[5] This method has made anterior decompression surgery for cervical myelopathy caused by OPLL safer and more reliable. The advantages of this procedure include gradual decompression without extirpation but with an anterior shift of the OPLL to avoid dural tears caused by ossification of the dura, and lower risk of injury to neural tissues.

In the present study of 27 consecutive patients who underwent ADF, graft complications occurred in 15% and additional surgical intervention was required in 26%. Postoperative deterioration of cervical alignment from lordotic to straight was observed in 3 patients (11%), whereas improvement of alignment was observed in 6 patients (22%). On the other hand, complications after laminoplasty included persistent neuropathic arm pain in 8% and postoperative deterioration of cervical alignment to kyphotic in 6%.[1] Deterioration of cervical alignment was related to poor surgical outcome for laminoplasty,[1] but not for the anterior procedure: mean recovery rate of 3 patients with postoperative change in cervical alignment after ADF was 54% (range, 44%–82%). Although ADF was not associated with any persistent postoperative problem, laminoplasty was superior in terms of surgery-related complications requiring additional surgeries.

■ Conclusion

ADF is technically demanding and is associated with a higher incidence of surgery-related complications. However, if surgeons seek to optimize neurologic outcome, ADF is preferable to laminoplasty for patients with occupying ratio of OPLL ≥60% and/or hill-shaped ossification. Surgical treatment for cervical myelopathy caused by OPLL should be chosen based on the following considerations: occupying ratio of OPLL, type and shape of ossification, sagittal curvature of the cervical spine, dynamic instability between the interrupted ossified lesions, patient age, and skill of the surgeon.

■ Key Points

- We retrospectively studied patients with cervical myelopathy due to OPLL to compare surgical outcome of anterior decompression and fusion with that of laminoplasty.
- In patients with occupying ratio ≥60%, anterior decompression and fusion yielded a better neurologic outcome than laminoplasty.
- Although anterior decompression and fusion is technically demanding and has a higher incidence of surgery-related complications, it is preferable to laminoplasty for patients with occupying ratio of OPLL ≥60%.

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* 2007;32:647–53.
2. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine* 1983;8:693–9.
3. Itoh T, Tsuji H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine* 1985;10:729–36.
4. Iwasaki M, Yonenobu K. Ossification of the posterior longitudinal ligament. In: *The Spine*, 5th ed. Philadelphia: Elsevier, 2006:896–912.
5. Yamaura I, Kurosa Y, Matuoka T, et al. Anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Clin Orthop* 1999;359:27–34.
6. Yonenobu K, Wada E, Ono K. Part B: Laminoplasty. In: Cervical Spine Research Society Editorial Committee, ed. *The Cervical Spine*, 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2005:1057–71.
7. Matsuoka T, Yamaura I, Kurosa Y, et al. Long-term results of the anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Spine* 2001;26:241–8.
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. Chiba K, Yamamoto I, Hirabayashi H, et al. Multicenter study investigating the postoperative progression of ossification of the posterior longitudinal ligament in the cervical spine: a new computer-assisted measurement. *J Neurosurg Spine* 2005;3:17–23.
10. Kawaguchi Y, Kanamori M, Ishihara H, et al. Progression of ossification of the posterior longitudinal ligament following en bloc cervical laminoplasty. *J Bone Joint Surg Am* 2001;83:1798–802.
11. Tomita T, Harata S, Ueyama K, et al. Radiological follow-up evaluation of the progression of ossification of posterior longitudinal ligament: the operative influence on the progression of ossification. *Rinsho Seikei* 1999;34:167–72.
12. Shinomiya K, Okamoto A, Kamikozuru M, et al. An analysis of failures in primary cervical anterior spinal cord decompression and fusion. *J Spinal Disord* 1993;6:277–88.
13. Yonenobu K, Hosono N, Iwasaki M, et al. Neurologic complications of surgery for cervical compression myelopathy. *Spine* 1991;16:1277–82.
14. Epstein N. The surgical management of ossification of the posterior longitudinal ligament in 51 patients. *J Spinal Disord* 1993;6:432–54.

論述

Myelopathy handの病態*

動画記録15秒テストを用いた観察

細野　昇*1)　坂浦　博伸*2)　向井　克容*2)
藤井隆太朗*2)　吉川　秀樹*2)　海渡　貴司*1)
冨士　武史*1)

Myelopathy Hand. Observation in Video-recorded Animation

Noboru Hosono*1), Hironobu Sakaura*2), Yoshihiro Mukai*2), Ryutaro Fujii*2), Hideki Yoshikawa*2), Takashi Kaito*1), Takeshi Fuji*1)

臨整外 42：115～122，2007

Key words：trick motion(トリックモーション), uncoordinated finger motion(指のばらつき), quantitative assessment(定量評価)

頚髄症患者と健常者を対象に最大努力での手指握り開き運動を15秒間動画記録して比較観察した．手指握り開きに伴って極端に手関節が背掌屈するtrick motionは健常群(4.8%)に比して頚髄症(11.7%)で有意に多かったが，手指をより完全に伸展させようとする意識が強い場合に生じる随意運動であると推察された．指のばらつき(uncoordinated finger motion)も健常群(7.1%)に比して頚髄症(15.6%)で有意に多く，多くは尺側遅れのパターンであった．指のばらつきは頚髄症に伴う麻痺の形態を示しているものと推察されたが，脊髄圧迫高位で説明することはできなかった．

We validated a method of quantifying motor paralysis of the fingers in cervical myelopathy by means of a 15-second test, in which the subject is asked to make a fist and release it as rapidly as possible for 15 seconds. Movies taken with a digital camera were slowed to half speed and independently assessed by three experienced spine surgeons in a blinded manner. Trick motion, i. e., exaggerated wrist motion synchronized with finger motion, was observed significantly more frequently in the myelopathy patients(11.7%) than in healthy controls(4.8%). Although trick motion has been considered a symptom of myelopathy, several findings suggested that it is a voluntary motion, not a neurological sign. Uncoordinated finger motion was observed significantly more frequently in the myelopathy patients(16.1%) than in the healthy controls(7.1%). Ulnar delay was the most frequent pattern of uncoordinated finger motion and uncoordinated finger motion seemed to be associated with asymmetrical distribution of the spinal cord lesions.

Myelopathy handは小野ら[6,7,8]によって提唱された頚髄症に特徴的な手指麻痺の形態である．手指の握り開きが素早くできないことは10秒テストの回数減少として現れ，尺側指の内転あるいはMP関節伸展ができないことはFES(finger escape sign)として評価されている．頚髄症における手指麻痺はまず小指側の掌側骨間筋に，ついで尺側の総指伸筋に出現するとされているが[6]，すべての頚髄症に共通の麻痺進行が認められるかどうかは明らかでない．従来，10秒テストにおいて

* 2006.9.25 受稿
*1) 大阪厚生年金病院整形外科〔〒553-0003 大阪市福島区福島4-2-78〕Department of Orthopedic Surgery, Osaka Kosei-nenkin Hospital
*2) 大阪大学大学院器官制御外科学(整形外科)　Department of Orthopedics, Osaka University Graduate School of Medicine

は10秒間に握り開きできる回数のみが評価の対象であったが，握り開きの態様にはかなりの多様性があることを日常臨床において経験する．手指握り開きに伴って手関節が不自然に背掌屈するtrick motionはその1つであるし，必ずしもすべての手指が協調して動くわけではないことも認識されている．それでは，こういった手指握り開きに伴って認められる運動の特徴は頚髄症に特異的な現象であり，健常者には認められないのであろうか．頚髄症に特徴的とすればどの程度の頻度で出現するのか，またその原因は何か．これまでこれらの点にアプローチした研究は皆無といってよい．

われわれは既に手指の握り開きを15秒間動画記録して客観的に評価することで回数減少や速度変化に頚髄症に特有の現象があることを報告した(動画記録15秒テスト)[4]．動画記録することによって，より客観的で再現性の高い評価が可能になる．今回は上記の疑問に答えるべく同じ症例を用いて手指や手関節の動きの特徴について評価したので報告する．

Ⅱ 対象と方法

圧迫性頚髄症で手術を施行した30人(男20人，女10人，頚椎症性脊髄症24人，後縦靱帯骨化症6人，平均年齢59.5±10.6歳)を対照として人工股・膝関節置換術目的で入院中の42人(男19人，女23人，同61.0±7.52歳，頚髄症群と年齢・性比に有意差なし)に動画記録15秒テストの測定を行った[4]．対照症例については頚椎疾患の既往がなく，手のしびれやその他の頚椎疾患を疑わせる症候のないこと，リウマチなど関節を侵す疾患，脳性麻痺など手指運動に変化を来しうる全身疾患のないことを確認し，倫理委員会の承認のもと文書による承諾を得てから測定した．健常群については入院時に1回，頚髄症症例については術前日と術後2週間目に測定を行った．測定方法については既に報告しているとおりで，合図と同時に可能な限り手指を早く，ただし中途半端にならないよう最後までしっかり握ってしっかり開くことを指示しておき，これを外側前方よりデジタルカメラ(DSC-F505 V，SONY，Tokyo)の動画モード(MPEG1形式)で左右別々に15秒間記録した．撮影に際しては患者名，撮影時期を特定できる情報が写らないよう工夫した．

記録された動画ファイルはソフト〔パワーディレクター，(株)ソースネクスト，東京〕を用いて初めから5秒ずつ取り出し，さらに2倍にスローモーション化した(以下5秒ファイルと呼ぶ)．0〜5秒を第1相，5〜10秒を第2相，10〜15秒を第3相とした．5秒ファイルの総数は健常例で3(第1，2，3相)×2(左右手)×1(入院時記録1回)×42(症例総数)＝252，頚髄症症例で3×2×2(頚椎手術前日，術後2週)×30(患者総数)＝360となった．乱数表を用いてこれら252＋360＝612の5秒ファイルに無作為に番号を付けた．さらにこの番号順に5秒ファイルを並べなおしてCDにコピーしたものを3枚作った．ここまでの処理を1人の医師が行い，これとは別の整形外科医A, B, C(大学病院で脊椎外科専門医として3年以上の経験を持つ3人．うち2人は脊椎脊髄病学会指導医，1人は日整会認定医)がこのCDを持ち帰って評価した．つまり3人の評価者は5秒ファイルをブラインドで独立して評価したことになる．

上記のファイルをもとに握り開きの回数と手指運動の特徴について評価した．握り開きの回数は0.5回単位(手指が開いた状態から握った状態までの動きを0.5回，握った状態から開いた状態までの動きも0.5回)で数えた．各5秒ファイルの回数をNi(第1相の握り開きの回数をN1，第2相をN2，第3相をN3)とし，各々の値は評価者A，B，Cの評価の相加平均とした．15秒間の握り開きの総回数Nはこれらの和($N=\Sigma Ni=N1+N2+N3$)として求めた．この方法による回数測定の信頼性が極めて高いことは，評価者間の級内相関係数(Intraclass Correlation Coefficient)の平均値が0.989であることで既に示した[4]．

手指の屈曲に際して手関節が極端に背屈し，手指の伸展に同期して手関節が極端に掌屈する現象を手関節のtrick motionと呼び頚髄症に特徴的な現象とされている[9,10]．今回の評価にあたってはその程度を無(Grade 0)，軽度(Grade 1；probable)，明らか(Grade 2；definite)に分けて記録した．3人