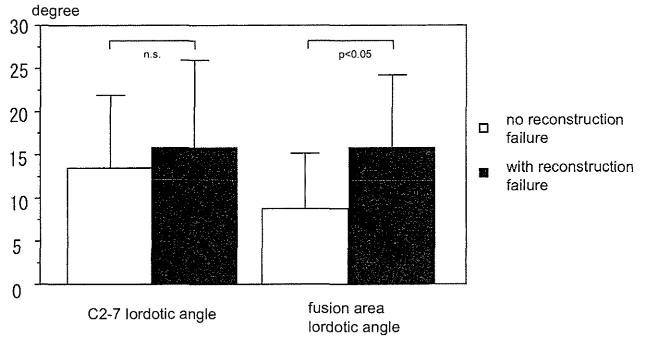

Figure 1. The postoperative C2–C7 lordotic angles and fusion area lordotic angles tended to be larger in patients who experienced reconstruction failure than they were in patients who did not experience reconstruction failure. The postoperative fusion area lordotic angles were statistically significant ($P < 0.05$).

(Figure 1). The C7 horizontal angle did not differ between these 2 groups. We did not observe any statistically significant differences between the groups with regard to changes in the C2–C7 lordotic angle or the fusion area lordotic angle (Table 4).

TABLE 4. Radiological Measurements (Degrees)

	Reconstruction Failures (6)	No Complication (24)	*P*
C2–C7 lordotic angle	13.5 ± 17.1	13.5 ± 10.9	n.s
Fused area lordotic angle	9.6 ± 13.1	7.4 ± 9.1	n.s
PO C2–C7 lordotic angle	15.6 ± 10.2	13.3 ± 8.5	n.s
PO fused area lordotic angle	15.6 ± 8.4	8.6 ± 6.4	$P<0.05$
C7 horizontal angle	22.7 ± 7.0	22.0 ± 6.8	n.s.
Change in C2–C7 lordotic angle	2.1 ± 11.8	0.23 ± 7.4	n.s.
Change in fused area lordotic angle	3.1 ± 9.0	0.9 ± 8.9	n.s.

DISCUSSION

Anterior cervical decompression and fusion is a valuable method for treating patients with cervical myelopathy caused by spondylosis or OPLL. However, among this procedure, a multilevel corpectomy and reconstruction are frequently accompanied by complications like plate dislodgement and graft migration.[5,6,13] Figure 2 shows a typical case of graft subsidence and migration with screw pullout that occurred in the early postoperative period. Figure 3 shows images from another patient who also experienced early reconstruction failure. The original cervical curve of this patient was slightly lordotic, and we tried to change the alignment of the cervical spine more lordotic to decompress the spinal cord. However, screw pullout and fracture of C7 vertebra occurred during the early postoperative period. Reformatted CT views showed that the C2–C7 lordotic angle had increased after surgery and that C7 fracture had occurred.

In this study, 6 of 30 (20%) patients who underwent mutlilevel corpectomy and reconstruction without the use of a halo

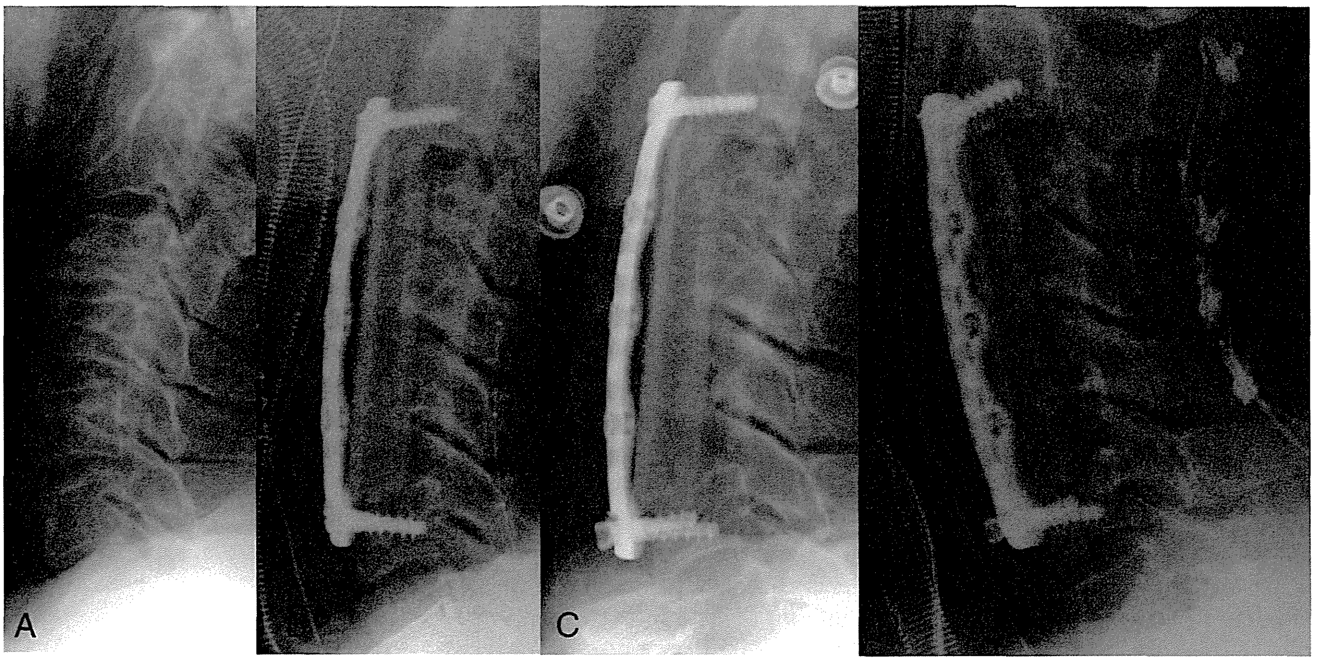

Figure 2. Preoperative radiograph of a 61-year-old man shows mixed-type OPLL with a fusion area lordotic angle of 25.8° (**A**). C2–C6 fusion was performed using an autologous fibular graft and a rotationally dynamic plate. Note the retention of the C6 endplate just after the operation (**B**). Graft subsidence and migration with screw pullout occurred 3 weeks after surgery (**C**). After in situ spinous process wiring, the degree of the patient's cervical lordosis decreased. However, solid fusion was observed (**D**).

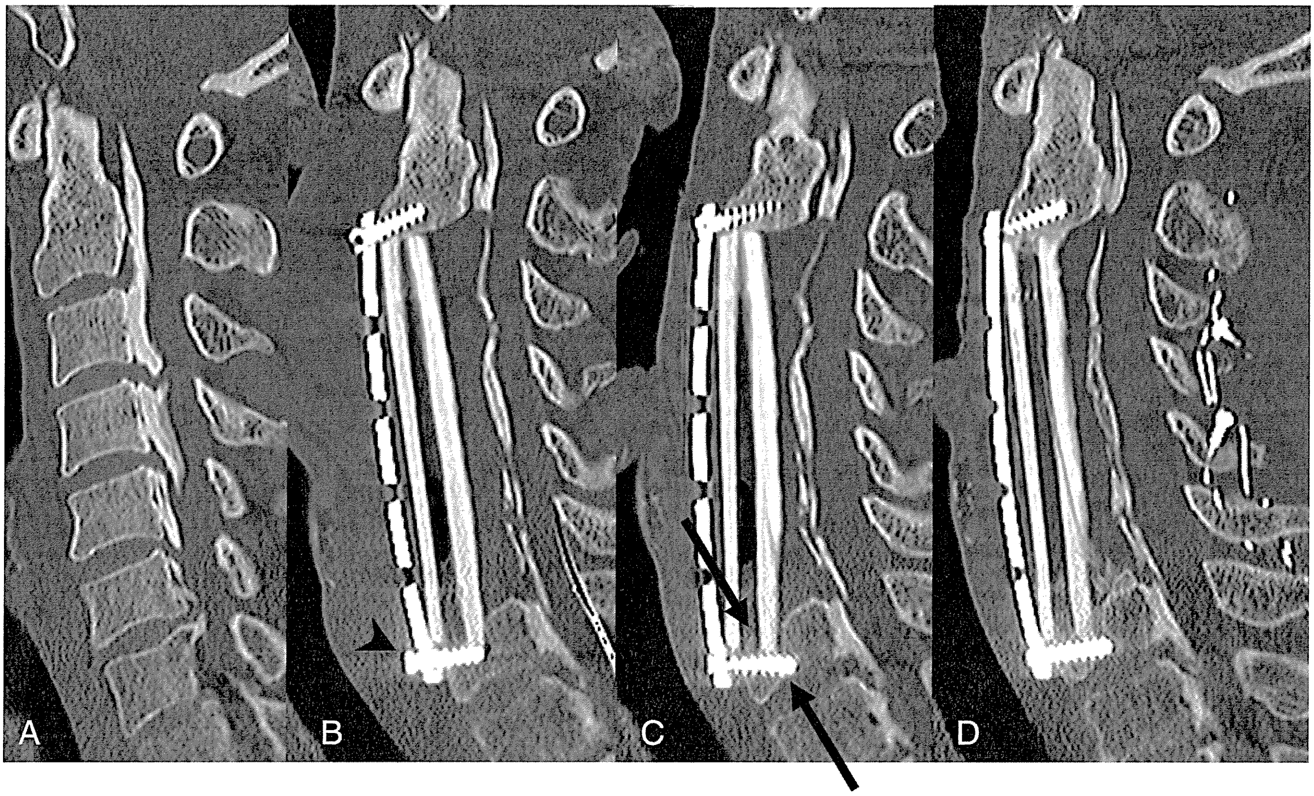

Figure 3. Preoperative radiograph of a 51-year-old man shows mixed-type OPLL with a slight lordosis (**A**). Postoperative scan taken 3 weeks after the surgery revealed screw pullout (arrow head) (**B**). Note cervical lordosis seemed to increase after the surgery. The screw was retightened, but graft subsidence and C7 fracture occurred (arrows) (**C**). After *in situ* spinous process wiring, the degree of the patient's cervical lordosis decreased. However, solid fusion was observed (**D**).

brace experienced reconstruction failures. The postoperative fusion area lordotic angle of the patients who experienced reconstruction failure was significantly larger than that of the patients who did not experience reconstruction failure (Figure 1). As seen in the scatter graph (Figure 4), 3 of the 6 patients who experienced early reconstruction failure exhibited postoperative fusion area lordotic angles of >15°. Although it is not easy to determine a cut-off with regard to the fusion area lordotic angle at which it is no longer advisable to perform this procedure, the risk of reconstruction failure may increase in patients with postoperative fusion area lordotic angles of >15°. In our study, this value (15°) was equal to the mean postoperative fusion area lordotic angle of the patients who did not experience reconstruction failure plus 1 standard deviation. Hyperlordosis of the cervical spine yields to high shear stress at the bottom of the fused segment, which can lead to anterior slippage of the construct. Herrmann and Geisler has pointed out that both device failure and pseudarthrosis have been observed with greater frequency at the inferior end of long-segment constructs than the top of the fused segment.[13,14] They speculated that the long lever arm of the anterior plate transmitted unacceptably high forces to the inferior level of the fusion area. They observed that shear stress increased at the bottom of the fusion area, especially in patients with a hyperlordotic alignment and continuing micromotion of their cervical spines, both of which can lead to reconstruction failure. These findings were similar to our results.

Additional factors that affected the 3 patients who experienced early reconstruction failure but did not have excessive lordosis of their cervical spines were not elicited in this study. We postulate that overdistraction during grafting could have been one of the causes of recon struction failure in these patients. We distracted the neck carefully while the graft was being inserted, but the distraction force was not controlled precisely.

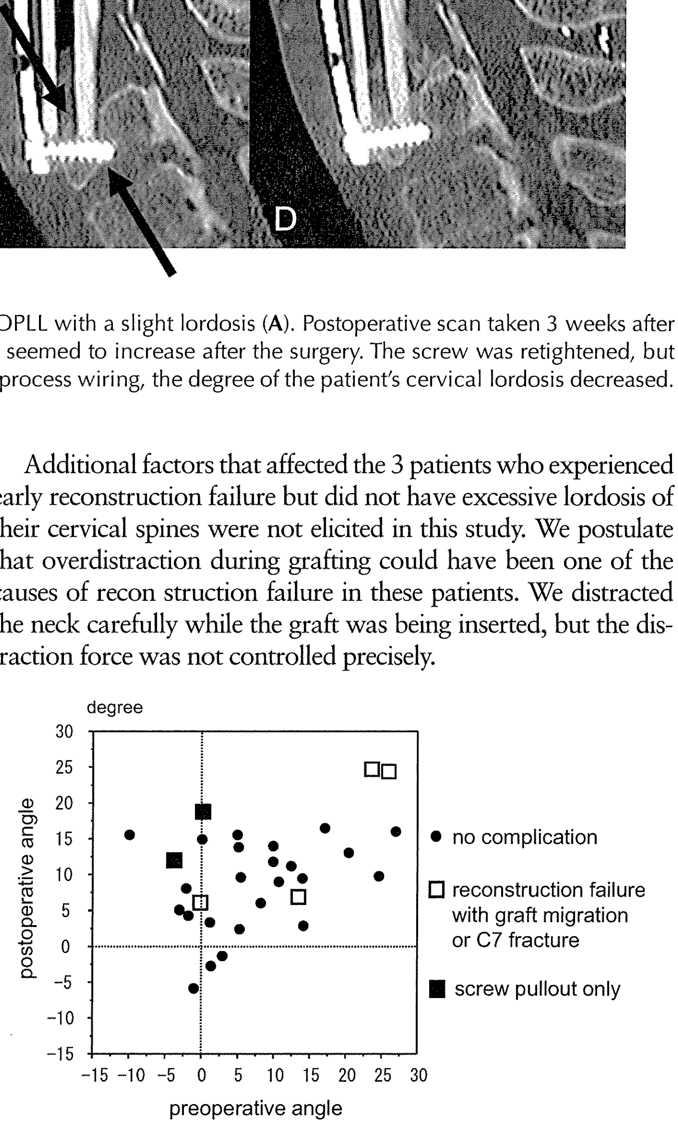

Figure 4. The preoperative and postoperative fusion area lordotic angles of the included patients have been plotted. Of the 6 patients, the 4 who experienced early reconstruction failure exhibited postoperative fusion area lordotic angles of >10°. Additional factors that affected the remaining 2 patients without excessive lordosis of their cervical spines were not elicited in the current study.

The following factors were not associated with reconstruction failure: age, gender, preservation of the vertebral endplate, screw type, the occurrence of postoperative graft subsidence within 1 week of surgery, and the use of intermediate screws for fibular grafting. However, preservation of the vertebral endplate is thought to be important in patients with osteoporosis. In a biomechanical study, Lim *et al* confirmed that load to failure tended to decrease with incremental removal of the endplate and the risk of failure tended to increase.[15]

When the alignment of the cervical spine is lordotic, laminoplasty is normally performed. However, the clinical outcomes of patients with massive OPLL or with a kyphotic cervical alignment treated by anterior cervical decompression and fusion have been previously shown to be better than those of patients treated with posterior decompression.[16] Thus, some patients with cervical myelopathy respond well to multilevel corpectomy and reconstruction.[17] Cervical lordosis is also normally thought to be important for preventing long-term fusionrelated problems such as adjacent segment degeneration. However, we hypothesized that postoperative cervical hyperlordosis may adversely affect graft stability in the early postoperative period.

When graft migration is discovered, posterior wiring can provide solid union. When the graft dislodges completely, reinforcement by screw fixation is needed. Because some authors recommend simultaneous anterior and posterior fixation for patients with hyperlordotic cervical spine alignments,[18,19] a combined surgical plan should be used to decrease the rate of early reconstruc tion failure in the limited number of patients this type of alignment.

The limitations of this study include its retrospective nature and the fact that only a small number of cases are included. A prospective study is, therefore, needed to further examine this paradoxical hypothesis that we generated based on the results of our study.

➢ Key Points

- ❑ A retrospective study was conducted to investigate risk factors for early reconstruction failure of multilevel cervical corpectomy and reconstruction with dynamic plate fixation.
- ❑ Six of 30 cases experienced reconstruction failures, including graft migration at the bottom of the graft in 2 cases, fracture of the C7 vertebral body in 2 cases, and pullout of a screw in 2 cases.
- ❑ On radiologic measurement, the fusion area lordotic angle after surgery in patients with reconstruction failures was significantly larger than that of the patients with no complication.

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Middle-Term Results of a Prospective Comparative Study of Anterior Decompression With Fusion and Posterior Decompression With Laminoplasty for the Treatment of Cervical Spondylotic Myelopathy

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Study Design. A clinical prospective study.

Objective. To assess whether clinical and radiologic outcomes differ between anterior decompression and fusion (ADF) and laminoplasty (LAMP) in the treatment of cervical spondylotic myelopathy (CSM).

Summary of Background Data. No reports to date have accurately and prospectively compared middle-term clinical outcomes after anterior and posterior decompression for CSM.

Methods. We prospectively performed LAMP (n = 50) in 1996, 1998, 2000, and 2002, and ADF (n = 45) in 1997, 1999, 2001, and 2003. The Japanese Orthopedic Association (JOA) score, recovery rate, and each item of the JOA score were evaluated. For radiographic evaluation, the lordotic angle and range of motion (ROM) at C2–C7 and residual anterior compression to the spinal cord (ACS) after LAMP on magnetic resonance imaging were investigated.

Results. Eighty-six patients (ADF n = 39; LAMP n = 47) could be followed for more than 5 years (follow-up rate 91.5%). Demographics were similar between the two groups. The mean JOA score and recovery rate in the ADF group were superior to those in the LAMP group from 2-year data collected after surgery. However, LAMP was safer and less invasive than ADF with respect to physical status and complications in the perioperative period. For individual items of the JOA score, the ADF group showed significantly more improvement of upper extremity motor function than the LAMP group ($P < 0.05$). There was a significant difference in maintenance of the lordotic angle in the ADF group compared with the LAMP group despite no difference in ROM.

The LAMP group was divided into two subgroups: (1) LAMP(+) (n = 16) comprising patients who had ACS at 2 years after surgery, and (2) LAMP(–) (n = 31) comprising patients without ACS. Recovery rate differed significantly between the LAMP(+) and LAMP(−) groups despite there being no difference between the LAMP(−) and ADF groups.

Conclusion. The recovery rate of the JOA score in the ADF group was better than that in the LAMP group. The clinical outcomes after LAMP could be influenced by ACS.

Key words: prospective comparative study, cervical spondylotic myelopathy, anterior decompression and fusion, laminoplasty, surgical approach, postoperative anterior compression. **Spine 2011;36:1940–1947**

There has been considerable debate regarding the best procedure for the treatment of patients with cervical spondylotic myelopathy (CSM). Several authors[1,2] have reported that both anterior and posterior procedures are generally identical with respect to neurologic improvement. However, it has never been ascertained whether there are any differences between the anterior and posterior procedures because the middle-term outcomes of prospective study has not been reported to date. Therefore, we designed a prospective study to evaluate whether there are any differences between anterior decompression and fusion (ADF) and laminoplasty (LAMP).

MATERIALS AND METHODS

Patients and Methods

This study is a prospective, comparative, single-institute trial of two surgical procedures for the treatment of CSM. The study was carried out with the approval of the Institutional Ethics Committee of Tokyo Medical and Dental University. Inclusion criteria were patients with cervical myelopathy caused by spondylosis. Patients with myelopathy caused by cervical disc herniation and ossification of posterior longitudinal ligament (OPLL), those with radiculopathy, and

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patients with a history of previous cervical spine surgery or injury were excluded. At the beginning of this study, we did not decide to exclude patients with excessive cervical kyphosis because it was unclear whether the cervical kyphosis was in fact related to postoperative outcome. However, we experienced no patient with preoperative excessive kyphosis above 15°. The spinal cord level responsible was diagnosed by spinal cord evoked potential[3] recorded from an epidural electrode and radiographic findings before surgery in all patients.

Choice of Surgical Procedure

After sufficient informed consent was obtained from 95 consecutive patients, every alternate year, 45 patients were enrolled in the ADF group in 1997, 1999, 2001, and 2003, and 50 patients were enrolled in the LAMP group in 1996, 1998, 2000, and 2002.

Operative Technique

Anterior Decompression with Fusion

Corpectomy with a strut graft[4,5] was performed by removing discs and vertebral bodies. Operative segments were selected on the basis of the findings of preoperative radiographic studies. A strut graft from the iliac crest[4,5] was inserted for less than two levels, and fibula strut grafts[6] for more than three levels of fixation. A neck collar was used after operation until bony union was confirmed. Plate and screws fixation was used in all cases.

Laminoplasty

Expansive laminoplasty, as described by Miyazaki and Kirita,[7] was performed. In this procedure, briefly, we detached the paravertebral muscles from the spinous processes on both the right and left sides and removed the processes at C4–C6. The laminae were split at the center and bilateral gutters were made using a high-speed air-burr drill. The bilateral laminae were kept open by anchor-sutures to the deep fascia, and small bone chips made from the spinous processes were inserted into the gap between the laminae and the facets on the hinge side. Patients were instructed to wear a neck collar for 3 to 4 weeks.

The senior author (K.S.) supervised four surgeons (A.O., M.T., S.K., and T.K.) who performed all procedures throughout this study: K.S. has more than 20 years of experience and has performed more than 200 surgeries for each procedure.

EVALUATION

Clinical Outcomes

The Japanese Orthopedic Association (JOA) scoring system was used for the evaluation of cervical myelopathy before and after surgery (Table 1). The recovery rate was calculated using Hirabayashi *et al*'s method[8] to compare preoperative and postoperative JOA scores. Each item of the JOA score was also investigated before surgery and after surgery, and the recovery rate of each of the seven functions was calculated as follows: recovery rate (%) = (postoperative individual score − preoperative individual score) × 100/(individual full

TABLE 1. Scoring System for Cervical Myelopathy (C-JOA score)

Upper Extremity Motor Function
0: Unable to feed oneself with any tableware including chopsticks, spoon, or fork, and/or unable to fasten buttons of any size
1: Can manage to feed oneself with spoon and/or fork but not chopsticks
2: Either chopsticks feeding or writing is possible but not practical, and/or large buttons can be fastened
3: Either chopsticks feeding or writing is clumsy but practical, and/or cuff buttons can be fastened
4: Normal
Lower extremity motor function
0: Unable to stand up and walk by any means
0.5: Able to stand up but unable to walk
1: Unable to walk without a cane or other support on level ground
1.5: Able to walk without support but with a clumsy gait
2: Walks independently on level ground but needs support on stairs
2.5: Walks independently when going upstairs, but needs support when going downstairs
3: Capable of walking fast but clumsily
4: Normal
Sensory function
A. Upper extremity
0: Complete loss of touch and pain sensation
0.5: 50% or below of normal sensation and/or severe pain or numbness
1: More than 60% of normal sensation and/or moderate pain or numbness
1.5: Subjective numbness of a slight degree without any objective sensory deficit
2: Normal
B. Upper extremity
Same as A
C. Trunk
Same as A
Bladder function
0: Urinary retention and/or incontinence
1: Sensory of retention, dribbling, thin stream and/or incomplete continence
2: Urinary retardation and/or pollakiuria
3: Normal

Total score for normal = (4 + 4 + 2 + 2 + 2 + 3) = 17.

Recovery rate = (postoperative score-preoperative score) × 100/ (17-preoperative score).

score − preoperative individual score). The occurrence of surgical complications, blood loss, and operation time were also investigated.

Radiologic Evaluation

Cervical sagittal alignment (C2–C7 lordotic angle) was measured by tangential lines on the posterior edge of C2 and C7 bodies on lateral radiograph in a neutral position. The range of motion (ROM) of the cervical spine was calculated on radiograph in flexion and extension before surgery and at the times of annual visit. Percentage of ROM was defined as (postoperative 5-year/preoperative ROM) × 100. Kyphotic change after surgery was determined as the difference between the preoperative and 5-year-after surgery C2–C7 angle.

Furthermore, the residual anterior compression to spinal cord after LAMP (ACS) at the responsible level was also evaluated on magnetic resonance imaging (MRI). The criteria[9] for defining significant ACS were as follows: (1) Effacement of anterior CSF buffer on the T2 sagittal and axial image; (2) Evidence of anterior compression of cord substance on the T1 sagittal and axial images. Whether the ACS would influence the clinical outcomes in the LAMP group was investigated. The radiographic analysis was performed by three independent spine surgeons who were blinded to the clinical status of the patients.

Statistical Analysis

The Mann-Whitney *U* test was used in the statistical analysis. All *P* values < 0.05 were considered significant.

RESULTS

Eighty-six (91.5%, 63 males; 23 females) of the 95 patients completed 5-year follow-up. Data for every annual follow-up were available for these 86 patients. Nine patients could not be tracked and so data are missing for these patients. The mean age was 59.2 years (range, 39–85 years) in the ADF group and 61.2 years (range, 42–86 years) in the LAMP group. The average duration of symptoms before surgery was 11.8 months (range, 0.5–48 months) for the ADF group and 10 months (range, 0.75–36 months) for the LAMP group. The average anterior-posterior canal diameter was similar between the two groups (ADF group, 12.6 mm; LAMP group, 12.8 mm). The average JOA score before surgery was 9.9 points in the ADF group and 9.7 points in the LAMP group. The average fused segment was 2.18 interspaces in the ADF group; posterior decompression was performed at C3–C7 in 27 patients and at C3–C6 in 20 patients in the LAMP group. There was no significant difference in demographic data between the two groups (Table 2).

TABLE 2. Demographic Data of the Patients With CSM

	ADF group (n = 39)	LAMP group (n = 47)	*P*
Year	1997, 99, 2001, 03	1996, 98, 2000, 02	—
Age (y-o)	59.2 ± 10.7	61.2 ± 10.1	ND
Male (%)	69.2%	76.6%	ND
Preoperative JOA score	9.9 ± 3.1	9.7 ± 2.9	ND
Duration of symptom	11.8 ± 7.6	10.0 ± 7.3	ND
Canal diameter	12.6 ± 0.7	12.8 ± 0.9	ND
Segments	2.18 ± 0.83	C3–C7: 27 cases C3–C6: 20 cases	—

Mean ± SD.

ND indicates not significant difference; ADF, anterior decompression and fusion; LAMP, laminoplasty; CSM cervical spondylotic myelopathy; JOA, Japanese Orthopedic Association.

Clinical Results

No patients showed deterioration after surgery in either group. However, there were significant differences in the recovery rate of the JOA score from 2 years after surgery (Table 3, Figure 1A, B). The recovery rate of each item of the JOA score were as follows: upper extremity motor function (82.0% *vs.* 62.3%), lower extremity motor function (75.8% *vs.* 63.2%), sensation of upper extremity (52.0% *vs.* 44.0%), sensation of trunk (81.8% *vs.* 74.4%), sensation of lower extremity (75.1% *vs.* 83.0%), and bladder function (84.3% *vs.* 78.4%). There was a significant difference between the two groups only in the improvement of upper extremity motor function ($P < 0.05$; Table 3). Operative data and complications are summarized in Table 3. The patients treated with ADF required significantly longer operative time (211 *vs.* 149 minutes), and had more blood loss (340 *vs.* 188 mL) and longer duration of neck collar fixation (9.6 *vs.* 3.8 weeks) than the patients treated with LAMP. No intraoperative complications occurred. Complications included two cases of meralgia and one case of C5 palsy in the ADF group, and three cases of C5 palsy in the LAMP group in this series. The occurrence of C5 palsy after surgery[10,11] was 2.6% in the ADF group and 6.4% in the LAMP group; these results were similar to those reported previously.[12] These complications disappeared 6 months after surgery. Three patients in the ADF group experienced airway problems, including dysphasia and laryngeal edema, immediately after surgery. Oral feeding needed to be delayed for a few days after surgery in all three cases. Both the dysphasia and laryngeal edema had recovered by 7 days after surgery. None of the patients suffered from either dysphonia or esophageal fistula. In addition, one patient with asymptomatic pseudarthrosis was found in the ADF group at the 1-year follow-up time point. Revision surgery of strut graft and plate was performed. Bone union at the site could be seen 6 months after reoperation. With regard to frequencies of peri- and postoperative complications, the LAMP group had fewer complications than the ADF group.

TABLE 3. Clinical Outcomes in ADF and LAMP Group

	ADF Group (n = 39)	LAMP Group (n = 47)	*P*
JOA score (pts)/recovery rate (%)			
Preoperative	9.9 ± 3.1/–	9.7 ± 2.9/–	ND
1-yr	14.0 ± 2.6/59.9 ± 27.4	13.3 ± 2.5/49.5 ± 25.8	ND
2-yr	14.8 ± 2.0/63.5 ± 28.6*	13.5 ± 2.5/50.4 ± 27.3	<0.05
3-yr	15.0 ± 2.3/74.1 ± 25.4*	13.5 ± 2.6/52.5 ± 27.3	<0.05
5-yr	14.9 ± 2.3/72.9 ± 28.3*	13.1 ± 2.9/50.2 ± 26.6	<0.05
Each function in JOA score			
Motor function			
Upper extremity	82.0 ± 30.9*	62.3 ± 38.9	<0.05
Lower extremity	75.8 ± 32.1	63.2 ± 39.4	ND
Sensation			
Upper extremity	52.0 ± 46.2	44.0 ± 40.8	ND
Trunk	81.8 ± 34.0	74.4 ± 38.0	ND
Lower extremity	75.1 ± 39.1	83.0 ± 25.5	ND
Bladder function	84.3 ± 36.8	78.4 ± 39.0	ND
Operation time (min)	211 ± 55.3†	149 ± 38.7	<0.005
Blood loss (mL)	340 ± 287†	188 ± 92.1	<0.005
Duration of neck collar fixation (weeks)	9.6 ± 2.1†	3.8 ± 1.1	<0.005
Complications			
Airway problems	3	C5 palsy	—
Meralgia	2		
C5 palsy	1	C5 palsy	1
Pseudoarthrosis	1	Pseudoarthrosis	1

Mean ± SD.

**P < 0.05.*

†P < 0.005 vs. LAMP group by the Mann-Whitney U test.

ND, not significant difference; JOA, Japanese Orthopedic Association.

Radiographic Results

The mean C2–C7 lordotic angle of neutral position changed from 12.8° to 17.7° in the ADF group, whereas it changed from 14.3° to 12.1° in the LAMP group. The ROM of the cervical spine decreased from 26.4 to 13.8 (51.5%) in the ADF group, and from 28.1 to 11.9 (42.3%) in the LAMP group. ADF was superior to LAMP for the maintenance of the lordotic angle of the cervical spine, whereas the ROM of the cervical spine decreased in both groups (Table 4).

Relationship Between Clinical Outcomes and ACS in the LAMP Group

Six patients had ACS just after receiving LAMP; 16 patients had ACS at 2 years after surgery, including these6 patients. The ACS of these patients was maintained until the 5-year follow-up time point. The occurrence of ACS, excluding that in the six patients who had ACS just after LAMP, followed the progression of the kyphotic change in seven cases, and spondylolisthesis at the responsible level in three cases. We focused on the MRI at the 2-year follow-up time point, when the difference in the recovery rate between the ADF and LAMP groups arose. The LAMP group was divided into two subgroups: the LAMP(+) group, comprising 16 patients who had ACS and the LAMP(−) group, comprising 31 patients without ACS. No significant differences were seen in preoperative JOA score, age, duration of symptoms, or preoperative C2–C7 lordotic angle between the two groups (Table 5). The mean kyphotic change of the cervical spine after LAMP was 4.0° in the LAMP(+) group and 1.3° in the LAMP(−) group; there was no significant difference in this angle between the

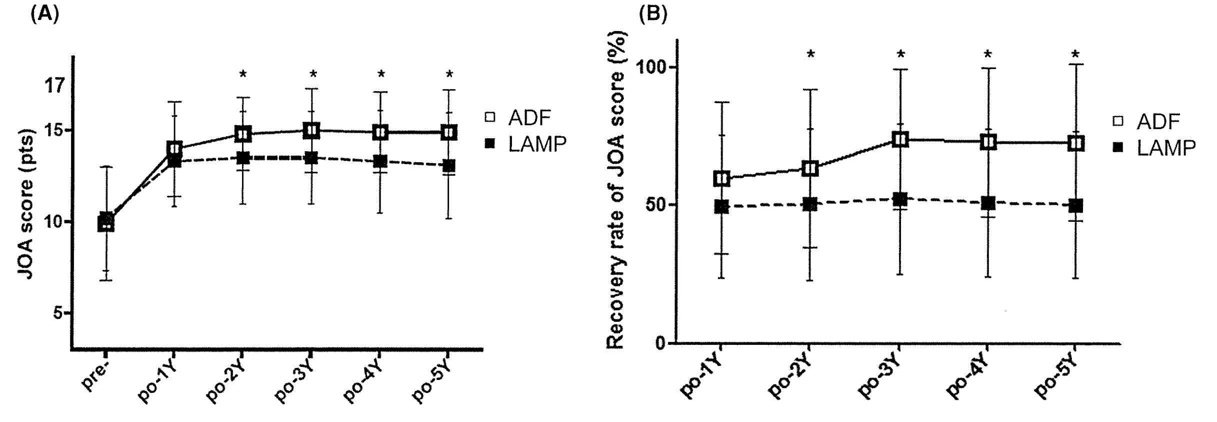

Figure 1. JOA score and recovery rate were significantly higher in the ADF group than in the LAMP group from the 2-year follow-up timepoint (**A** and **B**, *$P < 0.05$).

two groups. However, there was a significant difference in the recovery rate between the LAMP(+) (37.4%) and LAMP(−) (65.6%) groups ($P < 0.005$), although there was no difference between the ADF (72.9%) and LAMP(−) groups (Table 5 and Figure 2).

In addition, referring to K-line that was described by Fujiyoshi,[13] we attempted to confirm optionally whether a line connecting the midpoints of the spinal canal at C2 and C7 on preoperative MRI could be available for making the decision about which surgical treatment for CSM should be carried out. However, this line did not help in predicting ACS after LAMP for the treatment of CSM (data not shown). Thus, the existence of ACS is likely to depend on the postoperative malalignment, for example, kyphotic change, spondylolisthesis, and the occurrence of disc bulging, all of which are often unpredictable before surgery (Figure 3A–C).

DISCUSSION

Several authors have reported that the anterior and posterior procedures are similar in terms of clinical outcomes.[1,2,9,14–16] Edwards *et al*[14] comparatively analyzed matched patient cohorts for clinical outcomes between corpectomy (n = 13) and posterior decompression (n = 13), and showed that the improvement of myelopathy was similar between both procedures, whereas posterior decompression may be the preferred method of treatment for multiple-level cervical myelopathy. Wada *et al*[16] also reported that no significant difference in neurologic recovery was found between the anterior method and the posterior procedure after a long-term follow-up. However, there were more than a few biases in selecting surgical procedures for the treatment of CSM because these studies were retrospective series. To the best of our knowledge, this report describes the first prospective comparative study between ADF and LAMP for the treatment of CSM over a 5-year follow-up period. This study was designed to be as unbiased as possible.

LAMP has been adopted by many surgeons for the treatment of cervical myelopathy. Since the open-door method was first designed by Hirabayashi *et al*,[17] many modified techniques have been reported. However, there are only a few articles reporting whether there are any differences between the different posterior procedures. Hatakeyama *et al*[18] compared the results of two procedures for the treatment of CSM, including the midsagittal-splitting method and Miyazaki and Kirita's method.[7] On the contrary, Okada *et al*[19] compared prospectively the clinical outcomes of the open-door and French-door method, which is equal to Miyazaki and Kirita's method.[7] These two studies showed no significant differences between the procedures in terms of neurologic outcomes. According to these results, it is likely that each posterior procedure for the treatment of CSM is

TABLE 4. Radiographic Evaluation in ADF and LAMP Group

		ADF Group (n = 39)	LAMP Group (n = 47)	*P*
Radiographic evaluations				
C2–C7 angle	Preop.	12.8 ± 9.6	14.3 ± 11.9	ND
	5-yr	17.7 ± 8.6*	12.1 ± 14.7	<0.05
ROM	Pre-op	26.4 ± 14.0	28.1 ± 11.3	ND
	5-yr (%ROM)	13.8 ± 12.2 (51.5)	11.9 ± 9.6 (42.3)	ND

Mean ± standard deviation.

**P < 0.05 vs. LAMP group by the Mann-Whitney U test.*

ND, not significant difference; JOA, Japanese Orthopedic Association; ROM, range of motion.

TABLE 5. Compared With LAMP (−) and LAMP (+) Subgroups in Preoperative Condition and Postoperative Outcomes

	LAMP Group		
	LAMP (+) (n = 16)	LAMP (−) (n = 31)	*P*
Age (y-o)	62.4 ± 8.3	60.4 ± 10.2	ND
Duration of symptom	9.8 ± 8.8	10.1 ± 6.1	ND
Canal diameter	12.8 ± 1.3	12.8 ± 0.7	ND
C2–C7 angle	10.6 ± 12.9	16.6 ± 11.8	ND
JOA score			
Pre-op	9.5 ± 3.4	9.8 ± 2.5	ND
5-yr	12.0 ± 3.1	14.3 ± 2.5*	<0.05
Recovery rate	37.4 ± 17.6*	65.6 ± 26.8	<0.05
Kyphotic change (degree)	4.0 ± 10.2	1.3 ± 9.4	ND

Mean ± standard deviation. Kyphotic change of sagittal alignment was measured by a difference between preoperative and postoperative C2–C7 angle.

ND, not significant difference; JOA, Japanese Orthopedic Association.

**P < 0.05 vs. LAMP (−) group by the Mann-Whitney U test.*

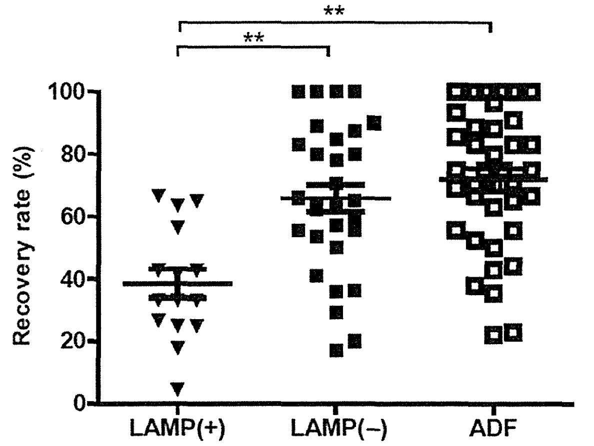

Figure 2. There were significant differences between the LAMP(+) and LAMP(−) groups (**$P < 0.005$), whereas a significant difference between LAMP(−) and ADF groups was not found.

similar. In addition, the clinical and radiographic outcomes after Miyazaki and Kirita's method[7] were similar to those reported previously.[20–23]

Kyphotic change in the cervical spine after LAMP is well known. Kimura *et al*[24] reported that LAMP did not provide a good outcome in the presence of kyphotic or S-shaped malalignment. This study demonstrated that the postoperative kyphotic changes observed in 46.8% of the LAMP group did not usually affect the clinical outcomes (data not shown). On the contrary, Suda *et al*[25] showed that preoperative local kyphosis was one of the most important risk factors for poor surgical outcomes after LAMP. In this study, there were nine patients with preoperative local kyphosis at the responsible level (range 3–7.1°; average 4.2°) in the LAMP group, and four (44.4%) of these nine fell in the LAMP(+) group. Preoperative local kyphosis, rather than the K-line on MRI, may help to foresee the probability of ACS after LAMP which can deteriorate clinical outcome, whereas the cervical sagittal alignment was not related to the neurologic outcomes directly (data not shown).

This study revealed that the patients with ACS often had poor outcomes, whereas those patients whose spinal cord could obtain a sufficient circumferential clearance after LAMP had satisfactory outcomes, as did the patients treated with ADF. Masini *et al*[26] showed that mechanical stress on the anterior aspect of the spinal cord increases with progression of kyphosis. Breig and colleagues[27,28] revealed that filling defects of arteries to the spinal cord occurs in cervical flexion, leading to a reduction in blood supply to the spinal cord. Given these reports and our results, ACS can chronically injure the spinal cord, and in particular, the anterior horn of the spinal cord can often be damaged, which may have resulted in preventing the improvement of upper extremity motor function in the patients in the LAMP group, thereby producing the

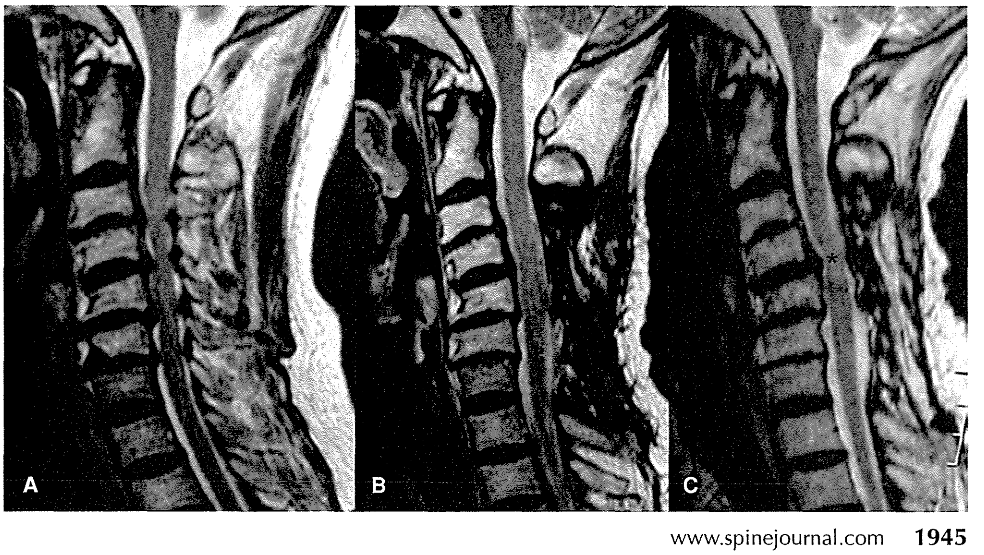

Figure 3. In this case, the preoperative score of upper extremity motor function was 1.5 points. Six months after surgery, the fine motor skills of his hands had slightly improved (2 points). However, he complained of a worsening of bilateral hand clumsiness (1.5 points). The preoperative MRI sagittal view **(A)** demonstrated multiple canal stenosis without kyphosis or spondylolisthesis. MRI obtained 6 months after LAMP **(B)** showed that mild kyphotic change occurred without ACS. **(C)** At the time of the 2-year follow-up time point, however, ACS at C4/5 (*) with both local kyphotic change and spondylolisthesis.

difference in clinical outcomes seen between the two groups at the 2-year follow-up time point. These mechanisms are similar to a risk factor for surgical outcome of LAMP in patients with OPLL. Seichi *et al*[29] reported that patients with residual cord compression caused by OPLL may have a risk of mild cord injury resulting from minor trauma. Masaki *et al*[30] also demonstrated that massive OPLL synchronizing with segmental mobility may damage the spinal cord if the cord experienced an insufficient posterior shift after LAMP. Likewise, ACS could be a risk factor for clinical outcomes in the treatment for CSM.

Several authors showed that ADF of three or more levels sometimes has less satisfactory outcomes, with the incidence of nonunion and other complications ranging from 17% to 53%.[31–36] In particular, according to a recent meta-analysis[37] of 2682 patients, the fusion rate for the anterior procedure with plating was 97.1% at the one-disc level, 94.6% at the two-disc level, and 82.5% at the three-disc level. We experienced one (2.6%) case with two segment fusions as a result of pseudarthrosis in the ADF group. In addition, postoperative MRI showed that disc degeneration at the adjacent segment occurred without neurologic deterioration in nine cases (23.1%) in the ADF group. Of these nine patients, eight cases were treated with multilevel fusion. Goffin *et al*[38] reported that 180 patients treated by the cervical anterior procedure were followed for longer than 5 years, and that 92% of the patients demonstrated a significant increase in disc degeneration at adjacent segments. Shinomiya *et al*[39] reported that a statistically significant correlation was found between the degree of adjacent level radiologic degeneration and the time interval after surgery, and also found that the risk of adjacent segment disorder after the anterior procedure often increases from 5 years after surgery. In our series, fortunately, the incidence of graft dislodgement, nonunion, and adjacent segment disorder after the anterior procedure was lower than published elsewhere. However, this study has the following limitations: (1) the 5-year follow-up may not be sufficient to be considered as a long-term outcome and (2) the number of patients was not so large. We urge others to make similar prospective studies, including using larger populations, to strengthen our data on the basis of which surgeons will need to make treatment recommendations.

In summary, although the anterior procedure is recognized to be a more invasive and problematic procedure than posterior decompression in terms of peri- and postoperative complications, it provided a significantly better recovery rate of the JOA score, particularly in regard to improvement of upper extremity motor function, after the 2-year time point and better cervical sagittal alignment. The reasons for these differences in neurologic and radiologic recovery are based on two advantages of ADF and one disadvantage of LAMP: (1) sufficient circumferential clearance of the cord can be obtained with anterior decompression, (2) the spinal column becomes more stable with anterior fusion, and (3) ACS after LAMP may reduce improvement of upper extremity motor function.

➢ Key Points

- ❑ This prospective comparative study showed that the improvement of JOA score in patients treated with ADF was significantly better than in those treated with LAMP from 2 years after surgery.
- ❑ A statistically significant difference was found between the ADF and LAMP groups only in improvement of upper extremity motor function among the individual items of the JOA score.
- ❑ The current study revealed that clinical outcomes after LAMP could be influenced by the residual existence of ACS.

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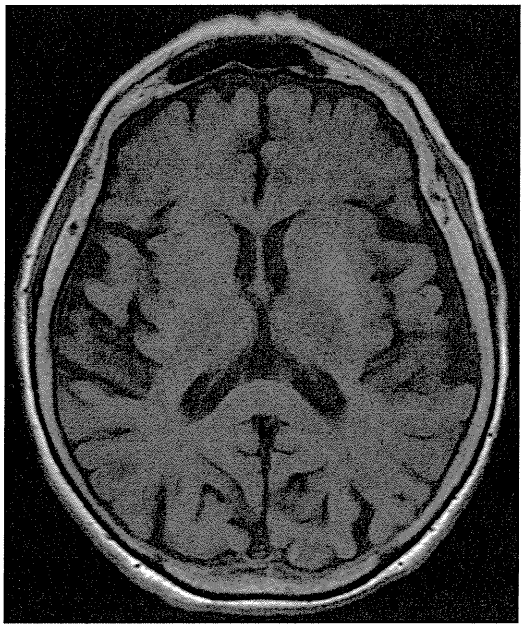

Fig. 2. Axial T1-weighted MRI at the same level shows hyperintensity of the left lentiform nucleus.

theories have been proposed to explain the imaging findings including calcium deposition, petechial haemorrhage, ischaemia, infarction, cytotoxic oedema and myelin breakdown. It is of note that this focal abnormality is induced by hyperglycaemia, a systemic disturbance. Pre-existing basal ganglia disease, such as focal small vessel ischaemia, may be present in these diabetic patients, with hyperglycaemia tipping the balance in these regions into cellular dysfunction. Hyperglycaemia impairs cerebral autoregulation, which may explain hypoperfusion on imaging, and causes gamma-aminobutyric acid (GABA) depletion in basal ganglia neurons as a result of anaerobic metabolism.[6] It may be the GABA depletion, the main inhibitory neurotransmitter in the basal ganglia, which results in chorea. Although much further investigation is needed, the pathological and radiological findings suggest that non-ketotic hyperglycaemic crisis induces ischaemia and metabolic disturbance resulting in basal ganglia dysfunction.

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Postoperative paralysis following posterior decompression with instrumented fusion for thoracic myelopathy caused by ossification of the posterior longitudinal ligament

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ABSTRACT

A 60-year-old man presented with thoracic myelopathy due to ossification of the posterior longitudinal ligament (OPLL). His spinal cord was severely impinged anteriorly by a beak-type OPLL and posteriorly by ossification of the ligamentum flavum at T4/5. He underwent surgical posterior decompression with instrumented fusion (PDF). Immediately after surgery, he developed a Brown-Séquard-type paralysis, which spontaneously resolved without requiring the addition of OPLL extirpation. This example highlights that the risk of postoperative neurological deterioration cannot be eliminated even when PDF is selected as the surgical procedure for thoracic OPLL, especially in instances in which the spinal cord is severely compressed.

1. Introduction

Despite the variety of surgical procedures for treating thoracic myelopathy due to ossification of the posterior longitudinal liga-

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ment (OPLL), postoperative paraplegia remains a major risk.[1,2] Twenty years ago, we hypothesized that stabilizing the spine with instrumentation could yield a certain degree of neurological recovery even without complete OPLL extirpation. Based on this hypothesis, in 1989 we introduced the surgical procedure of posterior decompression with instrumented fusion (PDF) for patients with thoracic OPLL. In our earlier study of 17 patients who underwent PDF for thoracic OPLL, all of the patients had a considerable degree of neurological recovery and no postoperative paralysis occurred.[3] Based on the results of that study, we have employed PDF for all instances of thoracic OPLL treated surgically at our institute since 2003. Subsequently, however, we had our first encounter with postoperative paralysis in our 23rd PDF patient.

2. Case report

A 60-year-old man had thoracic myelopathy with a Japanese Orthopaedic Association (JOA) score of 4.5, on a scale from 0 to 11. He complained of bilateral motor weakness of his lower extremities and was unable to walk without a cane. Lateral radiographs showed T4–9 OPLL. MRI scans showed severe narrowing of the spinal cord at T4/5. Reconstruction images from a CT myelogram showed impingement of the spinal cord anteriorly by a beak-type OPLL (Fig. 1) and posteriorly by ossification of the ligamentum flavum (OLF) (Fig. 1A) at T4/5. The image showing a beak-type OPLL also showed a non-ossified area between the ossified masses at T4/5 (Fig. 1A), indicating that the spinal column still had some mobility at the cord compression level.

We performed a T4–7 laminectomy and a T2–10 posterior instrumented fusion using pedicle screws as anchors at the T2, T3, T4, T8, T9 and T10 levels. An intraoperative spinal ultrasonography after the laminectomy showed continuing anterior impingement of the spinal cord by the beak-type OPLL at T4/5 and an absence of the subarachnoid space on the ventral side of the spinal cord (Fig. 2).

Immediately after surgery, the patient suffered a severe motor loss of his right lower limb (muscle strength at grade 0 out of 5) and analgesia of his left lower extremity and left trunk below the umbilicus, indicative of a Brown-Séquard-type paralysis. We immediately administered a 1000 mg bolus of methylprednisolone sodium succinate intravenously. One hour after surgery, we detected muscle contraction in the patient's right lower limb. The morning following surgery, his right lower limb showed a slight recovery of motor function (muscle strength at grade 1 to 3 out of 5). By the end of the day, the sensory loss in his left lower

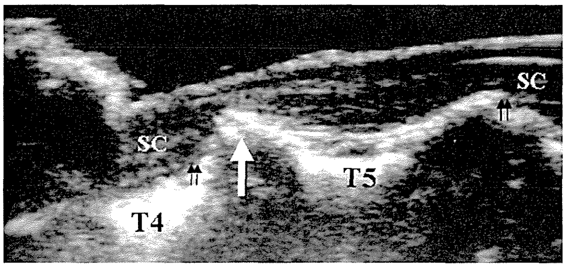

Fig. 2. Intraoperative spinal ultrasonography in the midsagittal plane after laminectomy showing anterior impingement of the spinal cord (SC) by the beak-type ossification of the posterior longitudinal ligament at T4/5 (arrow) and the absence of the subarachnoid space on the ventral side of the spinal cord from T4/5 to T5/6 (double arrows).

extremity and trunk had begun to diminish, showing hypalgesia at grade 5 to 8 out of 10. His neurological recovery gradually progressed from that point on. Three months after surgery, the patient could walk with a cane. Six months after surgery, his JOA score had risen to 7, and his recovery was 38.5%. At the final follow-up 5 years and 3 months after surgery, the patient could walk without a cane and his recovery remained at 38.5%.

3. Discussion

During PDF, we pay maximal attention to avoid injury to the spinal cord.[3] In spite of such efforts, neurological deterioration occurred immediately after surgery in this patient. This incident suggests that the decompression procedure itself entails a risk of postoperative paralysis in patients with a severely compressed spinal cord. It is possible that when the spinal cord is severely compressed by OPLL and OLF from both anterior and posterior directions, as in our patient, the risk of intraoperative injury to the spinal cord may increase. In instances with a severely pinched spinal cord, the risk of postoperative neurological deterioration evidently cannot be completely eliminated, even when PDF is selected as the surgical procedure for thoracic OPLL.

An alternative treatment option for this patient would have been single-stage anterior and posterior decompression for combined thoracic OPLL and OLF. Several authors have previously reported excellent clinical results using this procedure.[1,4] However, in the same papers, these authors also reported several examples of postoperative paralysis after single-stage anterior and posterior compression, which suggests that the overall outcomes of single-stage anterior and posterior decompression are not necessarily superior to the outcomes of PDF.[1,4]

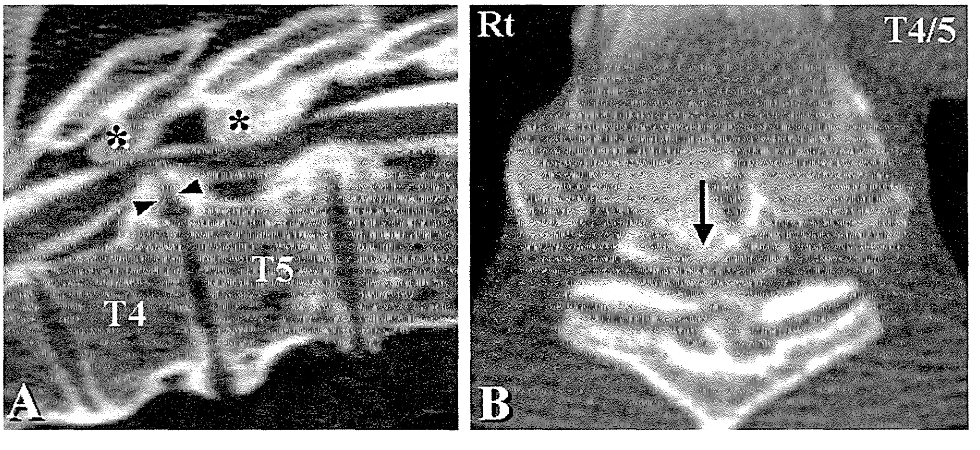

Fig. 1. Preoperative midsagittal (A) and axial (B) reconstruction images from a CT myelogram showing impingement of the spinal cord anteriorly by a beak-type ossification of the posterior longitudinal ligament (OPLL) (A, B, arrow) and posteriorly by ossification of the ligamentum flavum (A, asterisks) at T4/5. The mid-portion of the beak-type OPLL contains a non-ossified area (A, arrowheads).

Published studies have also shown that anterior decompression through thoracotomy does not necessarily produce favorable results when performed as rescue surgery on thoracic OPLL and OLF patients whose myelopathy worsens after laminectomy.[5,6] Of particular concern is the possibility that worsening myelopathy might indicate severe damage to the spinal cord resulting from the laminectomy, in which case the spinal cord may likely not further tolerate an anterior decompression procedure. Because of this risk, we did not choose anterior extirpation of OPLL through thoracotomy as rescue surgery in our patient.

Fortunately, our patient's paralysis spontaneously resolved without requiring us to add OPLL extirpation. In light of what appears to be a higher risk of postoperative paralysis following other surgical procedures such as laminectomy alone and OPLL extirpation,[1,2] we suggest that PDF is still the safest surgical procedure among the surgical treatment alternatives for thoracic OPLL. To further improve the safety of PDF for thoracic OPLL, however, we will need to further modify the treatment protocol to reduce the risk of damage to the spinal cord during PDF. One promising possibility is neuroprotective therapy with preoperative administration of neural growth factors.

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Fourth-ventricular immature teratoma

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Posterior fossa

ABSTRACT

Teratomas account for 3% of all childhood tumors. This group of non-germinomatous germ cell tumors exhibit cellular and structural characteristics associated with the three germ layers. The immature cells can differentiate into more malignant neoplasms. We report the presentation and management of a 4-year-old girl with an immature teratoma of the fourth ventricle. The outcome of this intracranial immature teratoma was poor, due to the patient's age, the extensive lesion at presentation and the grade of the tumor.

1. Introduction

Intracranial teratomas represent 2% to 5% of all teratomas in infancy and account for 0.3% to 0.6% of all intracranial neoplasms.[1,2] They are seen involving midline intracranial structures; are more commonly reported in the pineal region, third ventricle and suprasellar region; and present with obstructive hydrocephalus.[1,3,4] Teratomas are extremely rare in the posterior fossa and are seldom reported in children beyond 2 years of age. We present a rare, large immature teratoma based exclusively in the fourth ventricle.

2. Case report

A 4-year-old girl with a 2-month history of headaches and vomiting presented with two episodes of hydrocephalus. She had left-side abducens palsy and florid papilledema. Her head circumference was normal for her age. A CT scan of her head revealed an isodense lesion in the posterior fossa occupying the entire fourth ventricle and causing obstructive hydrocephalus, for which she underwent an emergency ventriculoperitoneal shunt (Fig. 1a). A MRI brain scan showed a lesion in the fourth ventricle arising from the vermis with mixed intensity on T1- and T2-weighted images, with cystic areas and exhibiting non-homogeneous contrast enhancement. The patient underwent a midline suboccipital craniotomy and decompression of the tumour through the vermis (Fig. 1b,c,d). The tumor was grey and soft to firm in consistency with areas of calcification. It was infiltrating the floor of the fourth ventricle and was merging imperceptibly with the vermis. Near-total decompression was achieved because of brainstem infiltration. A postoperative MRI scan showed residual tumor along the ventricular floor with minimal blood in the operative cavity (Fig. 2). Histopathological examination revealed an immature teratoma of the posterior fossa having glial components with immature neural

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Case report

Postmortem findings in a woman with history of laminoplasty for severe cervical spondylotic myelopathy

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Context: We report the autopsy of a 65-year-old woman who underwent a C3–C7 laminoplasty 4 years after the diagnosis of cervical spondylotic myelopathy (CSM). Her sensory disturbance, spasticity, and vesicorectal disturbance, which corresponded to long tract sign, had improved after surgery.
Findings: Cross sections at the C4–C5 level showed a triangular shape because of atrophied ventral gray matter. Moreover, despite the scarce glial scar formation around the cystic cavity, regeneration of gray matter had not occurred. In the white matter, the posterior and lateral funiculi were shrunken including three to four segments.
Conclusion: Pathological change of white matter did not coincide with relief of clinical symptoms in this case. These findings indicate that it may be better to operate earlier in cases of CSM, because delay may lead to irreversible histological change.

Keywords: Pathophysiology, Spinal cord, Myelopathy, Cervical spondylotic, Autopsy, Laminoplasty, Long tract sign

Introduction

Reports of the pathology of cervical spondylotic myelopathy (CSM) are rare because it is not a fatal disorder.[1–6] Autopsy reports of patients who have undergone laminoplasty for CSM are scarce. Here we report the autopsy of a woman who had a successful C3–C7 laminoplasty for CSM 9 years prior to her death, and correlate pathological findings with her clinical course.

Clinical summary

The woman was a 65 year old who had multiple joint contractures caused by rheumatoid arthritis (stage IV, class 4) for more than 30 years and barely ambulated using a walker. She had noticed progressive weakness in her bilateral lower extremities at 52 years of age and was diagnosed with CSM. She gradually developed right-sided muscle weakness and spasticity of her bilateral lower extremities and became confined to a wheelchair. Four years after the onset of these symptoms, she reported sensory disturbance on the left side of her body trunk and extremities and urinary frequency. She decided to undergo a C3–C7 laminoplasty, which led to improvement in sensory disturbance, spasticity, and vesicorectal disturbance but had little effect on her activities of daily living. She died 9 years after operation for an acute myocardial infarction.

Laboratory findings

Imaging

Plain radiographs and MRI 1 year after her operation showed sufficient surgical decompression (Figs 1 and 2A). Sagittal views of her spinal cord showed low intensity in T1-weighted images and high intensity in T2-weighted images at the level of C4–C5, and an axial view showed a 'snake-eyed' appearance at that site (Fig. 2B).

Pathological findings

Transplanted bone was fused with innate bone and no instability was apparent at any disk level. Macroscopically, dissected spinal cord had atrophy at the level of C4–C5, as seen on MRI.

Spinal cord cross sections were stained with hematoxylin and eosin (H&E), Luxol fast blue (LFB) and

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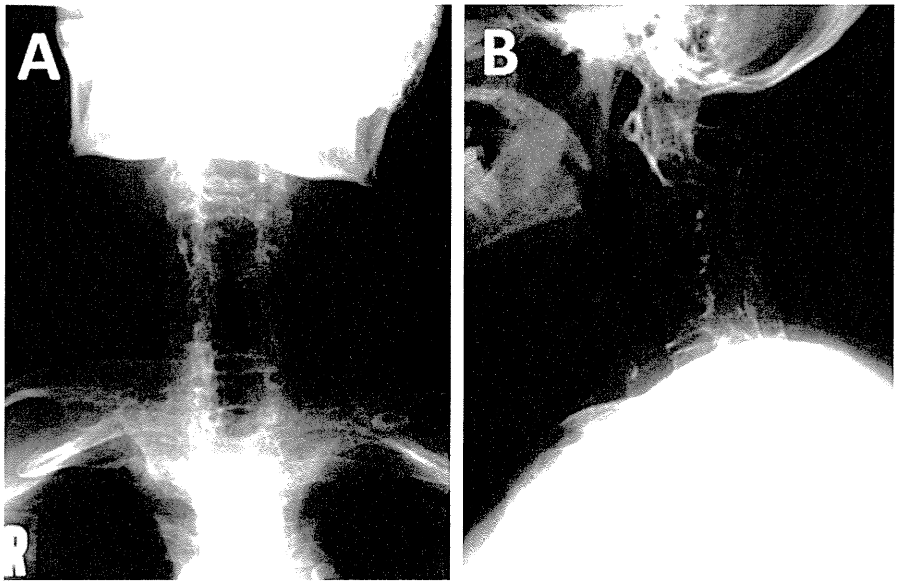

Figure 1 Cervical radiograph 1 year after C3–C7 laminoplasty (A: anterior–posterior view; B: profile view).

elastica van Gieson (EVG), and immunohistochemistry was performed for GFAP. Cross sections at the level of C4–C5 were of triangular shape because anterior horn neurons that had atrophied were lost in the ventral gray matter. Moreover, tissue was sufficiently degenerated to form a cystic cavity at the center of the gray matter of the posterior horn and funiculus (Fig. 3A and D). Atrophy of gray matter had spread vertically from the C6 to C7 segments (Fig. 3B and C). A cystic cavity was consistent with the 'snake-eyed' appearance of the axial view on T2-weighted MRI. GFAP staining showed that the glial reaction was comparatively rare around the cystic cavity (not shown). Vessels adjacent to the cystic cavity had a thickened outer membrane with hyaline degeneration. These vessels were lacking elastic fiber and had dilated or occluded lumens (Fig. 4). In the white matter, the posterior and lateral funiculi were shrunken and stained weakly with LFB (Fig. 3A). Their atrophy affected three to four segments, predominantly on the right side (Fig. 3B and C). The anterior funiculus remained comparatively intact compared with the posterior or lateral funiculus. Its atrophy had only spread within two segments. These findings of substance changes were predominantly on the right side of the spinal cord.

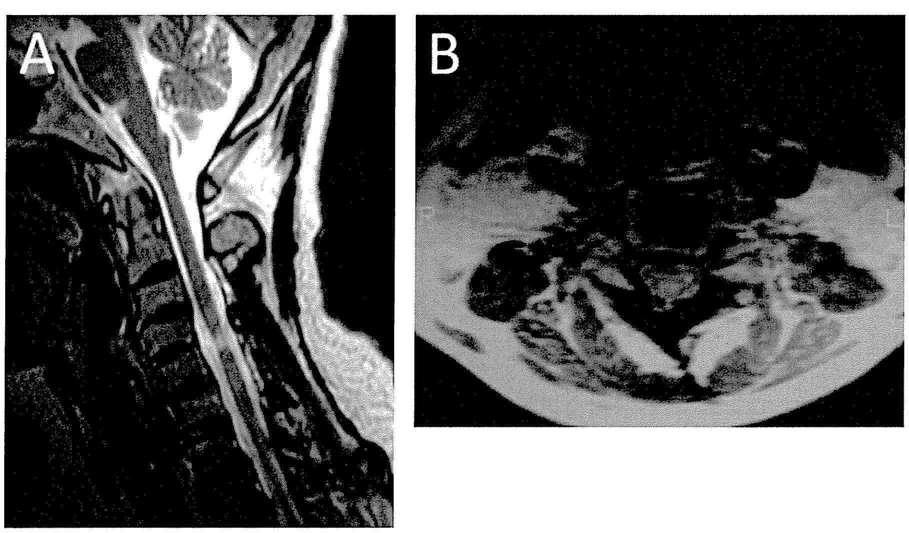

Figure 2 MRI findings 1 year after C3–C7 laminoplasty (A: T2-weighted sagittal view; B: T2-weighted axial view). Although subdural space is widely decompressed in the sagittal view, the high-intensity area at the level of C4/C5 remains (A). In the axial view of the spinal cord at the level of C4/C5, the gray matter shows a 'snake-eyed' appearance, where the high-intensity area is predominant (B).

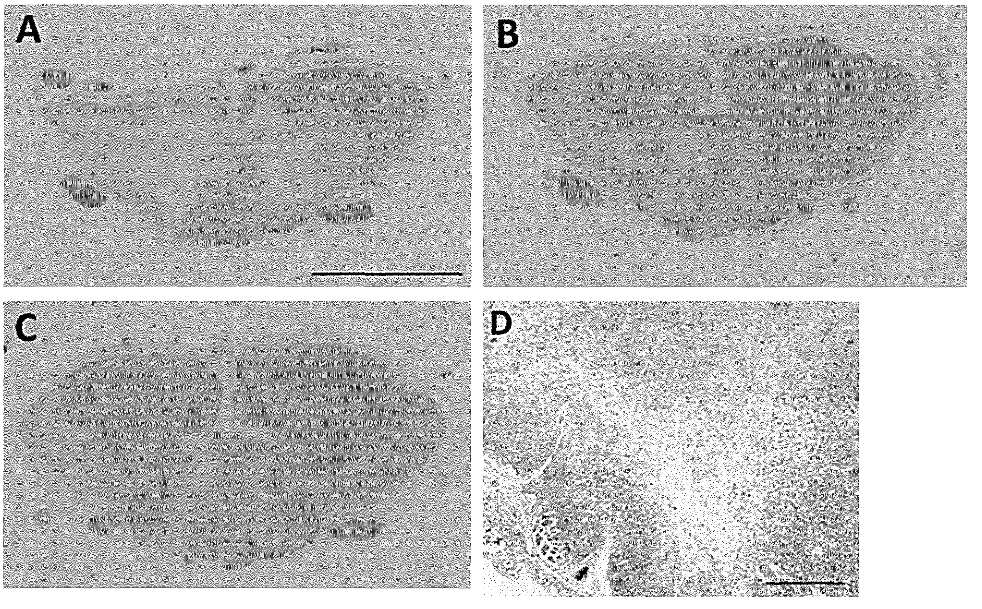

Figure 3 LFB staining of a cross section of the cervical spinal cord (A–C) and H&E staining of a serial section of A (D). A–C correspond with cross sections at C4/C5, C5/C6, and C6/C7. Bar = 1 cm for A–C and 50 μm for D.

Discussion

In CSM, disease onset is related to secondary circulatory disturbance with static or dynamic compression.[7] It is reported that chronic venous congestion is a cause of vessel changes.[8] Kameyama reports that some cysts had surrounding intact neurons, were disrupted alongside vessels, or contained many thickened vessels. He speculated that cysts formed from fused enlarged perivascular spaces caused by congestion and edema.[9] In the present pathology, we found many thickened vessels adjacent to the cystic cavity, with fibrotic changes and enlargement of their perivascular space. These findings coincided with the findings of chronic congestion caused by spinal cord compression.

In this patient, the cystic cavity had spread from the center of the gray matter to the posterior horn and funiculus. This phenomenon is explained by shear stress, which increases toward the middle and becomes highest in the center of the spinal cord.[10] It is reported that the center of gray matter and posterior and lateral funiculi are most subject to severe compression in CSM.[6] From this description, the location of the cystic cavity is reasonable in this case.

Before surgery, she had sensory disturbance of her body trunk, lower extremities, spasticity, hyper-reflexes, and vesico-rectal disturbance, which may have been caused by long tract disturbance. After surgery, manual muscle testing score of her right side lower extremity increased to 3. She was satisfied that her sensory disturbance, spasticity, and vesico-rectal disturbance, which were related to the long tract sign, had improved. Although it would be anticipated that many axons

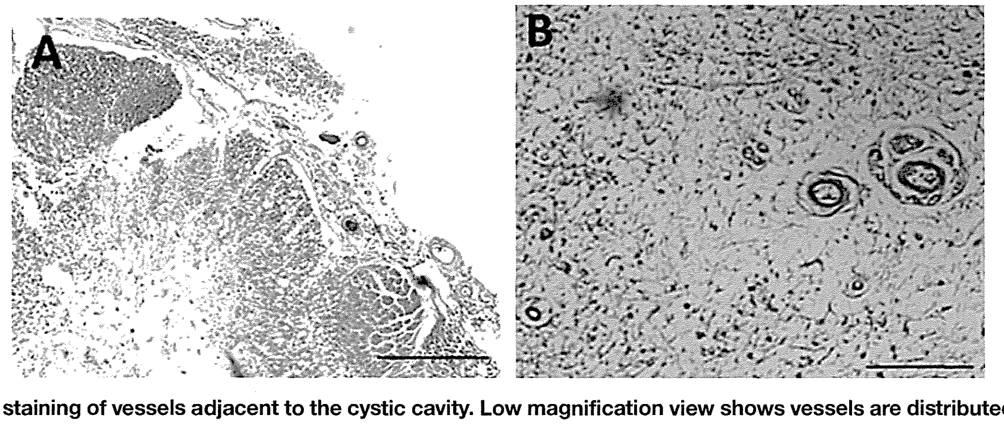

Figure 4 EVG staining of vessels adjacent to the cystic cavity. Low magnification view shows vessels are distributed around cystic cavity (A). Magnification view of A shows these vessels have a thickened outer membrane with hyaline degeneration (B). Bar = 5 0 μm for A and 20 μm for B.

reconnected or regenerated after decompressive surgery, the posterior and lateral funiculi were shrunken and atrophied for three to four segments. Ito reported the existence of thinned myelin sheaths in an autopsy case of CSM and postulated the possibility of demyelination and remyelination.[2]

Conclusion

In this case, pathological findings on autopsy did not correspond with the clinical course, i.e., the symptoms of long tract sign caused by the white matter lesion improved after surgical intervention. These findings indicate that early operative intervention may be optimal in cases of CSM, because delay may lead to irreversible histological change.

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Etiology of Cervical Spondylotic Myelopathy and Surgical Results of Anterior Cervical Surgery in Elderly Patients

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Key words : cervical spondylotic myelopathy, elderly people, anterior cervical surgery

Introduction

Despite the publication of several studies of cervical spondylotic myelopathy (CSM) in elderly patients[1,2,5,6], its etiology and surgical treatment still remain controversial. The purpose of this study was to characterize the etiology of CSM in elderly patients, discuss appropriate surgical treatment based upon its etiology, and evaluate the clinical outcomes of anterior cervical surgery in elderly CSM patients.

Materials and Methods

1. Patient Population

Between 1997 and 2005, 27 CSM patients over 70 years of age (elderly CSM group) and 27 CSM cases under 50 years of age (younger CSM group) were treated at our institute, all of whom underwent anterior cervical surgery. Mean age of the elderly CSM group (16 males, 11 females) was 76 years, ranging from 71 to 85 years. Mean age of the younger CSM group (21 males, 6 females) was 41 years, ranging from 33 to 49 years. Number of fused levels was as follows : among the elderly CSM group, one level (8 patients), two levels (14 patients), three levels (2 patients), and four levels (3 patients) ; among the younger CSM group, one level (7 patients), two levels (6 patients), three levels (4 patients), and four levels (10 patients).

2. Clinical Assessments

OR time, blood loss, and perioperative complications were compared between the elderly and younger CSM groups : preoperative and postoperative JOA scores were compared with each other within the same group.

3. Radiological Assessments

Diameter of spinal canal in cervical radiographs, olisthesis of each segment in flexion and extension radiographs, and the presence of high signal changes (HSCs) in preoperative and postoperative T2-weighted magnetic resonance (MR) images were compared between the elder and younger CSM groups.

4. Statistical Analysis

The Mann-Whitney *U* test or the Fisher exact probability test was used for statistical analysis. A *p*-value <0.05 was considered significant, and is identified in the Results section as (*).

Results

With respect to the clinical assessment parameters, among the elderly CSM group, mean JOA score was 8.8 points before surgery *vs.* 12.8 points after surgery (*), and the mean JOA score recovery rate was 49%. Mean OR time was 138 ± 44 minutes, mean blood loss was 59 ± 67 m*l*, and no patient required a blood transfusion. Perioperative complications consisted of

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Table 1 Clinical results

	CSM patients over 70 y/o group (n=27)	CSM patients under 50 y/o group (n=27)
JOA score		
Pre op	8.8±2.0	11.8±2.4
Post op	12.8±2.5	15.8±1.2
Post recovery ratio (%)	49±28	75±18
OR time (minutes)	138±44	175±70
Blood loss (ml)	59±67	96±121
Complications	Aspiration pneumonia 1 case C5 palsy 1 case	Aspiration pneumonia 1 case C5 palsy 1 case

Table 2 Spinal canal diameter

	CSM patients over 70 y/o group (n=27)	CSM patients under 50 y/o group (n=27)
C3	14.4±2.0mm	13.9±1.3mm
C4	14.2±1.5mm (p<0.05)	13.1±1.4mm
C5	14.3±1.3mm (p<0.05)	13.2±1.5mm
C6	14.6±1.3mm (p<0.05)	13.7±1.4mm
C7	15.0±1.3mm	14.8±1.3mm

Table 3 Olisthesis in each segment

	CSM patients over 70 y/o group (n=27)	CSM patients under 50 y/o group (n=27)
C3-4	2.0±1.5mm (p<0.05)	0.5±0.6mm
C4-5	1.2±1.4mm	1.3±1.0mm
C5-6	0.9±1.3mm (p<0.05)	2.0±0.9mm
C6-7	0mm	0.3±0.5mm

one patient developing an aspiration pneumonia and one patient developing C5 palsy. Among the younger CSM group, mean JOA score was 11.8 points before surgery *vs.* 15.8 points after surgery (*), and the mean JOA score recovery rate was 75%. Mean OR time was 175±70 minutes, mean blood loss was 96±121ml, and no patient required a blood transfusion. Perioperative complications consisted of one patient developing an aspiration pneumonia and one patient developing C5 palsy (Table 1).

With respect to the radiological assessment parameters, comparisons of spinal canal diameter between the elderly and younger CSM groups, respectively, were as follows : 14.4±2.0mm *vs.* 13.9±1.3mm at C3, 14.2±1.5mm *vs.* 13.1±1.4 at C4 (*), 14.3±1.3mm *vs.* 13.2±1.5mm at C5 (*), 14.6±1.3mm *vs.* 13.7±1.4mm at C6 (*), and 15.0±1.3mm *vs.* 14.8±1.3 at C7 (Table 2). The incidence of developmental canal stenosis in which spinal canal diameter was less than 13mm in the elderly CSM group was 12 of 27 cases (44%) *vs.* 5 of 27 cases (19%) (*) in the younger CSM group. Comparisons of mean olisthesis between the elderly and the younger CSM groups, respectively, were as follows : 2.0±1.5mm *vs.* 0.5±0.6mm at C3-4 (*), 1.2±1.4mm *vs.* 1.3±1.0mm at C4-5, 0.9±1.3 mm *vs.* 2.0±0.9mm at C5-6 (*), and 0mm *vs.* 0.3±0.5mm at C6-7 (Table 3). Comparisons of the number of patients with HSCs in the spinal cord on T2-weighted MR imaging between the elderly and younger CSM groups, respectively, were as follows : 11 *vs.* 2 patients at C3-4 (*), 14 *vs.* 3 patients at C4-5 (*), 4 *vs.* 16 patients at C5-6 (*), and 0 *vs.* 2 patients at C6-7 (Table 4).