

Incidence and Risk Factors for Late Neurologic Deterioration after C3–C6 Laminoplasty for Cervical Spondylotic Myelopathy

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Abstract

Study Design Retrospective study.

Objective We previously reported that the long-term neurologic outcomes of C3–C6 laminoplasty for cervical spondylotic myelopathy (CSM) are satisfactory, with reduced frequencies of postoperative axial neck pain and kyphotic deformity. However, only 20 patients were included, which is a limitation in that study. The present study investigated the incidence of late neurologic deterioration (LND) of myelopathic symptoms after C3–C6 laminoplasty for CSM and attempted to identify significant risk factors for LND in a larger patient population.

Methods Subjects comprised 137 consecutive patients with CSM who underwent C3–C6 laminoplasty (bilateral open-door laminoplasty, $n = 85$; unilateral open-door laminoplasty, $n = 52$) and were followed for >24 months (mean follow-up, 70 months; range, 25 to 124 months). The patients' medical records were examined for evidence of LND due to cervical myelopathy. The age at time of surgery, sex, surgical procedures, anteroposterior spinal canal diameter at the C7 level, type of C6 spinous process, pre- and postoperative C2–C7 angle, C3–C6 range of motion (ROM), and disk height at the C6–C7 level were analyzed to identify risk factors for LND.

Results Three patients (2.2%) developed LND of myelopathic symptoms due to caudal segment pathology adjacent to the C3–C6 laminoplasty (LND group). In these three patients, mean Japanese Orthopaedic Association (JOA) score improved from 10.2 before surgery to 12.2 at the time of maximum recovery, and declined to 9.7 just before additional surgery. On the other hand, in 134 patients without LND (non-LND group), the mean JOA score significantly improved from 10.2 before surgery to 13.4 at the time of maximum recovery and was maintained by the final follow-up (13.2). Compared with the non-LND group, the LND group showed significantly smaller anteroposterior spinal canal diameter at C7, more restricted postoperative C3–C6 ROM, and greater postoperative decrease in disk height at C6–C7, although a logistic regression analysis showed no significant differences.

Conclusions In patients with CSM with more severe developmental spinal canal stenosis at C7, accelerated degeneration at the caudal segment resulting from restricted C3–C6 ROM after C3–C6 laminoplasty might lead to LND.

Keywords

- ▶ cervical spondylotic myelopathy
- ▶ C3–C6 laminoplasty
- ▶ late neurologic deterioration
- ▶ developmental spinal canal stenosis
- ▶ restricted postoperative range of motion

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Introduction

We previously reported satisfactory long-term neurologic outcomes for C3–C6 laminoplasty with preservation of the muscles attached to the C2 and C7 spinous processes in patients with cervical spondylotic myelopathy (CSM), and we described that this procedure maintained reduced frequencies of postoperative axial neck pain and kyphotic deformity over the long-term.¹ However, one limitation in that previous prospective long-term follow-up study was that the subjects comprised only 20 patients.¹ One of the major concerns for C3–C6 laminoplasty is whether improvement of myelopathic symptoms can be maintained over the long term. Thus, whether late neurologic deterioration (LND) after C3–C6 laminoplasty for CSM can result from progression of degenerative changes at C6–C7 and/or caudal levels must be clarified. No reports have yet examined the incidence and risk factors for LND after C3–C6 laminoplasty for CSM. The purposes of this retrospective study were therefore to investigate the incidence of LND in myelopathic symptoms after C3–C6 laminoplasty for CSM and to identify significant risk factors for LND in a larger patient population.

Materials and Methods

Patients

All patients with CSM at our institute have been treated using C3–C6 laminoplasty, with the exception of those with cervical kyphosis ≥ 15 degrees, single-level anterior lesion without narrow spinal canal, or spinal cord compression at the C6–C7 and/or caudal levels. Based on our criteria, the subjects comprised 137 consecutive patients (80 men, 57 women) who underwent C3–C6 laminoplasty for CSM between September 2003 and October 2011 and who were followed for >24 months (mean follow-up, 70 months; range, 25 to 124 months). Patients with rheumatoid arthritis, stage 5 chronic kidney disease requiring hemodialysis, or cerebral palsy were excluded from this study. The mean age of patients at the time of surgery was 69.9 years (range, 44 to 88 years). Four surgeons performed only bilateral open-door laminoplasty with interpositional autologous bone grafts and/or hydroxyapatite spacers in 85 patients according to surgeon preferences (double-door group). Another four surgeons performed only unilateral open-door laminoplasty using interpositional autologous bone grafts and/or hydroxyapatite spacers in 52 patients according to surgeon preferences (single-door group). For the first 2 weeks after surgery, all patients wore a soft collar. Myelopathic symptoms improved in all 137 patients after the initial C3–C6 laminoplasty. No significant differences in age at the time of surgery, duration of follow-up, or Japanese Orthopaedic Association (JOA) scores² before surgery and at final follow-up were seen between the double-door and single-door groups.

The protocol of this study was approved by the institutional review board of the hospital, and written informed consent was obtained from all participants prior to enrollment.

Clinical and Radiologic Evaluations

The medical records of the participants were examined for evidence of LND by a single observer (H.S.). Myelopathic symptoms were assessed using the JOA score. In this study, LND was defined as a deterioration in JOA score due to cervical myelopathy. In patients who showed a decreased JOA score during postoperative follow-up, the causes of deterioration were precisely investigated by a medical interview, extensive examination of systemic neurologic symptoms, and problems of joints to rule out any other disorders such as lumbar spinal stenosis, peripheral neuropathy, and osteoarthritis of the knee joint.

The maximal flexion, neutral position, and maximal extension were examined on lateral radiography of the cervical spine performed before surgery in all the patients and at final follow-up in the patients without LND (the non-LND group) or just before the second surgery in those with LND (the LND group). The anteroposterior spinal canal diameter at the C7 level was measured on a lateral radiograph of the cervical spine taken before surgery (**► Fig. 1**). The sagittal alignment of the cervical spine, C3–C6 range of motion (ROM), and disk height at the C6–C7 level both before the surgery and at final follow-up or just before the second surgery were also measured. The sagittal alignment of the cervical spine was measured as the C2–C7 angle, formed by two lines drawn parallel to the posterior margin of the C2 and C7 vertebral bodies on a radiograph in the neutral position (**► Fig. 1**). The C3–C6 ROM was calculated by subtracting the C3–C6 angle in maximal flexion from the C3–C6 angle in maximal extension (**► Fig. 1**). The disk height at the C6–C7 level was measured as the intervertebral disk height at the anteroposterior midpoint of the disk on a radiograph in the neutral position (**► Fig. 1**).

The types of C6 spinous process were divided into two groups according to the findings for the funicular section of the nuchal ligament on preoperative magnetic resonance imaging (MRI): preoperative sagittal T1-weighted MRI showed the funicular section of the nuchal ligament, depicted as a very low-intensity wide band, tightly attached to both the C6 and C7 spinous processes (C6 + 7 type), or not attached to the C6 spinous process but tightly attached to the C7 spinous process (C7 type; **► Fig. 2**).³ Some surgeons have reported that a loss of cervical lordosis and destabilization at the C6–C7 segment are significantly greater in patients with the C6 + 7 type than in patients with the C7 type after conventional C3–C7 laminoplasty.^{4,5}

Risk Factors for LND

Age at time of surgery, sex, surgical procedures, anteroposterior spinal canal diameter at the C7 level, type of C6 spinous process, pre- and postoperative C2–C7 angle, C3–C6 ROM, and disk height at the C6–C7 level were analyzed to identify risk factors for LND.

Statistical Analysis

The unpaired *t* test, Fisher exact probability test, and logistic regression analysis were used for statistical analysis with JMP version 5.0.1 software (SAS Institute, Cary, North Carolina,

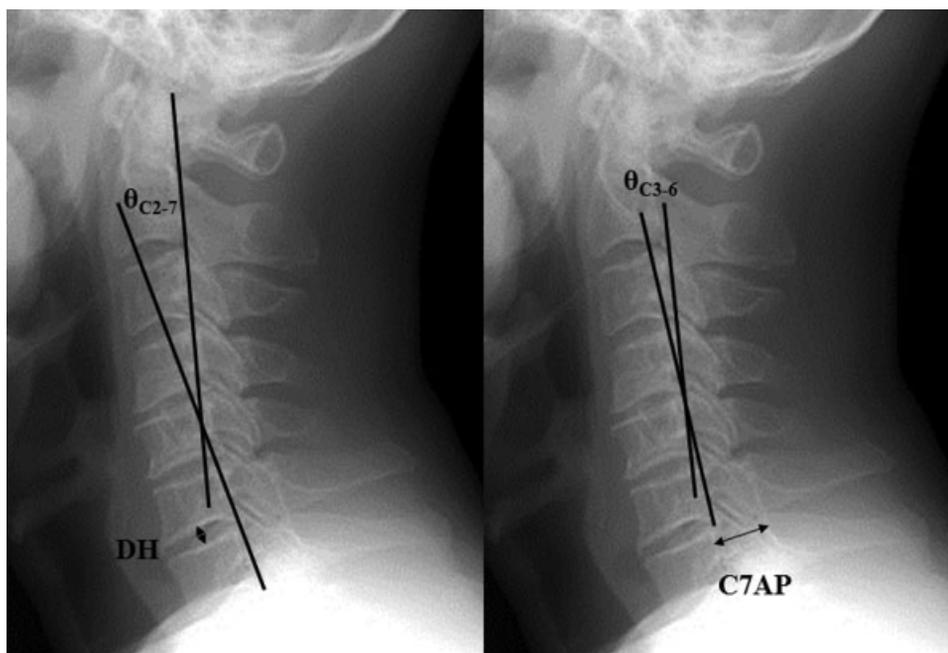


Fig. 1 Radiologic measurements. C3–C6 range of motion was calculated by subtracting C3–C6 angle in maximal flexion from C3–C6 angle in maximal extension. DH at the C6–C7 level was measured as intervertebral disk height at the anteroposterior midpoint of the disk on a radiograph in the neutral position. Abbreviations: C7AP, anteroposterior spinal canal diameter at the C7 level; DH, disk height; θ_{C2-7} , the C2–C7 angle measured as the angle formed by two lines drawn parallel to the posterior margin of the C2 and C7 vertebral bodies on a radiograph in the neutral position; θ_{C3-6} , the C3–C6 angle measured as the angle formed by two lines drawn parallel to the posterior margin of the C3 and C6 vertebral bodies.

United States), as appropriate. Values of $p < 0.05$ were considered significant.

Results

Incidence of LND after C3–C6 Laminoplasty for CSM

Three patients (2.2%) developed LND of myelopathic symptoms due to caudal segment pathology adjacent to the C3–C6 laminoplasty (LND group, ▶Table 1). All three patients developed late spastic gait disturbance. In these three patients, the mean JOA score improved from 10.2 before surgery to 12.2 at the time of maximum recovery, and declined to 9.7 just before additional surgery (▶Table 2). A 55-year-old man and a 71-year-old man suffered from deterioration of cervical myelopathy resulting from stenosis at the C6–C7 level due to progression of degenerative changes at 16 and 48 months after C3–C6 laminoplasty, respectively, and both patients underwent additional C7 laminoplasty (▶Tables 1 and 2). The remaining patient, a 63-year-old man, developed deterioration of myelopathic symptoms due to C7 listhesis 60 months after C3–C6 laminoplasty and was treated with additional C7–T1 laminoplasty (▶Tables 1 and 2, ▶Fig. 3). In all three patients, myelopathic symptoms improved after the additional surgery (▶Table 2).

On the other hand, in 134 patients of the non-LND group, the mean JOA score (\pm standard deviation) significantly improved from 10.2 ± 2.3 before surgery to 13.4 ± 2.1 at the time of maximum recovery, and the improvement was maintained by the final follow-up (13.2 ± 2.2).

Factors Associated with LND after C3–C6 Laminoplasty for CSM

All three patients in the LND group were younger than those in the non-LND group. The mean C2–C7 angles in the LND group were less lordotic than those in the non-LND group both before surgery and at final follow-up. However, no significant differences were evident between the LND and non-LND groups in age at time of surgery, sex, surgical procedures (bi- or unilateral open-door laminoplasty), type of C6 spinous process (C7 or C6 + 7 type), C2–C7 angle both before surgery and at final follow-up, preoperative C3–C6 ROM, and disk height at C6–C7 both before surgery and at final follow-up (▶Table 3). In contrast, compared with the non-LND groups, the LND group showed a significantly smaller spinal canal diameter at C7, more restricted postoperative C3–C6 ROM, and greater postoperative decrease in disk height at C6–C7 (▶Table 3). However, a logistic regression analysis showed no significant differences among these three factors associated with LND (▶Table 4).

Discussion

Some surgeons have applied less-invasive selective laminoplasty to reduce damage to the cervical posterior elements such as the paraspinal muscles and the nuchal ligament to prevent some surgery-associated problems, including axial neck pain and loss of cervical lordosis.^{6–9} Takeuchi and Shono reported no significant difference in mean recovery rate of the JOA score at 2-year follow-up between C3–C6

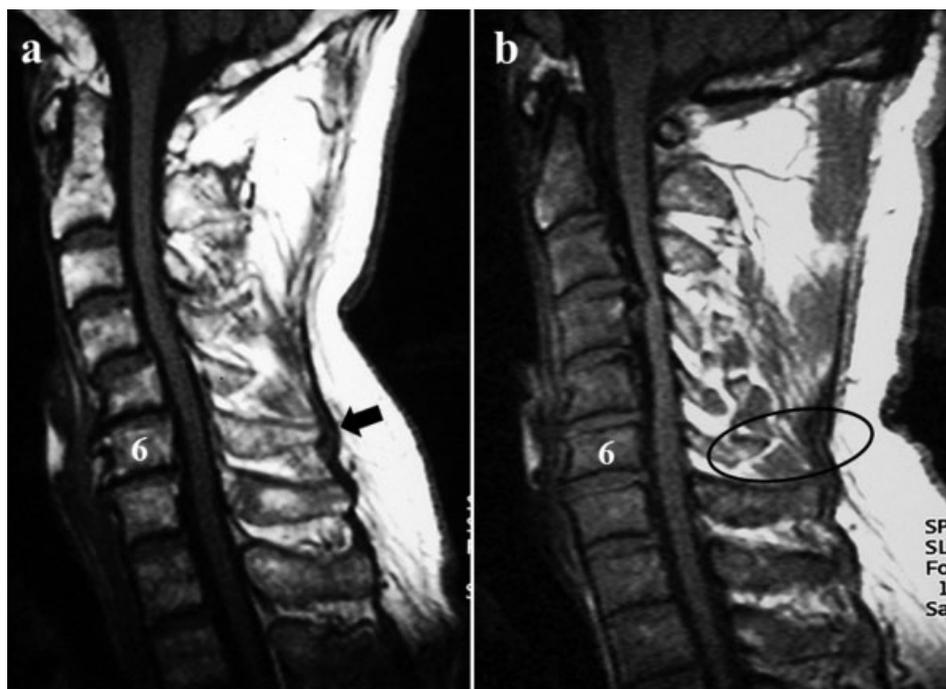


Fig. 2 Types of the C6 spinous process. (a) Sagittal T1-weighted magnetic resonance imaging (MRI) shows the funicular section of the nuchal ligament tightly attached to both the C6 and C7 spinous processes (C6 + 7 type, arrow). (b) Sagittal T1-weighted MRI shows the funicular section of the nuchal ligament not attached to the C6 spinous process but tightly attached to the C7 spinous process (C7 type, circle).

laminoplasty and C3–C7 procedure.⁷ Compared with the conventional C3–C7 laminoplasty, a more selective laminoplasty for CSM reportedly provides comparable short-term (2-year) neurologic improvement.⁸ The long-term (8 to 10 years) neurologic outcomes of our C3–C6 unilateral open-door laminoplasty preserving muscles attached to the C2 and C7 spinous processes were satisfactory, with reduced frequencies of postoperative axial neck pain and kyphotic deformity.¹ No patients had developed LND of myelopathic symptoms due to cervical spine lesions by the latest follow-up.¹ Higashino et al also reported that no patient had experienced LND resulting from the progression of cervical spine degeneration after C3–C6 bilateral open-door laminoplasty in their study (mean follow-up, 9.6 years; minimum, 5 years).⁶ In patients with CSM, the prevalence of spinal cord compression at the C6–C7 level is relatively low.^{10,11} These results suggest that the risk of LND due to progression of degenerative changes at C6–C7 and/or lower levels after C3–C6 laminoplasty could be reduced. However, a major

limitation in these two studies concerning long-term outcomes of C3–C6 laminoplasty for CSM was that only 20 patients were investigated,¹ and the retrospective study by Higashino et al included only 42 patients.⁶ Therefore, whether LND after C3–C6 laminoplasty for CSM can result from progression of degenerative changes at C6–C7 and/or caudal levels must be clarified in a larger patient population.

The present study retrospectively investigated the incidence of LND after C3–C6 laminoplasty for CSM in 137 consecutive patients. As a result, three patients (2.2%) developed LND of myelopathic symptoms due to the progression of degenerative changes subjacent to C3–C6 laminoplasty. Long-term follow-up studies of conventional C3–C7 (or T1) laminoplasty for CSM have shown the incidence of LND reaching 0 to 5.7%.^{12–15} Given these results, we consider the incidence of LND after C3–C6 laminoplasty for CSM in this study (2.2%) as acceptable, but this value should not be understated.

The present study also investigated significant risk factors for LND after C3–C6 laminoplasty for CSM. There were no

Table 1 Three cases of late neurologic deterioration after C3–C6 laminoplasty

Case no.	Age at initial surgery (y)/sex	Cause of late neurologic deterioration	Duration between initial and additional surgery (mo)	Additional surgical procedure
1	55/male	C6–C7 stenosis	16	C7 laminoplasty
2	71/male	C6–C7 stenosis	48	C7 laminoplasty
3	63/male	C7 listhesis	60	C7–T1 laminoplasty

Table 2 Clinical results in three cases of late neurologic deterioration after C3–C6 laminoplasty

Case no.	JOA score before initial surgery (points)	JOA score at the time of maximum recovery (points)	JOA score before second surgery (points)	JOA score at final F/U (points)/F/U period after second surgery (mo)
1	9.0	11.5	9.5	11.0/68
2	10.0	12.5	9.5	11.5/76
3	11.5	12.5	10.0	12.0/18

Abbreviations: F/U, follow-up; JOA, Japanese Orthopaedic Association.

significant differences in age at time of surgery, sex, surgical procedures, type of C6 spinous process, C2–C7 angle both before surgery and at final follow-up, preoperative C3–C6 ROM, and disk height at C6–C7 both before surgery and at final follow-up between the LND and non-LND groups. On the other hand, the LND group showed a significantly smaller anteroposterior spinal canal diameter at C7, more restricted postoperative C3–C6 ROM, and greater postoperative decreases in disk height at C6–C7 compared with the non-LND group, although a logistic regression analysis showed no significant differences. All three patients developed LND of myelopathic symptoms due to the progression of

degenerative changes at the segment immediately caudal to C3–C6 laminoplasty in the present study. These results might indicate that, similar to adjacent segment disease after spinal fusion surgery, severe restriction of C3–C6 ROM after C3–C6 laminoplasty could alter the spinal biomechanics of the caudal segments and affect the mechanical stress on these segments. Therefore, in patients with CSM with more severe developmental spinal canal stenosis at C7, accelerated degeneration at the caudal segments resulting from restricted C3–C6 ROM after C3–C6 laminoplasty might lead to LND. Some surgeons have reported similar cases, supporting our idea.^{14,16,17} In the present series, some patients developed

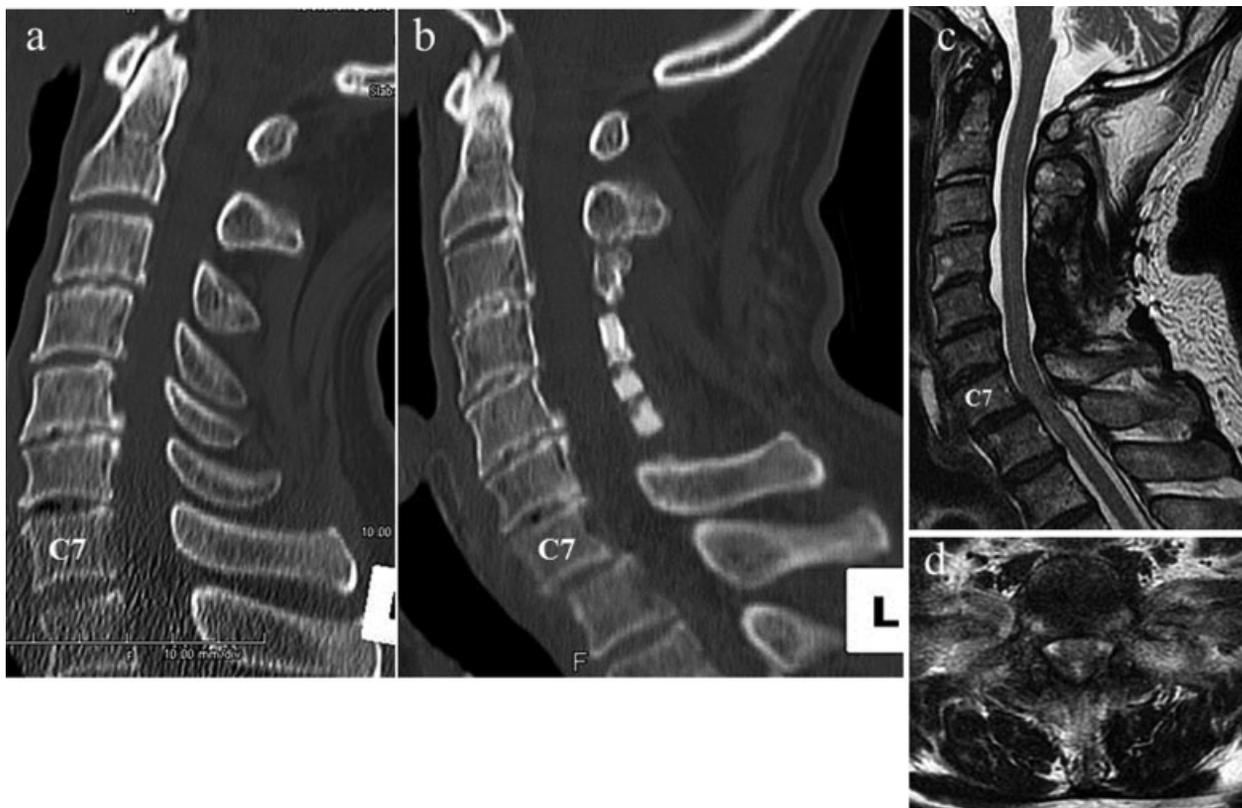


Fig. 3 Case 3. A 63-year-old man who developed late deterioration of myelopathic symptoms due to C7 listhesis at 60 months after C3–C6 laminoplasty for cervical spondylotic myelopathy. (a) Sagittal reconstruction of computed tomography (CT) shows no C7 listhesis before the initial C3–C6 laminoplasty. (b) Sagittal reconstruction of CT demonstrates C7 listhesis 60 months after C3–C6 laminoplasty. (c) T2-weighted sagittal magnetic resonance imaging (MRI) shows spinal canal stenosis at C7–T1 due to C7 listhesis. (d) T2-weighted axial MRI demonstrates spinal cord compression at C7–T1.

Table 3 Factors associated with late neurologic deterioration after C3–C6 laminoplasty

	LND group	Non-LND group	p
Age at the initial surgery (y)	63.0 ± 8.0	70.9 ± 10.0	0.186 ^c
Sex (male: female)	3: 0	77: 57	0.066 ^d
Surgical procedure (double-door: single-door)	3: 0	82: 52	0.172 ^d
Anteroposterior spinal canal diameter at C7 (mm)	11.3 ± 1.3 ^a	12.6 ± 1.1	0.047 ^c
Types of C6 spinous process (C7 type: C6 + 7 type)	1: 2	54: 80	0.810 ^d
C2–C7 angle before surgery (degrees)	2.6 ± 8.7	11.6 ± 11.3	0.183 ^c
C2–C7 angle at final F/U (degrees)	1.3 ± 11.0	8.9 ± 10.1	0.216 ^c
Loss of C2–C7 angle (degrees)	1.3 ± 2.3	2.8 ± 7.5	0.744 ^c
C3–6 ROM before surgery (degrees)	25.3 ± 14.2	28.6 ± 9.6	0.583 ^c
C3–6 ROM at final F/U (degrees)	8.7 ± 6.4 ^a	20.1 ± 8.6	0.028 ^c
Loss of C3–6 ROM (degrees)	16.7 ± 11.0	8.5 ± 7.8	0.091 ^c
Disk height at C6–C7 before surgery (mm)	4.8 ± 1.3	4.4 ± 1.5	0.693 ^c
Disk height at C6–C7 at final F/U (mm)	4.0 ± 1.5	4.1 ± 1.6	0.906 ^c
Loss of disk height at C6–C7 (mm)	0.8 ± 0.3 ^b	0.3 ± 0.4	0.041 ^c

Abbreviations: double-door, bilateral open-door laminoplasty; F/U, follow-up; LND, late neurologic deterioration; ROM, range of motion; single-door, unilateral open-door laminoplasty.

Note: Values are given as mean ± standard deviation.

^aSignificantly smaller than non-LND group.

^bSignificantly greater than non-LND group.

^cUnpaired t test.

^dFisher exact probability test.

Table 4 Factors associated with late neurologic deterioration after C3–C6 laminoplasty (logistic regression analysis)

	p	Odds ratio	95% confidence interval
Anteroposterior spinal canal diameter at C7 (mm)	0.114	9.434	8.013–10.855
C3–C6 ROM at final F/U (degrees)	0.101	1.542	1.278–1.806
Loss of disk height at C6–C7 (mm)	0.056	0.004	–2.921–2.929

Abbreviations: F/U, follow-up; ROM, range of motion.

severe restriction of C3–C6 ROM after C3–C6 laminoplasty, although all patients wore a soft collar only for the first 2 weeks after surgery and their necks were mobilized when the soft collar was taken off 2 weeks postoperatively. Because it is impossible to predict which patients would develop severe postoperative restriction of C3–C6 ROM, patients with more severe developmental spinal canal stenosis at C7 may benefit from C3–C7 laminoplasty even if spinal cord compression at the C6–C7 segment is not apparent before the surgery.

Few reports have described revision surgery following cervical laminoplasty.^{16–18} The revision rate for LND of myelopathic symptoms after laminoplasty reaches 1.7 to 4.6%.^{16,17} The surgical procedures for revision vary according to the pathologic condition and the preferences of the individual surgeon: posterior decompression and/or posterior spinal fusion, anterior decompression and fusion, or circumferential fusion.^{16–18} In the present series, myelopathic

symptoms improved after additional laminoplasty in all three patients who required revision surgery. Because the number of patients who underwent revision surgery after cervical laminoplasty was very small in the previous reports,^{16–18} the optimal surgical procedures remain controversial. The surgical procedures should thus be tailor-made for each case according to the existing pathologic conditions.

A key limitation of the present study was that the number of patients who developed LND of myelopathic symptoms after C3–C6 laminoplasty for CSM was very small. Because a logistic regression analysis showed no differences in significant risk factors for LND, this limitation led to a relatively low statistical power. Further follow-up studies with much larger patient populations than this study are needed to more accurately clarify the incidence of LND after C3–C6 laminoplasty for CSM and to confirm significant risk factors for LND.

In conclusion, 3 of the 137 patients (2.2%) developed LND of myelopathic symptoms due to caudal segment pathology

adjacent to the C3–C6 laminoplasty for CSM. Smaller anteroposterior spinal canal diameter at C7, more restricted postoperative C3–C6 ROM, and greater postoperative decrease in disk height at C6–C7 were significantly associated with LND, although a logistic regression analysis showed no significant differences. In patients with CSM with more severe developmental spinal canal stenosis at C7, accelerated degeneration at the caudal segments resulting from restricted C3–C6 ROM after C3–C6 laminoplasty might lead to LND.

Disclosures

Hironobu Sakaura, none

Toshitada Miwa, none

Yusuke Kuroda, none

Tetsuo Ohwada, none

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