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Reoperation for Late Neurological Deterioration After Laminoplasty in Individuals With Degenerative Cervical Myelopathy

Comparison of Cases of Cervical Spondylosis and Ossification of the Posterior Longitudinal Ligament

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Study Design. Retrospective cohort study.

Objective. The objective of this study was to elucidate the rate and causes of reoperation for late neurological deterioration after cervical laminoplasty by comparing cases of cervical spondylotic myelopathy (CSM) with those of ossification of the posterior longitudinal ligament (OPLL).

Summary of Background Data. Although the long-term surgical outcomes of cervical laminoplasty in patients with CSM or OPLL are satisfactory, reoperation is sometimes required for late neurological deterioration after laminoplasty. However, limited information is available about long-term follow-up in such cases.

Methods. This retrospective cohort study included 623 patients who underwent cervical laminoplasty for cervical myelopathy (average follow-up duration, 6.1 [range, 2–15] years). The rate of reoperations for late neurological deterioration (>6 mo after the initial surgery) was investigated.

Results. Primary diagnoses were CSM and OPLL in 522 (83.8%) and 101 (16.2%) patients, respectively. During the follow-up period, 10 (1.6%) patients required reoperation: 7 (1.3%) in the CSM group and 3 (3.0%) in the OPLL group. No significant difference was found between the CSM and OPLL groups regarding patients requiring reoperation ($P = 0.26$). The mean elapsed time between primary surgery and reoperation was 4.7 ± 3.2 and 10.0 ± 5.7 years in the CSM and OPLL groups, respectively. The predicted risk percentages of reoperation at 10 years after primary surgery were 2.9% and 1.0% in the CSM and OPLL group, respectively. The causes of reoperation for CSM were C5 palsy in five, severe radiculopathy in one, and restenosis due to instability after laminoplasty in one case; the cause of reoperation for OPLL was enlargement of ossification in all three cases.

Conclusion. Although the clinical outcomes of laminoplasty were favorable in most patients, reoperation for late neurological deterioration was required in approximately 1.0% to 3.0% of CSM and OPLL cases within 10 years after laminoplasty.

Key words: C5 palsy, cervical laminoplasty, cervical spondylotic myelopathy, long-term outcomes, neurological deterioration, ossification of the posterior longitudinal ligament, reoperation.

Level of Evidence: 4

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Degenerative cervical myelopathy (DCM) is an overarching term that refers to various conditions, including nontraumatic and degenerative forms of cervical myelopathy due to cervical spondylosis, disc herniation, calcification, or ossification.[1] DCM is the leading cause of adult spinal cord dysfunction worldwide; it often progresses and leads to functional impairment.[1] Surgical decompression is a standard method used to treat neurological deterioration and prevent further disability in patients with symptomatic DCM.[2] Several studies have validated positive functional and quality-of-life outcomes after surgery and a relatively low rate of surgical complications.[2–4]

Among various surgical techniques, cervical laminoplasty is considered useful in achieving posterior decompression in

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individuals with multilevel cervical spinal cord compression.[5–7] Numerous reports have shown favorable long-term outcomes more than 10 years after laminoplasty. Based on the Japanese Orthopaedic Association (JOA) scores, a recovery rate of approximately 70% may be achievable, and the reoperation rate for recurrent neurological deterioration is quite low.[8–11]

Although C5 palsy is a common perioperative complication occurring immediately after primary surgery,[12,13] information about late neurological deterioration, which is observed more than 6 months after surgery, is limited. In clinical practice, reoperation for this condition after laminoplasty is sometimes performed.[14] However, the proportion of patients requiring reoperation and the timing of reoperation are not known due to the lack of studies focusing on revision surgery after laminoplasty. In addition, no studies have yet compared the rates of and causes of reoperation among patients with DCM, such as cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL).

The present study aimed to retrospectively evaluate the rate of reoperation for late neurological deterioration over the course of more than 2 years of follow-up in a large cohort of patients with DCM. Moreover, the rates of and causes of CSM and OPLL were compared. Finally, the risk factors for revision surgery after cervical laminoplasty were evaluated.

MATERIALS AND METHODS

This was a retrospective case series study. After the institutional review board approved the study, a surgical database was searched to identify all patients who had undergone cervical laminoplasty from 2003 to 2016. The inclusion criteria were as follows: (1) patients with confirmed CSM- or OPLL based-on magnetic resonance imaging (MRI) and computed tomography (CT) scan results and (2) those who underwent cervical laminoplasty as a treatment method. Meanwhile, patients who underwent cervical laminoplasty for trauma, those with infection and tumor, those younger than 20 years, and those with a history of cervical spine surgery or other neurological diseases were excluded. A total of 662 patients met the inclusion criteria of the current study. However, 39 did not undergo the 2-year follow-up and were therefore excluded. Finally, 623 patients (follow-up rate: 94.1%) were included in the analysis. The mean duration of follow-up after surgery was 6.1 ± 3.4 years, and 423 patients were men and 200 women, with a mean age of 66.1 ± 10.9 years at the time of surgery. Among 623 patients, 355 (57.0%) and 124 (19.9%) of the patients received 5- and 10-year follow-up, respectively. The clinical results were evaluated using the JOA scores.

Radiographical Assessment

Lateral cervical radiography was performed to measure the K-line[15] in patients with OPLL. A K-line is a straight line connecting the midpoints of the spinal canal at C2 and C7 on a neutral lateral radiograph. K-line (–) indicates that OPLL extends beyond the K-line, whereas K-line (+) indicates that OPLL does not extend beyond the K-line. C2-7 lordotic angle was also measured in a lateral cervical radiography.

Preoperative CT scan was performed to determine the ossification type (segmental, continuous, mixed, or circumscribed) of the OPLL based on the guidelines of the Investigation Committee on the Ossification of the Spinal Ligaments.[16,17] In addition, CT scan was conducted to measure the width of the intervertebral foramen at C5 in the intervertebral disc. The width of the intervertebral foramen on CT scan was measured at its narrowest point. The width of the foramen was measured on the palsy side in patients with C5 palsy. Meanwhile, the width was measured on both sides and the average was calculated in patients without palsy. To compare the radiological findings of patients with late-onset C5 palsy and those without, 100 patients without C5 palsy were randomly selected.

Surgical Procedure for Cervical Laminoplasty

A modified surgery based on the method described by Kurokawa was performed.[7,18] After exposing the lamina, the spinous processes were resected from their bases. The center of the lamina was cut, and bilateral grooves were created using a high-speed burr. The gap between the lamina was then bridged by local or artificial bone struts. Foraminotomy was not performed in any of the patients included in the current study.

Definition of the Second Cervical Spine Surgery for Late Neurological Deterioration

Surgeries for late-onset myelopathy, paralysis, or severe radicular pain ($\geq$6 months after laminoplasty) were investigated. Other reoperations for infection, epidural hematoma, or C5 palsy conducted immediately after surgery ($<$6 months after surgery) and surgeries for the cervical spine after trauma were not included in the analysis.

Statistical Analysis

Student *t* test and Fisher exact test were used to compare the variables between the two groups. Survival rates were expressed using the Kaplan-Meier method. The difference between the proportion of patients with CSM and OPLL who require reoperation was investigated using the log-rank test. *P* values less than 0.05 were considered statistically significant. The Statistical Package for the Social Sciences software version 26 was used for all analyses (SPSS Inc., Chicago, IL).

RESULTS

The primary diagnoses were CSM in 522 (83.8%) and OPLL in 101 (16.2%) patients. The preoperative JOA score was 9.9 ± 3.2 points, which had improved to 13.5 ± 2.5 points at 2 years after surgery and remained at 13.3 ± 2.3 points until 10 years after surgery. During the follow-up period, 10 (1.6%) patients required reoperation: 7 (1.3%) with CSM and 3 (3.0%) with OPLL. No significant

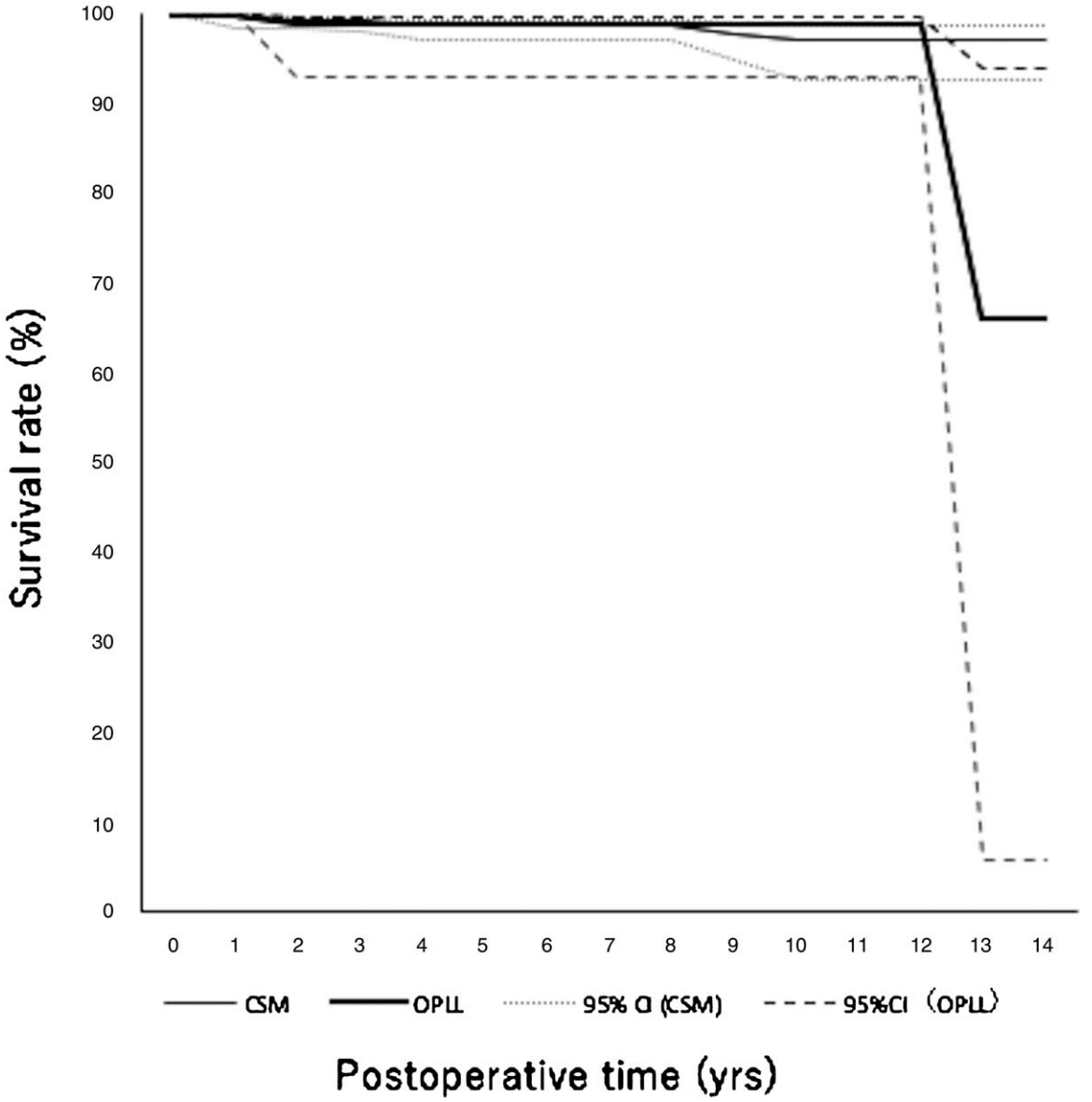

Figure 1. Revision surgery-free survival rates after cervical laminoplasty in patients with cervical spondylosis (CSM) or ossification of the posterior longitudinal ligament (OPLL). The revision surgery–free survival rates at 10 years were 97.1% (95% confidence interval [CI]: 92.9–98.8) and 99% (95% CI: 93.2–99.9) in patients with CSM and OPLL, respectively.

difference was observed between the CSM and OPLL groups in terms of reoperation rates based on the log-rank test ($P = 0.26$) (Figure 1). The mean elapsed time between primary surgery and reoperation were 4.7 ± 3.2 and 10.0 ± 5.7 years in the CSM and OPLL groups, respectively.

The predicted risk percentages of reoperation in CSM cases were 0.4%, 1.2%, and 2.9% at 2, 5, and 10 years after surgery, respectively, whereas those in OPLL cases were 1.0%, 1.0%, and 1.0% at 2, 5, and 10 years, respectively. In the CSM group, the causes of reoperation were C5 palsy in five, severe radiculopathy in one, and restenosis due to instability after laminoplasty in one patient. Meanwhile, the cause of reoperation in all three patients in the OPLL group was enlargement of ossification, which was observed at the caudal adjacent segment level in two patients and at the surgical level due to axial enlargement of ossification in one patient.

Regarding the risk factors for reoperation in patients with CSM, foraminal size at C4–5 was significantly smaller in patients requiring reoperation than in those who did not require reoperation (2.6 ± 1.1 *vs.* 3.7 ± 1.2 mm; $P = 0.03$) (Table 1). However, no significant differences were observed in terms of age, sex presence of diabetes mellitus (DM), or C2–7 lordotic angle (Table 1). In terms of the risk factors for reoperation in patients with OPLL, continuous- or mixed-type OPLL was primarily observed in patients requiring reoperation. However, no statistically significant difference was observed ($P = 0.62$, Table 2). In addition, age, sex, presence of DM, C2–7 lordotic angle, or K-line did not significantly differ (Table 2).

TABLE 1. Comparison Between Cervical Spondylotic Myelopathy Patients With and Without Late-onset C5 Palsy

	Patients With Late-onset C5 Palsy	Control Patients	*P*
Number of cases	5	100	
Age (yr)	67.3 ± 8.2	66.5 ± 10.4	0.87
Sex (male/female), n	5/0	68/32	0.32
DM (±), n	1/4	11/89	0.46
C2–7 lordotic angle	10.2 ± 10.8	11.3 ± 11.2	0.83
Preoperative width of the C5 intervertebral foramen (mm)	2.6 ± 1.1	3.7 ± 1.2	0.03

DM indicates diabetes mellitus; n, number.

REPRESENTATIVE CASE

A 55-year-old man presented with bilateral hand clumsiness, hand numbness, and walking disability. MRI showed cord compression and signal intensity change. The patient was diagnosed with CSM (Figure 2A and B). We performed laminoplasty from C3 to C6. The patient's condition improved and the JOA score increased from 7 to 14 points. Although his neurological recovery was maintained, he presented with left side C5 palsy 9 years after laminoplasty (Figure 2C and D). His manual muscle strength test score for the left deltoid and biceps was 2/5. He underwent anterior discectomy and fusion at C4–5 because his C5 palsy did not improve after 3 months of conservative rehabilitation treatment. Three months after anterior discectomy and fusion at C4–5, his C5 palsy had disappeared (Figure 2E), and the JOA score was 14 points at 2 years after the second surgery.

DISCUSSION

Several studies have investigated the long-term (>10 yr) clinical outcomes of cervical laminoplasty. Although these studies have shown satisfactory results, as indicated by the JOA score,[8–11] information about revision surgery for late neurological deterioration is limited.[14] Although most patients had favorable outcomes after laminoplasty for DCM, the current study showed that 1.6% of patients with DCM underwent second cervical spine surgery for late neurological deterioration within 10 years of primary surgery. Moreover, the risk ratios in patients with CSM and OPLL requiring revision surgery were not significantly different at 10 years after primary surgery. However, the causes of revision surgery were different. That is, the main causes of revision surgery after cervical laminoplasty were C5 palsy in patients with CSM and progression of ossification in patients with OPLL. Moreover, this study revealed that the mean elapsed time from primary to secondary surgery was more than 5 years, indicating that cautious follow-up after laminoplasty is essential.

Cervical laminoplasty was developed in the 1990s to prevent spinal problems associated with laminectomy, which include postoperative segmental instability, kyphosis, or postlaminectomy adhesion around the dura matter.[5] Since then, several modified procedures, such as open or French door laminoplasty, have been developed.[6,7] The indication of laminoplasty is cervical myelopathy due to multilevel canal stenosis without cervical kyphosis or large OPLL, which has been used quite often for the treatment of DCM.

Several reports have shown favorable long-term outcomes, with maintenance of the JOA score in most cases, and only a small proportion of patients has low scores

TABLE 2. Comparison Between Ossification of the Posterior Longitudinal Ligament Patients With and Without Late Neurological Deterioration

	Patients With Late Neurological Deterioration	Control Patients	*P*
Number of cases	3	98	
Age (yr)	58.7 ± 14.3	64.4 ± 10.6	0.87
Sex (male/female), n	3/0	71/27	0.32
DM (±), n	0/3	25/73	0.46
Type of OPLL, n			0.62
Continuous	1	37	1.00
Mixed	2	34	0.29
Segmental	0	24	1.00
Circumscribed	0	3	1.00
C2–7 lordotic angle	8.2 ± 11.5	10.3 ± 11.7	0.76
K-line ±, n	2/1	75/23	0.56

DM indicates diabetes mellitus; n, number; OPLL, ossification of the posterior longitudinal ligament.

Figure 2. Representative images of a 79-year-old man with late left C5 palsy. **A**, Preoperative lateral radiography image, (**B**) preoperative magnetic resonance imaging (MRI) images, (**C**) lateral x-ray image 9 years after surgery, (**D**) axial MRI images 9 years after surgery, and (**E**) lateral x-ray image after revision surgery.

associated with other spine lesions or age-related factors.[8–11] Seichi *et al*[8] have first investigated the long-term (>10 yr) outcomes of cervical double-door laminoplasty in 35 patients with DCM. Neurological deterioration was observed in 10 patients, with an average follow-up of 8 years after surgery. The condition of the three patients worsened because of thoracic myelopathy due to ossification of the yellow ligament. Cervical myelopathy worsened in seven patients, and deterioration in neurological status after sustaining minor trauma was observed in five of them; the remaining two patients experienced neurological deterioration due to age-related changes. Moreover, Iwasaki *et al*[9] have reported about the long-term (>10 yr) outcomes of cervical laminoplasty for

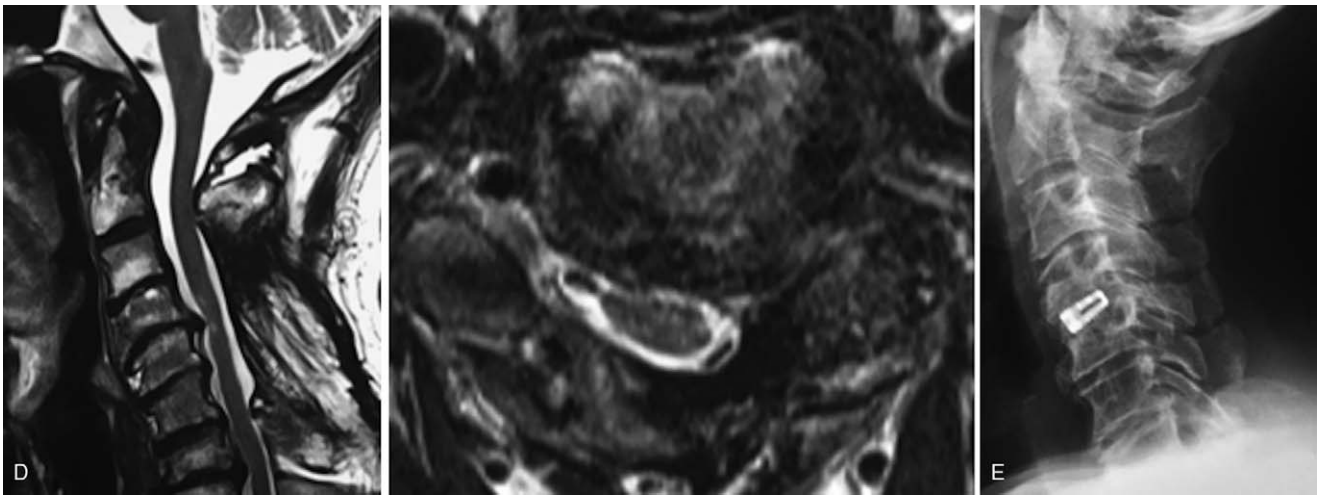

Figure 2. (Continued).

OPLL in 64 patients. Late neurological deterioration occurred in eight (14%) patients 5 to 15 years after surgery; the most frequent cases of late deterioration were degenerative lumbar diseases (n = 3), thoracic myelopathy (n = 2), and postoperative progression of OPLL at the surgical level (n = 2). Postoperative progression of OPLL was observed in 70% of patients. However, only two (3%) had deterioration in neurological status. Moreover, Kawaguchi *et al*[10] have reported about long-term outcomes (>10 yr) after cervical laminoplasty in 126 patients with cervical myelopathy. The JOA score and recovery rate were maintained at 13.4 points and 55.1%, respectively, during the last follow-up. However, the JOA score decreased in 20 (15.9%) patients, and the causes of the decrease in score include axial spread of OPLL, other spinal lesions, cerebral infarction, and peripheral neuropathy. Postoperative radiculopathy occurred in nine (7.1%) patients. However, it disappeared in five of these patients. Furthermore, Chiba *et al*[11] have reported about long-term efficacy and spinal problems after laminoplasty in 80 patients with cervical myelopathy due to CSM and OPLL. Although OPLL progression was observed in 66% of patients, the long-term outcomes were satisfactory; progression did not affect clinical outcomes. Neurological deterioration, as assessed using the JOA scores (change >1 point), was observed in 1.3%, 6.3%, and 2.5% of patients within 5 years, between 5 and 10 years, and more than 10 years after surgery, respectively. However, the decrease in score was attributed to age-related comorbidities, which include dementia and osteoarthritis in the lower extremity.

As in these reports, neurological deterioration was attributed to age-related changes or other spinal problems. However, the occurrence of neurological deterioration due to cervical problems after laminoplasty was rare, except for OPLL progression. OPLL progression based on radiography was commonly observed. However, it is not significantly associated with neurological deterioration.[10,11] In general, the development of ossification is more common in patients who underwent posterior decompression surgery than in those who underwent anterior fusion due to instability after decompression.[19] In addition, postoperative kyphosis, which is correlated to neurological deterioration, occurred in some patients after laminoplasty.[20] As for OPLL progression observed on radiography, 70% of patients showed an increase in OPLL size 10 years after surgery.[21] The size of ossification commonly increases in young adults and those with continuous- or mixed-type OPLL.[21] Numerous patients with OPLL progression required reoperation after laminoplasty.[8,19,20,22–24] However, the risk factors for revision surgery are not fully elucidated due to the lack of studies focusing on revision surgery. In our study, only continuous- or mixed-type OPLL was observed in patients who underwent revision surgery, which is similar to the risks of OPLL progression in previous reports. Further studies with a larger number of patients must be conducted to clearly identify the risk factors for reoperation in patients with OPLL.

The need for revision surgery for late neurological deterioration in patients with CSM was not identified until recently. Rodriguez-Feo *et al*[14] have reported that 14 (6.3%) of 222 patients with cervical laminoplasty underwent reoperation outside of the acute postoperative period due to the following causes: development of a new radiculopathy (n = 6 [2.7%]), recurrent myelopathy (n = 3 [1.3%]), development of neurologic symptoms with kyphotic deformity (n = 2 [0.9%]), and unknown reasons (because some patients underwent reoperation in other hospitals; n = 3 [1.3%]). Radicular symptoms were the most common cause of late reoperations based on the study of Rodriguez-Feo *et al*; this result was similar to that in our current study. However, the Rodriguez-Feo *et al*'s study included patients who underwent not only laminoplasty alone but also other surgeries (50%, concomitant laminectomies; 3%, arthrodesis; and 38%, concomitant foraminotomies). Consequently, the surgical outcomes after laminoplasty alone were not clearly elucidated in

their study. As mentioned earlier, C5 palsy was the main cause in the current study. However, information about late-onset C5 palsy is limited. Patients with C5 palsy had unilateral symptoms and foraminal stenosis in the current study. Because MRI did not show any recurrent central canal stenosis, anterior cervical discectomy and fusion at C4–5 were performed to decompress the affected foramen, and neurological recovery was achieved in all cases. C4–5 foraminotomy might be useful to minimize reoperation for CSM with laminoplasty. However, the rate of reoperation is not high, so foraminotomy is not necessarily recommended for all cases with preoperative foraminal stenosis. The number of reoperation cases was limited in the current study; future large-scale studies involving many cases of reoperation are needed to validate prophylactic foraminotomy.

The present study had a couple of limitations. First, the follow-up rate was 94% at 2 years after surgery; however, the follow-up rate is not high at 10 years. Then, several patients might have reoperations at other hospitals without our knowledge. Although the Kaplan-Meier Analysis was used rather than direct analysis of the reoperation rate in the current study, a future study with higher rate of long-term follow-up is necessary. Second, this was a retrospective study, and the indications for laminoplasty were not standardized due to the study design. Posterior cervical decompression and fusion or anterior fusion were performed on patients with kyphosis, spondylolisthesis, or large OPLL. The indications for decompression surgery for DCM varied. Furthermore, the indications for a second surgery were not standardized. Thus, future large-scale prospective studies must be conducted.

In conclusion, cervical laminoplasty is a useful surgical technique for most patients with DCM. However, in this study, 1.6% of patients required reoperation for late neurological deterioration. Preoperative foraminal stenosis was a risk factor for revision surgery in patients with CSM, and cautious follow-up of these patients is crucial.

➢ Key Points

- ❑ A total of 623 patients with late neurological deterioration after cervical laminoplasty for degenerative cervical myelopathy were investigated.
- ❑ The primary diagnoses were CSM and OPLL in 522 (83.8%) and 101 (16.2%) patients, respectively, with an average follow-up of 6.1 years.
- ❑ Ten (1.6%) patients required reoperation: seven (1.3%) in the CSM group and three (3.0%) in the OPLL group.
- ❑ The predicted risk percentages of reoperation at 10 years after primary surgery were 2.9% in CSM cases and 1.0% in OPLL cases.

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