Surgical treatment assessment of cervical laminoplasty using quantitative performance evaluation in elderly patients: a prospective comparative study in 505 patients with cervical spondylotic myelopathy

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KEY POINTS

- Surgical outcomes of non-elderly and elderly patients with cervical spondylotic myelopathy (CSM) who underwent laminoplasty were compared.
- The achieved Japanese Orthopaedic Association for cervical myelopathy (JOA) score was not significantly different between the non-elderly and elderly groups.
- Both groups showed a postoperative increase in scores for the 10-s grip and release test (10-s G&R) test and the 10-s step test, indicating that elderly and non-elderly patients benefit similarly from laminoplasty.
- The 10-s G&R test and the 10-s step test are useful quantitative parameters for the assessment of surgical outcome in CSM.

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a neurological disorder caused by spinal canal stenosis due to degenerative changes in the cervical spine.[1-3] Patients with CSM may have various symptoms, such as spastic gait, spasticity with muscular atrophy, sensory impairment of the hands, and sphincter disturbances. In mild cases, various conservative treatment options, such as rest, cervical traction, cervical braces, and medication, may be used.[1,2] Surgical intervention is indicated in severe and progressive cases or in cases where conservative treatment is ineffective.[4]

Cervical laminoplasty is a suitable surgical option in many patients with cervical myelopathy caused by multilevel spinal cord compression,[5] and numerous studies have documented satisfactory results with this method.[6-12] However, several authors have reported that the surgical outcome of laminoplasty is worse in elderly patients than in younger patients.[11,13-15] Recovery of spinal cord function may be insufficient in the elderly because of increased vulnerability of the spinal cord.

We hypothesized that elderly patients with CSM could obtain reasonable recovery after cervical laminoplasty, and laminoplasty would be beneficial for them. Although a few studies have focused exclusively on the outcome of a single surgical procedure for CSM in elderly patients,[4,16,17] the surgical outcome of laminoplasty has not been fully evaluated, especially in a large-scale study. Therefore, we designed a large-scale cohort study to examine the outcome of laminoplasty for CSM in elderly patients, compare it with that in non-elderly patients, and determine the impact of age on the outcome using a quantitative evaluation method.

MATERIALS AND METHODS

Study Population

quantitative evaluation in elderly patients

Between January 2007 and March 2011, 701 consecutive patients underwent modified double-door laminoplasty for CSM. The exclusion criteria were as follows: (1) presence of ossification of the posterior longitudinal ligament (OPLL); (2) history of rheumatoid arthritis, cerebral palsy, or tumors; (3) spinal injuries; (4) destructive spondyloarthritis caused by hemodialysis; (5) previous cervical surgery; (6) spinal fusion with instrumentation; (7) thoracic spondylotic myelopathy; and (8) lumbar spinal canal stenosis. Of the 701 patients, 528 with CSM were eligible for participation in the study; and of them, 505 who were followed up for >12 months after surgery were prospectively enrolled (follow-up rate, 95.6%). The final sample comprised 311 males and 194 females (mean age, 66.6 years; range, 41–91 years).

Patients were divided into the following three groups by age: non-elderly (<65 years, n = 201), young-old (65–74 years, n = 186), and old-old (≥75 years, n = 118) (Figure 1).[17] Clinical outcome was investigated among the three groups based on the primary hypothesis. Differences in the following parameters were evaluated among the three groups: age, gender, symptom duration, body height, body weight, body mass index (BMI), cervical alignment and range of motion (ROM), occurrence of increased signal intensity (ISI) on magnetic resonance T2-weighted imaging (MRT2WI), diabetes, hypertension, hyperlipidemia, use of anticoagulant or antiplatelet agents, smoking history, and postoperative follow-up duration.

All patients presented with symptoms of myelopathy. Magnetic resonance imaging (MRI) and myelography findings were consistent with myelopathy secondary to multisegmental cervical spondylotic stenosis. Each patient had myelopathy confirmed by a physical examination, and cord compression was present between C2/C3 and C7/T1 disc levels. Our Institutional Review Board approved this study, and written informed consent was obtained from each patient before study participation or surgery.

quantitative evaluation in elderly patients

Surgical Technique for Modified Double-Door Laminoplasty

We performed double-door laminoplasty as described by Kurokawa with some modifications.[12,18,19] The muscles attached to the C2 spinous process were preserved without detachment. Surgical exposure was limited as much as possible. The spinous processes between C3 and C7 were resected at their bases, and the laminae were cut at the center with a high-speed drill. Bilateral gutters were created as hinges at the border between the laminae and the facets in a manner that was slightly more medial than originally described, thus minimizing invasion of the facets. After elevating the halves of the laminae like a French door, the bone graft struts (16–18 mm long) created from the C6 or C7 spinous process were tied to bridge the bilateral edges of the laminae.

Postoperative Considerations

All patients, with exceptions, were allowed to sit up and walk on postoperative day 1 while wearing a Philadelphia collar. The collars were fitted to all patients, but they were able to remove them at their discretion. Cervical range of motion exercises were performed as soon as possible during the rehabilitation program. Ideal spinal alignment was explained to all patients after surgery.

Clinical Outcome

Operation time and blood loss were assessed. The severity of myelopathy before and after surgery was evaluated according to a scoring system proposed by the Japanese Orthopaedic Association for cervical myelopathy (JOA score).[11,20] The assessment of postoperative JOA score was performed 1 year after surgery and at the final follow-up (Table 1). The recovery rate (RR) of the JOA score was calculated using the formula suggested by Hirabayashi et al.[20] [RR = postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100%]

quantitative evaluation in elderly patients (Table 1). The achieved JOA score (postoperative JOA score − preoperative JOA score) was also evaluated.[17,21]

To quantitatively assess performance, the 10-s grip and release test (G&R test) was used for upper limb function and the 10-s step test was used for trunk and lower limb function.[22,23] In the 10-s G&R test, data were collected from the left or right side, depending on which side was weaker.

10-s G&R test[22]

Each patient was asked to grip and release with the fingers as rapidly as possible with the forearm kept in pronation and the wrist in mild extension. The number of complete cycles of movement within 10 s was counted on each side separately.

10-s step test[23,24]

Each patient was asked to take high steps by bending their knee 90°, making their thighs parallel to the floor. They were asked to take as many of these steps as they could in place, without holding on to anything for balance for 10 s. If the patient seemed at risk of falling, the test was performed in proximity to a hand bar.

Complications

Complications, such as dural tear, postoperative epidural hematoma, C5 palsy, and local wound problems (i.e., infection and delayed wound healing) were investigated. C5 palsy was defined as paresis of the deltoid [manual muscle test (MMT) score of 0–2] with or without the involvement of the biceps with no loss of strength in other muscles.[25] Major complications such as death, myocardial infarction, heart failure, pulmonary thrombosis, pneumonia, cerebral infarction, and organ failure were assessed.

Radiographic outcomes

The lordotic angle between C2 and C7 was measured before surgery and at the final follow-up in the neutral and maximal flexion–extension lateral radiographic view (Cobb method), with negative and positive lordotic angles indicating cervical kyphosis and lordosis, respectively. The alignment change was also assessed: [Alignment change (degree) = (preoperative C2–C7 lordotic angle) − (postperative C2–C7 lordotic angle)].[26]

ROM of the cervical spine was assessed by measuring the difference in alignment at flexion and extension. Angles created by a line parallel to the inferior aspect of the C2 vertebral body and a line parallel to that of the C7 vertebral body were measured on flexion and extension lateral radiographs, and a total ROM value was obtained by summation of these angles. ROM preservation was assessed by the formula [ROM preservation (%) = (postoperative ROM)/(preoperative ROM) × 100].[26]

Statistical Analysis

Data were analyzed using SPSS statistical software (version 18.0; SPSS, Inc., Chicago, IL, USA). All values are expressed as mean ± standard deviation. The Mann–Whitney U test was performed to determine differences between two groups, and the Kruskal–Wallis test was used to analyze differences among three groups. The chi-square test was used to analyze differences between groups. $P < 0.05$ was considered statistically significant.

RESULTS

Laminoplasty was performed at the following disc levels: C3–C7 (n = 432), C3–C6, along with C7 dome-shaped fenestration (n = 37), C4–C7 (n = 21), C3–C6 (n = 11), and C3–T1 (n = 4). Mean operation time was 76.6 min (range, 38–160 min); mean blood loss was 51.2 ml (range, 1–500 ml); mean postoperative follow-up duration was 26.5 months (range, 12–66 months); mean disease duration was 15.4 months (range, 1–200 months); mean preoperative JOA score was 10.6 ± 2.6 points; and the mean postoperative JOA score was 13.6 ± 2.5 points at 1 year after surgery and 13.8 ± 2.5 points at the final follow-up. Mean RR of the JOA score was 51.8% ± 32.0%.

There was no significant intergroup difference in patient demographic data, except for gender, body height, and weight (Table 2). Although the elderly group showed a significantly higher prevalence of hypertension and greater use of anticoagulants and/or antiplatelet agents compared with the non-elderly group, there was no significant difference in prevalence of diabetes and hyperlipidemia or smoking history (Table 2). There was no significant difference in the follow-up duration among three groups (Table 3). Surgery time and blood loss decreased significantly with increasing age (Table 3). The mean preoperative JOA scores were 11.4, 10.5, and 9.5 in non-elderly, young-old, and old-old groups, respectively, and the mean postoperative JOA scores were 14.6, 13.7, and 12.5, respectively; the differences were significant between the elderly and non-elderly groups ($P < 0.0001$). The mean RR of the JOA score was 58.0%, 51.8%, and 41.3%, respectively, indicating a significant decrease with increasing age ($P < 0.0001$). However, the mean achieved JOA scores were 3.1, 3.2, and 3.0, respectively, with no significant difference among three groups ($P = 0.5735$) (Table 3 & Figure 2).

Furthermore, preoperative mean number of 10-s G&R test on the weaker side was 17.3, 14.4, and 13.0 in non-elderly, young-old, and old-old groups, respectively, indicating a significant decrease with increasing age ($P < 0.0001$). Postoperative results significantly improved to 21.0, 17.9, and 16.3, respectively ($P < 0.0001$) (Table 4 & Figure 3). Similarly, the 10-s step test significantly decreased with increasing age, with preoperative mean numbers of 14.3, 11.5, and 8.6, respectively ($P < 0.0001$) and postoperative results improving to 17.3, 14.9, and 12.5, respectively ($P < 0.0001$) (Table 4 & Figure 4).

No group had any major complications, such as death, myocardial infarction, or pulmonary thrombosis, and no intraoperative neural deterioration was detected. However, two patients in the non-elderly group had superficial wound complications, and one in the young-old group had postoperative deep infection below the deep fascia and muscles. There was no significant difference in surgical site infection among the three groups. The non-elderly, young-old, and old-old groups had intraoperative dural tears requiring repair in one, three, and two patients, respectively and C5 palsy in three, three, and one, respectively. Postoperative epidural hematoma was present in two non-elderly and one young-old, and heart failure was found in one young-old and one old-old. Pneumonia was present in one old-old, and cerebral infarction occurred in one young-old and one old-old. No patient with a C5 palsy needed additional surgery. All patients were treated conservatively with rest, rehabilitation of muscle strength, and ROM exercises in bed and further physiotherapy after their pain subsided. Seven patients had spontaneous recovery from C5 palsy at the final follow-up, and satisfactory recovery was achieved. There was no significant difference in the postoperative complication rate among the three groups [8/201 (4.0%) vs. 10/186 (5.4%) vs. 6/118 (5.1%), $P = 0.7971$] (Table 5).

Pre- and postoperative C2–C7 lordotic angle gradually increased with age and significantly increased after surgery ($P < 0.0001$). The pre- and postoperative cervical ROM significantly decreased with increasing age and significantly decreased following surgery ($P < 0.0001$). There was no significant difference in alignment change among the three groups ($P = 0.3402$) (Table 3).

DISCUSSION

quantitative evaluation in elderly patients

As the number of elderly in the population increases, so does the need to understand how age impacts surgical outcomes for the elderly. Age at time of surgery influences surgical outcome.[1,3,4,13-17,27]A number of laminoplasty procedures have been developed for the treatment of CSM.[6,7,18,19] This study aimed to compare laminoplasty outcomes for CSM patients based on age. We found that even elderly patients achieved a significant improvement of JOA score after surgery. Based on the achieved JOA score, no significant difference was observed in the surgical outcome among the 3 groups. Pre- and postoperative scores of the 10-s G&R and 10-s step tests were low in elderly patients, but the relative improvement in these measures was not significantly different from the other groups, demonstrating that surgical outcomes in elderly patients were comparable to those in non-elderly patients. Therefore, laminoplasty is beneficial and indicated in elderly patients with CSM who are in good physical condition. Advanced age alone is not a contraindication to surgical treatment.

A limitation of previous studies was the difficultly elderly patients often had in precisely describing their symptoms. The JOA score was used to comprehensively evaluate sensory and motor functions and surgical outcome. Several factors influenced activities of daily living (ADL) and the JOA score in the elderly. For example, the preoperative JOA score in elderly patients may be low due to physical weakness by age, cerebral vascular disorder, hip and knee osteoarthritis, entrapment peripheral neuropathy, diabetic neuropathy, benign prostatic hypertrophy, or urinary stress incontinence.[4]

Previously, it was found that outcomes of laminoplasty in elderly patients were poorer than in non-elderly patients.[11,13-15] Matsuda et al reported that although RR of the JOA score was lower in elderly patients, there was no significant difference in the preoperative JOA score among groups.[13] Other studies, however, have reported that both pre- and postoperative JOA scores and RR are lower in elderly patients.[14,15]

In contrast, Kawaguchi et al reported no significant difference in surgical outcomes between non-elderly and elderly patients; they also reported that cervical laminoplasty improved the quality of life and ADL in elderly patients with CSM.[16] Another study found that although there was no significant difference in RR of the JOA score among the different age groups, the preoperative JOA score was lower in elderly patients.[27]

Elderly patients often have complications such as hypertension; therefore, surgery should be as minimally invasive as possible. Since it is advisable to start rehabilitation early, the chosen surgical procedure should enable early ambulation. Most elderly CSM patients have multilevel spinal cord compression, and hypertrophy of the ligamentum flavum often causes posterior spinal cord compression. Since the incidence of damage to the adjacent segment is low after laminoplasty, it is the treatment of choice and allows for ambulation on postoperative day 1.[19] Moreover, lordosis is more common in elderly patients than in non-elderly patients. Hence, posterior decompression as laminoplasty is expected to be the suitable treatment option. Early ambulation and rehabilitation following surgery enabled elderly patients to maintain cervical lordosis similar to that of non-elderly patients, and cervical ROM was also preserved.[17]

JOA score alone is not sufficient to effectively quantify outcomes. Therefore, we utilized the 10-s G&R and 10-s step tests to quantitatively measure symptom severity.[22-24] Preoperatively, performance on both tests was lower in elderly patients than in non-elderly patients. However, both groups had improved performance on the two tests postoperatively, demonstrating that improvement after surgery is similar in both elderly and non-elderly patients and that these tests are useful for quantitatively evaluating surgical outcome in CSM.

quantitative evaluation in elderly patients

Left untreated, CSM causes irreversible paralysis and sensory damage.[28] Therefore, diagnosis at an appropriate stage is important, and surgical intervention is the only effective treatment option. However, when considering surgery for elderly CSM patients, risks of surgery should be fully explained, and the patient's general condition should be thoroughly ascertained.

There are, however, some limitations to our study. The follow-up duration was relatively brief. Moreover, patient-based objective outcomes, such as quality of life, as determined using the Short-Form Health Survey 36, subjective satisfaction, and axial back pain, as measured with the visual analog scale, were not assessed. We did not compare the surgical outcomes between patients with CSM who underwent double-door laminoplasty with those who underwent either anterior or another posterior surgery. Despite these limitations, it is important to note that this study is the largest of its kind to evaluate patients who underwent the same single procedure and that these patients were prospectively followed up with high a follow-up rate.

CONCLUSION

The elderly patients recovered to similar levels as the non-elderly patients after laminoplasty in terms of achieved JOA score, 10-s G&R test, and 10-s step test. Thus, laminoplasty for CSM is beneficial in elderly patients.

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Table 1.

Evaluation of cervical myelopathy using the scoring system proposed by the Japanese Orthopaedic Association (JOA score) and recovery rate of the JOA score.

JOA score

I. Motor function of the upper extremity
- 0. Impossible to eat with chopsticks or spoon
- 1. Possible to eat with spoon, but not with chopsticks
- 2. Possible to eat with chopsticks, but inadequate
- 3. Possible to eat with chopsticks, awkward
- 4. Normal

II. Motor function of the lower extremity
- 0. Impossible to walk
- 1. Needs cane or aid on flat ground
- 2. Needs cane or aid only on stairs
- 3. Possible to walk without cane or aid but slowly
- 4. Normal

III. Sensory function
- A. Upper extremity
  - 0. Apparent sensory loss
  - 1. Minimal sensory loss
  - 2. Normal
- B. Lower extremity (same as A)
- C. Trunk (same as A)

IV. Bladder function
- 0. Complete retention
- 1. Severe disturbance (sense of retention, dribbling, incomplete continence)
- 2. Mild disturbance (urinary frequency, urinary hesitancy)
- 3. Normal

Recovery rate of the JOA score (Hirabayashi method),
Recovery rate (%) = [Postoperative score − Preoperative score] / [Full score (17) − Preoperative score] × 100
Achieved JOA score,
Achieved JOA score (points) = Postoperative score − Preoperative score

Table 2.

Patient demographics, summary details and comorbidities for the three groups

	Non-elderly	Young-old	Old-old	*P* value
Number of patients	201	186	118	
Age (years)	56.5 ± 6.1	69.4 ± 2.8	79.5 ± 3.4	<0.0001
Gender (Males/Female)	146/55	114/72	51/67	<0.0001
Duration of symptom, months	15.7 ± 26.8	14.5 ± 21.2	16.2 ± 23.1	0.4979
Body height (cm)	163.0 ± 8.5	158.8 ± 8.4	152.7 ± 8.2	<0.0001
Body weight (kg)	63.3 ± 11.1	58.9 ± 9.4	54.2 ± 9.8	<0.0001
BMI	23.7 ± 3.5	23.3 ± 3.0	23.2 ± 3.4	0.2591
Occurrence of ISI on MRT2WI	133 (66.2%)	120 (64.5%)	84 (71.2%)	0.4736
Diabetes	36 (17.9%)	43 (23.1%)	26 (22.0%)	0.4200
Hypertension	59 (29.3%)	91 (48.9%)	79 (66.9%)	<0.0001
Hyperlipidemia	16 (8.0%)	27 (14.5%)	15 (12.7%)	0.1158
Use of Anticoagulant/Antiplatelet agent	28 (13.9 %)	50 (26.9%)	38 (32.2%)	0.0003
Smoking history	55 (27.4%)	49 (26.3%)	30 (25.4%)	0.9326

Values given are mean ± SD unless otherwise specified.
BMI indicates body mass index; ISI, increased signal intensity; MRT2WI, magnetic resonance T2-weighted imaging; SD, standard deviation.

Table 3.

Clinical and radiographic outcomes in the three groups

	Non-elderly	Young-old	Old-old	*P* value
Follow-up period (months)	27.2 ± 13.2	27.2 ± 11.7	24.4 ± 12.2	0.0539
Surgery time (minutes)	79.8 ± 25.6	76.2 ± 20.4	71.8 ± 19.3	0.0339
Blood loss (ml)	58.2 ± 51.8	48.5 ± 47.8	43.6 ± 51.8	0.0159
Preoperative JOA score (points)	11.4 ± 2.4	10.5 ± 2.6	9.5 ± 2.5	<0.0001
Postoperative JOA score at 1 year (points)	14.4 ± 2.3	13.5 ± 2.4	12.4 ± 2.5	<0.0001
Postoperative JOA score at final follow-up (points)	14.6 ± 2.3	13.7 ± 2.4	12.5 ± 2.6	<0.0001
Recovery rate of the JOA score (%)	58.0 ± 34.8	51.8 ± 30.8	41.3 ± 26.1	<0.0001
Achieved JOA score (points)	3.1 ± 2.3	3.2 ± 2.1	3.0 ± 2.1	0.5735
Preoperative C2–C7 lordotic angle (°)	8.7 ± 8.8	12.1 ± 10.0	13.6 ± 8.8	<0.0001
Preoperative ROM (°)	39.8 ± 10.1	38.9 ± 9.6	36.8 ± 10.5	0.0226
Postoperative C2–C7 lordotic angle (°)	13.2 ± 9.3	15.7 ± 11.6	16.2 ± 11.3	0.0160
Postoperative ROM (°)	35.7 ± 9.9	33.6 ± 9.5	32.2 ± 8.5	0.0098
Alignment change (°)	+ 4.5 ± 6.0	+ 3.6 ± 7.1	+ 2.6 ± 7.1	0.3402
ROM preservation (%)	94.2 ± 37.6	89.4 ± 29.0	91.2 ± 25.5	0.0197

Values given are mean ± SD unless otherwise specified.

JOA score indicates Japanese Orthopaedic Association score for cervical myelopathy; ROM, range of motion; SD, standard deviation.
Alignment change (°): (preoperative C2–C7 lordotic angle) − (postoperative C2–C7 lordotic angle).
ROM preservation (%) = (postoperative ROM) / (preoperative ROM) × 100.

Table 4.

Preoperative and postoperative quantifiable tests in the three groups (10-s G&R test and 10-s step test)

	Non-elderly	Young-old	Old-old	*P* value
Preoperative 10-s G&R test (right)	17.3 ± 5.1	14.4 ± 4.4	13.0 ± 4.1	<0.0001
Preoperative 10-s G&R test (left)	17.3 ± 5.1	15.0 ± 4.3	13.2 ± 4.4	<0.0001
Preoperative 10-s step test	14.3 ± 3.8	11.5 ± 4.4	8.6 ± 4.7	<0.0001
Postoperative 10-s G&R test (right)	21.0 ± 4.6	17.9 ± 4.2	16.3 ± 3.8	<0.0001
Postoperative 10-s G&R test (left)	21.1 ± 4.4	18.0 ± 4.3	16.3 ± 4.1	<0.0001
Postoperative 10-s step test	17.3 ± 3.4	14.9 ± 3.8	12.5 ± 4.2	<0.0001

Values given are mean ± SD unless otherwise specified.
10-s G&R test indicates the 10-s grip and release test; SD, standard deviation.

Table 5.

The intraoperative and postoperative complications in the three groups

	Non-elderly	Young-old	Old-old	*P* value
Dural tear	1	3	2	0.5065
C5 palsy	3	3	1	0.8849
Epidural hematoma	2	1	-	0.5319
Superficial infection	2	-	-	0.2191
Deep infection	-	1	-	0.4235
Heart failure	-	1	1	0.4716
Pneumonia	-	-	1	0.1934
Cerebral infarction	-	1	1	0.4716
Complication rate	8 (4.0%)	10 (5.4%)	6 (5.1%)	0.7971

FIGURE LEGENDS

Figure 1

The classification flow chart

Patients were divided into the 3 groups by age.

Figure 2

The achieved Japanese Orthopaedic Association for cervical myelopathy (JOA) score

No significant difference is observed in the achieved JOA score among the 3 groups.

NS = no significant difference

Figure 3

The pre- and postoperative 10-s G&R test in the three groups (weaker side)

A significant difference is observed in pre- and postoperative JOA scores among the 3 groups.

Figure 4

The pre- and postoperative 10-s step test in the three groups

A significant difference is observed in pre- and postoperative JOA scores among the 3 groups.