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Original Article

Corresponding Author
Kota Watanabe
https://orcid.org/0000-0002-4830-4690

Department of Orthopaedic Surgery, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan
Email: kw197251@keio.jp

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Surgical and Functional Outcomes of Expansive Open-Door Laminoplasty for Patients With Mild Kyphotic Cervical Alignment

Narihito Nagoshi, Satoshi Nori, Osahiko Tsuji, Satoshi Suzuki, Eijiro Okada, Mitsuru Yagi, Masaya Nakamura, Morio Matsumoto, Kota Watanabe

Department of Orthopaedic Surgery, Keio University School of Medicine, Tokyo, Japan

Objective: To evaluate the cervical dynamics, neurological function, pain, and quality of life in patients with mild cervical kyphotic alignment who underwent expansive unilateral open-door laminoplasty (ELAP).
Methods: In this retrospective single-center study, we reviewed the surgical outcomes of 80 patients with cervical spondylotic myelopathy who were followed for at least 2 years. The patients were categorized into the preoperative kyphotic group (C2–7 angle $< 0°$) and nonkyphotic group (angle $\geq 0°$). We compared clinical information, radiographic parameters, Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) scores, and cervical Japanese Orthopaedic Association (JOA) scores between the groups.
Results: The kyphotic and nonkyphotic groups comprised 17 and 63 patients, respectively. The preoperative C2–7 angles were -3.7° in the kyphotic group and 15.4° in the nonkyphotic group ($p < 0.01$). In the kyphotic group, kyphotic alignment improved to lordosis at the final follow-up (2.6°, $p = 0.01$). The preoperative (16.4° vs. 24.1°, $p < 0.01$) and final-follow-up (17.8° vs. 24.5°, $p < 0.01$) C7 slopes were significantly smaller in the kyphotic group. ELAP reduced pain in the arms or hands ($p = 0.02$) and improved the JOA scores ($p < 0.01$) in the kyphotic group. Patient-reported outcomes assessed using the JOACMEQ showed comparable effective rates in both groups.
Conclusion: Patients with mild cervical kyphosis showed smaller C7 slopes as a compensatory mechanism. Kyphotic angles significantly improved to lordosis after ELAP, resulting in favorable clinical outcomes. ELAP is a useful surgical option for patients even if they present mild kyphotic cervical angles.

Keywords: Cervical spondylotic myelopathy, Expansive unilateral open-door laminoplasty, Kyphotic cervical alignment

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a degenerative disease that causes neurological deficits by spinal cord compression. To halt the dysfunctional progress and initiate neurological recovery, surgical treatment is frequently performed. Numerous studies have demonstrated the usefulness of unilateral open-door laminoplasty for CSM and have reported beneficial surgical outcomes.[1-3]

Laminoplasty is a safe and less invasive technique that does not necessitate interspinal fixation surgery. The indication of laminoplasty for patients with CSM should be considered cautiously because preoperative malalignment could affect surgical results.[1,4-9] Chiba et al.[1] reported that functional recovery was significantly negatively correlated with the degree of preoperative cervical kyphosis. Miyamoto et al.[6] demonstrated that posterior fixation surgery was more suitable for patients with > 5° local kyphosis in view of the acquisition of postoperative lordotic alignment and neurologic improvement. Other studies reported poor neurological improvement after laminoplasty in patients whose C2–7 sagittal angles were < 0°.[7,8] In contrast to these adverse effects of preoperative cervical kyphotic alignment, Uchida et al.[9] evaluated the surgical outcomes of patients who had cervical local kyphosis of > 10° preoperatively and underwent either laminoplasty or anterior spondylectomy. They reported comparable recovery of cervical Japanese Orthopaedic Association (JOA) scores in both groups after long-term follow-up despite the fact that cervical kyphosis was maintained in patients who underwent only laminoplasty. The results of these studies suggest that there is no consensus for the treatment of patients with CSM with baseline cervical kyphosis. Although the modified K-line is a useful and convenient method to decide surgical indication of posterior decompression surgery, previous studies targeted only double-door laminoplasty, and there is limited evidence of comprehensive clinical results in terms of cervical alignment changes and patient-reported functional outcomes postoperatively.[10-12]

Therefore, it is quite meaningful from our therapeutic experience to present the surgical outcomes of patients who had preoperative cervical spinal kyphosis and underwent unilateral open-door laminoplasty. This study aimed to investigate the cervical dynamics, neurological function, pain, and quality of life (QoL) in these patients.

MATERIALS AND METHODS

1. Participants

This study included 80 patients with clinically and radiographically confirmed CSM who were treated using expansive unilateral open-door laminoplasty (ELAP)[2] at one institution between 2008 and 2014. Nine board-certified spinal surgeons performed the surgeries. Patients were included if they (1) presented with at least one clinical sign of myelopathy, (2) exhibited cervical spinal cord compression on magnetic resonance imaging (MRI) or computed tomography, and (3) had no history of cervical spine surgery. Patients were excluded if they were asymptomatic; were diagnosed with ossification of the posterior longitudinal ligament, active infection, neoplastic spinal disease, rheumatoid arthritis, or ankylosing spondylitis; or had been treated for osteoarthritis of the hip or knee with concomitant lumbar canal stenosis.

The patients were categorized into the preoperative cervical kyphotic group (C2–7 angle < 0°) and nonkyphotic group (C2–7 angle ≥ 0°).

This study received ethical approval from the Institutional Review Board of Keio University School of Medicine (20110142). We certify that all applicable institutional regulations concerning the ethical use of human volunteers were followed during the course of this study.

2. Surgical Procedure

ELAP was performed as described previously.[2,13,14] Briefly, the laminae were exposed through a midline incision, followed by the dissection of the bilateral paracervical muscles. A gutter was created using a drill at the junction of the lamina and facet joint, and the ventral cortex of the lamina was perforated. Another gutter was created in the opposite side as a hinge, and the laminar door was lifted and fixed in the expanded position using sutures or plates (Centerpiece Plate Fixation System; Medtronic Sofamor Danek, Memphis, TN, USA). The patients began walking without a brace the day after surgery.

3. Data Collection

We retrospectively collected the demographic information, medical history, and imaging data of the patients and evaluated their functional status preoperatively and at the final follow-up (at least 2 years postoperatively) using the cervical JOA scores and JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). We did not set a limit for the maximum follow-up duration. Pain, stiffness, and numbness were assessed using the visual analogue scale (VAS) included in the JOACMEQ. Surgery-related events within 30 days postoperatively were defined as perioperative complications. The JOACMEQ defines effective treatment as (1) a posttreatment score of ≥ 20 points above the pretreatment score or (2) a pretreatment score of < 90 and a posttreatment score of ≥ 90.[15] Patients with both pretreatment and posttreatment scores of ≥ 90 were counted but excluded from further analysis. A group's effective rate was calculated as follows: [(number of patients judged "effective") / [(total number of patients in the group) – (number of patients with pre- and posttreatment scores of ≥ 90)]. The postoperative recovery rate (JOA recovery rate), described by Hirabayashi et al.[14] was calculated as follows: recovery rate (%) = (postoperative JOA score − preoperative JOA score) × 100/(17−preoperative JOA score).

4. Imaging

Cervical alignment was assessed by measuring the intermittent C2–7 angles, which were determined by tangential lines on

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the posterior edge of the target vertebral bodies, on plain radiographs in the neutral position. We calculated the cervical range of motion (ROM) by subtracting the flexion from the extension C2–7 angles. The C7 slope was measured as the angle between the superior endplate of C7 and a horizontal line. The C7 slope was used as a substitute for the T1 slope.[16,17] The C2–7 sagittal vertical axis (SVA) was defined as the distance between the C2 plumb line and posterior superior corner of the C7 vertebral body.

5. Statistical Analysis

Continuous variables and frequencies were presented as mean ± standard deviation, and the unpaired t-test was performed to compare these parameters between the groups. Categorical variables were shown as percentages and were compared using the chi-square test. Changes between the preoperative and final JOA scores, VAS scores, and imaging findings were assessed using paired *t*-tests. All statistical analyses were performed using IBM SPSS Statistics ver. 26.0 (IBM Co., Armonk, NY, USA). A p-value of < 0.05 was considered significant.

RESULTS

1. Demographic Characteristics

Table 1 shows the demographic characteristics of patients who underwent ELAP at our institution. Seventeen patients exhibited preoperative cervical kyphosis (kyphotic group), and 63 patients exhibited preoperative cervical lordotic alignment (nonkyphotic group). The average age was younger in the kyphotic group (59.5 ± 13.4 years vs. 65.8 ± 11.3 years), although it was not statistically significant (p = 0.053). There were more men in the kyphotic group (82.4%) than in the nonkyphotic group (71.4%) (p = 0.54). Body mass index and duration of initial symptoms were not significantly different between the groups. The average follow-up periods were 3.1 ± 0.8 years and 2.8 ± 0.5 years in the kyphotic and nonkyphotic groups, respectively (p = 0.11). Regarding comorbidities, there were no significant differences in the prevalence of hypertension (p = 0.32), diabetes mellitus (p = 0.32), cardiac disease (p = 0.38), cerebrovascular disease (p = 0.80), and psychiatric disease (p = 0.80). No patient had renal, respiratory, or rheumatologic diseases.

2. Surgical Characteristics

Surgical information is presented in Table 2. The average operative duration was 83.4 ± 26.5 minutes in the kyphotic group and 80.1 ± 28.3 minutes in the nonkyphotic group (p = 0.67). The average numbers of operated laminae were also comparable between the groups (4.7 ± 0.9 vs. 4.6 ± 0.9; p = 0.71). One (5.4%) and 12 patients (19.0%) in the kyphotic and nonkyphotic groups, respectively, underwent laminoplasty with plates (p = 0.28). For C2 decompression, only laminotomy (not laminoplasty) was performed to drill a caudal portion of the lamina. Only 1 patient (5.4%) in the kyphotic group and 2 (3.2%) in the nonkyphotic group underwent this procedure. At the C3 level, 13 (76.5%) and

Table 1. Demographic characteristics of patients with kyphotic and nonkyphotic cervical alignment

Characteristic	Kyphotic group (n = 17)	Nonkyphotic group (n = 63)	p-value
Age (yr)	59.5 ± 13.4 (32–76)	65.8 ± 11.3 (39–86)	0.05
Sex (% male)	82.4	71.4	0.54
Body mass index (kg/m^2)	24.5 ± 4.6 (18.8–33.5)	24.1 ± 3.6 (17.8–34.2)	0.71
Duration of symptoms (mo)	61.0 ± 88.1 (1–360)	36.6 ± 45.4 (1–240)	0.29
Follow-up period (yr)	3.1 ± 0.8 (2.0–5.0)	2.8 ± 0.5 (2.0–5.0)	0.11
Comorbidities (%)			
Hypertension	23.5	36.5	0.32
Diabetes mellitus	5.9	14.3	0.32
Cardiac disease	5.9	1.6	0.38
Renal disease	0	0	-
Cerebrovascular disease	0	1.6	0.80
Respiratory disease	0	0	-
Rheumatologic disease	0	0	-
Psychiatric disease	0	1.6	0.80

Values are presented as mean ± standard deviation (range) unless otherwise indicated.

Table 2. Surgical characteristics and perioperative information

Characteristic	Kyphotic group (n = 17)	Nonkyphotic group (n = 63)	p-value
Operative duration (min)	83.4 ± 26.5 (43–137)	80.1 ± 28.3 (32–209)	0.67
Number of operated laminae	4.7 ± 0.9 (3–6)	4.6 ± 0.9 (2–6)	0.71
Use of laminar plates (%)	5.8	19.0	0.28
Duration of hospital stay (days)	15.9 ± 7.4 (9–42)	14.5 ± 3.7 (9–28)	0.29
Perioperative complications (%)			
C5 palsy	0	3.2	0.62
Surgical site infection	5.9	0	0.21
Epidural hematoma	5.9	3.2	0.52
Dural tear	0	1.6	0.79

Values are presented as mean ± standard deviation (range) unless otherwise indicated.

Table 3. Imaging characteristics

Characteristic	Kyphotic group (n = 17)	Nonkyphotic group (n = 63)	p-value
C2–7 angle (neutral)			
Preoperation (°)	-3.7 ± 3.0 (-11.0 to -0.1)	15.4 ± 8.0 (1.2–38.9)	< 0.01
Final follow-up (°)	2.6 ± 10.2 (-15.0 to 22.8)	13.8 ± 9.9 (-4.1 to 37.8)	< 0.01
C2–7 angle (flexion)			
Preoperation (°)	-22.2 ± 10.2 (-43.0 to -1.0)	-9.4 ± 9.8 (-27.3 to 17.9)	< 0.01
Final follow-up (°)	-14.9 ± 9.1 (-30.0 to -2.4)	-2.4 ± 10.4 (-39.1 to 25.1)	< 0.01
C2–7 angle (extension)			
Preoperation (°)	12.5 ± 11.3 (-9.0 to 30.5)	27.1 ± 7.6 (11.6–47.0)	< 0.01
Final follow-up (°)	12.0 ± 11.3 (-6.6 to 31.6)	23.1 ± 10.0 (-0.4 to 44.3)	< 0.01
Cervical range of motion			
Preoperation (°)	34.2 ± 12.8 (14.5–58.2)	36.6 ± 10.6 (11.3–61.3)	0.45
Final follow-up (°)	26.9 ± 10.3 (9.3–47.1)	25.5 ± 8.8 (3.9–44.3)	0.59
C7 slope			
Preoperation (°)	16.4 ± 5.3 (7.7–25.5)	24.1 ± 7.5 (8.6–44.5)	< 0.01
Final follow-up (°)	17.8 ± 6.5 (6.8–25.6)	24.5 ± 8.1 (8.8–53.8)	< 0.01
Intermediate C2–7 sagittal vertical axis			
Preoperation (mm)	26.5 ± 11.8 (7.0–56.3)	22.3 ± 14.1 (-7.5 to 57.5)	0.27
Final follow-up (mm)	22.3 ± 15.0 (-5.8 to 46.4)	25.2 ± 14.8 (-8.3 to 70.0)	0.47

Values are presented as mean ± standard deviation (range) unless otherwise indicated.

52 patients (82.5%) in the kyphotic and nonkyphotic groups, respectively, underwent decompression. In the kyphotic group, 3 of 13 patients underwent laminoplasty, whereas the other 10 patients underwent total laminectomy. In the nonkyphotic group, laminoplasty was performed for 7 of 52 patients, and the other 45 patients underwent laminectomy. For C7 laminae, 12 (70.6%) and 45 patients (71.4%) in the kyphotic and nonkyphotic groups, respectively, underwent surgical decompression. In the kyphotic group, 2 of 12 patients underwent laminoplasty, whereas the other 10 patients underwent laminotomy to decompress a rostral portion of the lamina. In the nonkyphotic group, laminoplasty was performed for only 3 of 45 patients, and the other 42 patients underwent laminotomy.

The length of hospital stay was 15.9 ± 7.4 days in the kyphotic group and 14.5 ± 3.7 days in the nonkyphotic group ($p = 0.29$). In terms of perioperative complications, the occurrence rates of C5 palsy ($p = 0.62$), surgical site infection ($p = 0.21$), epidural hematoma ($p = 0.52$), and dural tear ($p = 0.79$) did not show significant differences.

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3. Imaging Characteristics

The preoperative intermediate C2–7 angles were -3.7° ± 3.0° (range, -11.0° to -0.1°) in the kyphotic group and 15.4° ± 8.0° (range, 1.2°–38.9°) in the nonkyphotic group ($p < 0.01$) (Table 3). This difference was maintained postoperatively at the final follow-up in the kyphotic (2.6° ± 10.2°) and nonkyphotic (13.8° ± 9.9°) groups ($p < 0.01$). With regard to temporal changes in cervical alignment, the kyphotic group presented significant improvement to lordotic alignment at the final follow-up ($p = 0.01$), whereas the nonkyphotic group maintained comparable alignment pre- and postoperatively ($p = 0.16$). The preoperative cervical ROM was 34.2° ± 12.8° in the kyphotic group and 36.6° ± 10.6° in the nonkyphotic group ($p = 0.45$) and changed to 26.9° ± 10.3° and 25.5° ± 8.8°, respectively, at the final follow-up ($p = 0.59$). On evaluating ROM temporally, the angle reduced postoperatively in the nonkyphotic ($p < 0.01$) and kyphotic ($p = 0.054$) groups. The C7 slope was significantly smaller in the kyphotic group preoperatively (16.4° ± 5.3° vs. 24.1° ± 7.5°, $p < 0.01$) and at the final follow-up (17.8° ± 6.5° vs. 24.5° ± 8.1°, $p < 0.01$). The preoperative intermediate C2–7 SVAs were 26.5 ± 11.8 mm and 22.3 ± 14.1 mm in the kyphotic and nonkyphotic groups, respectively ($p = 0.27$). The SVA at the final follow-up was similar between the groups (22.3 ± 15.0 mm vs. 25.2 ± 14.8 mm, $p = 0.47$). Temporal changes in the C7 slope and C2–7 SVA did not show significant differences in both groups. The breakdown of each neutral C2–7 alignment in the kyphotic group is shown in Table 4.

Table 4. C2–7 angles (neutral) and cervical JOA scores at preoperation and final follow-up in each patient with kyphotic cervical alignment

Patient No.	Neutral C2–7 angles (°)		JOA scores	
	Preoperation	Final follow-up	Preoperation	Final follow-up
1	-11.0	-15.0	11	14.5
2	-7.4	7.6	14	15
3	-6.9	-8.5	13.5	15.5
4	-5.9	-13.9	13	14
5	-5.9	-0.8	8.5	12
6	-5.6	5.7	16	17
7	-3.9	2.0	9	16
8	-3	7.7	13	17
9	-2.8	2.3	13	15
10	-2.5	22.8	15	15.5
11	-2.5	18.0	13	16
12	-2.3	7.8	7.5	10
13	-1.6	7.5	9	9
14	-1.3	8.5	11	11
15	-0.5	-7.8	10	14
16	-0.1	3.7	13	13.5
17	-0.1	-4.0	4	10

JOA, Japanese Orthopaedic Association.

4. Surgical Outcomes

The cervical JOA scores, which were used to evaluate neurologic function, were 11.4 ± 3.1 in the kyphotic group and 11.6 ± 2.7 in the nonkyphotic group ($p = 0.82$) (Table 5). Equivalent improvement of neurologic function was observed in both groups at the final follow-up (13.8 ± 2.5 vs. 14.0 ± 2.5, $p = 0.84$). Each group showed significant functional recovery when comparing the baseline and final JOA scores temporally ($p < 0.01$). The recovery rates of the JOA scores were also similar between the groups (46.7% vs. 46.4%, $p = 0.97$). Linear multiple regression analysis was performed to evaluate the JOA scores at the final follow-up after adjusting for variables, and there was no statistically significant difference between the groups.

Among the 9 attending surgeons, 6 (group A) performed surgeries for patients in both the kyphotic and nonkyphotic groups, and the other 3 (group B) performed surgeries for only patients in the nonkyphotic group. We compared the clinical results between group A ($n = 46$) and group B ($n = 17$) in the nonkyphotic group, which revealed no significant differences in JOA scores at preoperation (11.6 ± 2.7 vs. 11.4 ± 2.9, $p = 0.76$) and final follow-up (13.9 ± 2.4 vs. 14.1 ± 2.6, $p = 0.85$).

On comparing the surgical outcomes between patients whose cervical alignment progressed to more kyphosis ($n = 5$; patients 1, 3, 4, 15, 17) and improved to lordosis ($n = 12$; all other patients) in the kyphotic group (Table 4), the preoperative C2–7 angles were -4.9° ± 4.6° and -3.2° ± 2.1°, respectively ($p = 0.48$). The preoperative cervical JOA scores were 10.3 ± 3.8 and 11.8 ± 2.8 ($p = 0.36$), respectively, and this difference was comparable at the final follow-up (13.6 ± 2.1 vs. 13.9 ± 2.8, $p = 0.82$).

The following 4 aspects were evaluated using VAS: pain or stiffness in the neck or shoulders, tightness in the chest, pain or numbness in the arms or hands, and pain or numbness from the chest to toe.[15] The results were comparable for all aspects between the groups both pre- and postoperatively (Table 5). In the kyphotic group, the VAS scores for pain or numbness in the arms or hands significantly reduced postoperatively (58.8 ± 33.0 mm to 39.4 ± 31.5 mm, $p = 0.02$). In the nonkyphotic group, the VAS scores significantly reduced for pain or numbness in the

Table 5. Clinical outcomes

Variable	Kyphotic group (n = 17)	Nonkyphotic group (n = 63)	p-value
Cervical JOA score			
Preoperation	11.4 ± 3.1 (4.0–16.0)	11.6 ± 2.7 (4.5–16.5)	0.82
Final follow-up	13.8 ± 2.5 (9.0–17.0)	14.0 ± 2.5 (8.0–17.0)	0.84
Recovery rate (%)	46.7 (0–100)	46.4 (0–100)	0.97
VAS score for neck or shoulder			
Preoperation (mm)	44.7 ± 36.3 (0–100)	45.8 ± 28.9 (0–100)	0.90
Final follow-up (mm)	34.1 ± 33.7 (0–100)	37.5 ± 30.8 (0–100)	0.70
VAS score for chest			
Preoperation (mm)	3.5 ± 10.0 (0–40)	10.2 ± 22.3 (0–80)	0.08
Final follow-up (mm)	9.4 ± 18.9 (0–70)	9.0 ± 20.8 (0–100)	0.95
VAS score for arms or hands			
Preoperation (mm)	58.8 ± 33.0 (0–100)	61.0 ± 31.4 (0–100)	0.81
Final follow-up (mm)	39.4 ± 31.5 (0–100)	39.7 ± 32.3 (0–100)	0.98
VAS score from chest to toe			
Preoperation (mm)	38.2 ± 30.1 (0–100)	39.8 ± 33.5 (0–100)	0.86
Final follow-up (mm)	27.6 ± 33.6 (0–100)	31.7 ± 35.2 (0–100)	0.67
Effective rate for the JOACMEQ (%)			
Cervical spine	36.4	58.5	0.16
Upper extremity	30.8	43.2	0.42
Lower extremity	46.2	34.7	0.33
Bladder	16.7	20.0	0.58
QoL	18.8	31.7	0.24

JOA, Japanese Orthopaedic Association; VAS, visual analogue scale; JOACMEQ, Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire; QoL, quality of life.

arms or hands (61.0 ± 31.4 mm to 39.7 ± 32.3 mm, $p < 0.01$) and from the chest to toe (39.8 ± 33.5 mm to 31.7 ± 35.2 mm; $p = 0.02$). Other scales did not show statistically significant changes.

The JOACMEQ results revealed effective rates of 36.4% (4 of 11) and 58.5% (31 of 53) for cervical spine function, 30.8% (4 of 13) and 43.2% (19 of 44) for upper extremity function, 46.2% (6 of 13) and 34.7% (17 of 49) for lower extremity function, 16.7% (2 of 12) and 20.0% (10 of 50) for bladder function, and 18.8% (3 of 16) and 31.7% (20 of 63) for QoL in the kyphotic and nonkyphotic groups, respectively (Table 5). None of the rates differed significantly between the groups. Binomial logistic regression analysis was performed to evaluate the effective rates after adjusting for variables, and there was no significant difference between the groups.

5. Case Presentation

1) Patient 2

A 37-year-old man who was diagnosed with CSM was referred to our institution for surgical treatment. He complained of hand clumsiness and gait impairment, and his cervical JOA score was 14. In radiographic findings, the C2–7 angle was -7.4°, and the C7 slope was 16.2° (Fig. 1A). T2-weighted MRI revealed multiple cervical canal stenosis from C3 to C7 and intramedullary high signal intensity at the C6/7 spinal level (Fig. 1B). Because dynamic canal stenosis was identified at the C4/5 and C5/6 levels, he underwent ELAP from the C3 to C7 laminae. His symptoms improved postoperatively, and at 5 years postoperatively, his JOA score recovered to 15, C2–7 angle was 7.6°, and C7 slope was 17.1° (Fig. 1C). MRI showed expanded cervical canal space and maintenance of favorable decompression (Fig. 1D).

2) Patient 10

A 66-year-old man complained of bilateral hand clumsiness and numbness of the upper extremities. His cervical JOA score was 15. Radiographic findings showed a C2–7 angle of -2.5° and

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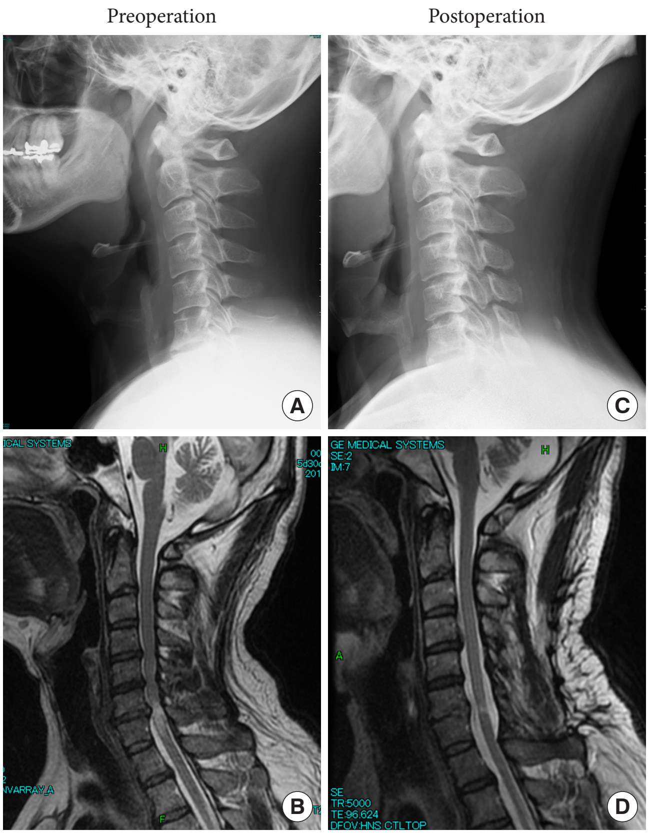

Fig. 1. Case presentation of a 37-year-old man. (A) The preoperative C2–7 angle was -7.4° in an x-ray image. (B) Sagittal T2-weighted magnetic resonance imaging revealed cervical canal stenosis at multiple intervertebral levels. (C) After laminoplasty, the C2–7 angles improved to a lordotic angle of 7.6°. (D) Appropriate spinal cord decompression was observed postoperatively.

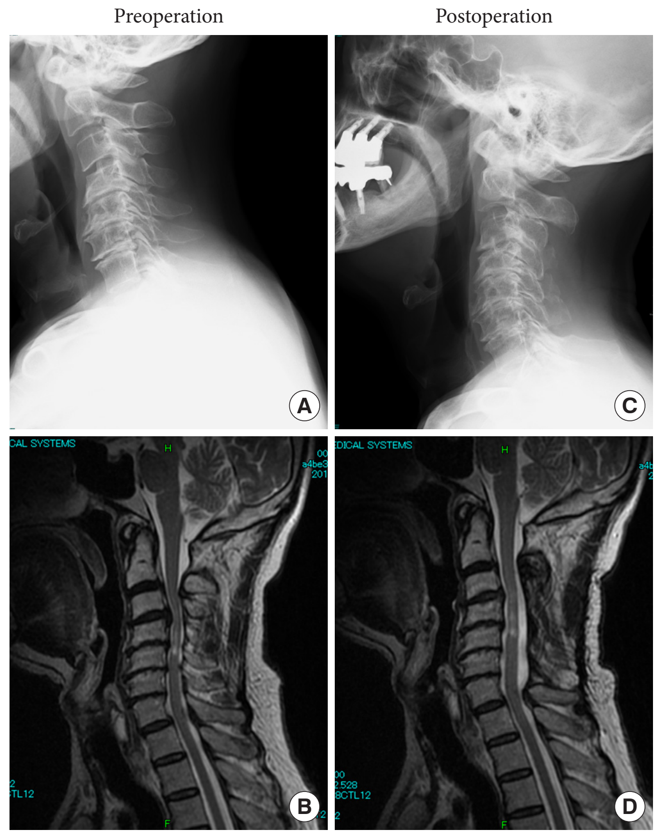

Fig. 2. Case presentation of a 66-year-old man. (A) The preoperative C2–7 angle was -2.5° in an x-ray image. (B) Sagittal T2-weighted magnetic resonance imaging revealed cervical canal stenosis at multiple intervertebral levels with intramedullary high signal intensity. (C) After laminoplasty, the C2–7 angles improved to a lordotic angle of 22.8°. (D) Appropriate spinal cord decompression was observed postoperatively.

C7 slope of 22.6° (Fig. 2A). T2-weighted MRI revealed multiple canal stenosis with intramedullary high signal intensity (Fig. 2B). He underwent ELAP from the C3 to C7 laminae. His postoperative course was uneventful. At 5 years postoperatively, his JOA score recovered to 15.5, C2–7 angle was 22.8°, and C7 slope was 25.1° (Fig. 2C). MRI revealed decompression of the cervical spinal cord (Fig. 2D).

DISCUSSION

In this study, ELAP was performed for patients with CSM with kyphotic cervical alignments, which were ≤ -11° in C2–7 angles. This kyphotic angle was sustained by compensatory lower angle of the C7 slope compared with that in patients with preoperative C2–7 lordotic alignment (Table 3). However, even in patients with cervical kyphosis, the alignment significantly improved to lordotic angle postoperatively. Regarding clinical outcomes, perioperative complications equivalently developed in the kyphotic and nonkyphotic groups (Table 2). The surgical treatment reduced pain in the arms or hands and recovered the neurologic status, which was evaluated using JOA scores (Table 5). The patient-reported outcomes assessed using the JOACMEQ also revealed comparable effective rates of cervical spine, extremity, and bladder functions and QoL in both groups. These results indicate that ELAP is a useful surgical option for patients even if they present mild kyphotic cervical angles.

Several studies have reported the progression of kyphotic angles after laminoplasty.[5-7] Although we targeted patients with only mild kyphotic angles, our findings indicate that patients with cervical spinal kyphosis had the potential to attain lordotic angles postoperatively. In corroboration, Kim et al.[18] reported that the subpopulation of patients who had kyphotic cervical alignment did not show development of kyphosis even after laminoplasty. These patients had radiographically reducible lordotic alignment before surgery at the extension view of the cervical spine. In our patients with preoperative cervical kyphosis, the average baseline C2–7 angles at extension was 12.5° (Table 3), which was within the acceptable range as reducible lordotic alignment. Therefore, patients with mild cervical kyphosis in our study were deemed to have favorable radiographical and functional outcomes after ELAP. Thus, if surgical treatment is necessary for patients with cervical spinal kyphosis, the evaluation of alignment at extension could be an important indicator to decide the actual operative technique.

In the present study, the C7 slope was significantly smaller in patients with preoperative cervical kyphosis than in patients with lordotic alignment (Table 3). Although Ames et al. used the T1 slope as a substitute parameter of the C7 slope, they reported that lower T1 slope was significantly correlated with smaller C2–7 lordosis.[19] In their study, they demonstrated that cervical alignment showed adaptive characteristics and changes relative to the other thoracic and lumbar spinal segments to maintain the head over the pelvis and horizontal gaze. Therefore, we believe that kyphotic cervical curvature in our study was not the cause but rather the result of a smaller C7 slope by a compensatory mechanism of spinal dynamics. With regard to postoperative cervical alignment, Kim et al.[20] reported that patients with larger preoperative T1 slopes presented more kyphotic alignment changes after cervical laminoplasty. In contrast, C7 slopes in patients with cervical kyphosis in the present study were comparable before and after surgery within the ranges of lower angles (Table 3), and these results led to the prevention of kyphotic changes. However, because the C7 slope gradually increases with age,[17] cervical kyphosis may progress in the future after surgical intervention. Therefore, careful attention should be paid regarding changes in cervical alignment with longer follow-up periods.

Based on our results, we did not conclude the limitation of the indication for ELAP in patients with kyphotic cervical alignment due to the lack of patients who had hyperkyphosis. Generally, the current therapeutic strategy for cervical deformity is spinal fixation surgery[21]; therefore, we avoided ELAP for patients with excessive kyphotic angles of the cervical spine preoperatively. Several studies have reported that kyphotic angles of > 5°–10° increase the risk of malalignment progression and functional deterioration if laminoplasty is performed.[4,6-8] The average kyphotic angle in our subjects was 3.7° in the kyphotic group, and this small angle resulted in the prevention of worsening kyphotic deformity postoperatively. Further evidence is needed to achieve a consensus regarding the indication of surgical techniques with and without spinal fixation for cervical kyphosis.

Several limitations were noted in this study. First, this was a retrospective study, which inevitably has a low evidence level. Second, we did not analyze global spinal alignment, which could affect cervical dynamics after laminoplasty.[22] Third, differences in postoperative medication and rehabilitation, which were left to the surgeon's discretion, could have affected the clinical outcomes. Finally, the results should be carefully interpreted because this study was performed using a single surgical technique and assessment questionnaire at a single institution.

CONCLUSION

We evaluated the cervical spinal dynamics and functional outcomes of patients with mild kyphotic cervical alignment who underwent ELAP. The average preoperative C2–7 angle in the kyphotic group was -3.7°, and these patients presented favorable surgical outcomes regarding neurologic function, pain, and QoL, with a reduction in the cervical alignment to lordotic angle. However, this beneficial result was achieved in patients who had cervical alignment within -10° and were followed up for only a few years. Further studies are necessary to evaluate the efficacy of ELAP for more kyphotic alignment with a longer observational period.

CONFLICT OF INTEREST

The authors have nothing to disclose.

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