CLINICAL ARTICLE

Expansive open-door laminoplasty and selective anterior cervical decompression and fusion for treatment of multilevel cervical spondylotic myelopathy

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Objective: To evaluate the clinical results of combined expansive open-door laminoplasty by splitting of spinous processes and selective anterior cervical decompression and fusion in treatment of multilevel severe cervical spondylotic myelopathy (CSM).

Methods: Twenty-eight patients (16 men and 12 women) underwent one-stage combined expansive open-door laminoplasty and selective anterior decompression and fusion for severe CSM; the average patient age was 51.3 years (range, 32–63 years). Clinical results were assessed by Japanese Orthopaedic Association (JOA) scores, number of finger grip and releases (G and R) in ten seconds, hand-grip strength, visual analog scale (VAS) of axial pain, and C2-C7 angle.

Results: There was no worsening of neurological symptoms due to cord injury, cerebrospinal fluid leakage, or wound infection. All cases completed one-year follow-up. The JOA scores, number of G and R in ten seconds, and hand-grip strength were all significantly improved ($P < 0.05$). Satisfactory decompression was shown by MRI or CT to have been achieved in all cases. The C2-C7 angle did not differ significantly from that found pre-operatively. The axial neck pain score was 2.0 ± 0.1 on VAS.

Conclusion: Combined expansive open-door laminoplasty by splitting of spinous processes and selective anterior decompression and fusion achieves complete spinal canal decompression with minimal morbidity; this strategy is effective in improving the surgical outcomes of CSM in one-year follow-up.

Key words: Cervical spondylosis; Decompression; Spinal fusion

Introduction

The goals of operative intervention in treatment of cervical spondylotic myelopathy (CSM) are to decompress the spinal cord and nerve roots, correct deformity, maintain spinal stability, and alleviate pain. However, the optimal surgical treatment for multilevel cervical spinal cord compression caused by cervical spondylosis remains controversial. Important influential factors include age, comorbidities, number of levels involved, bone quality, functional status, reducibility of any existing deformity,

sagittal alignment, and the presence of instability¹. Anterior decompression and fusion, laminectomy with or without fusion, expansive laminoplasty, and combined anterior and posterior surgery have all been used in the treatment of multilevel CSM^{2–6}. In most circumstances, single posterior or anterior surgery can achieve complete decompression. According to published reports, the clinical outcomes of anterior and posterior surgeries in CSM are comparable; however, complications are more frequent with anterior surgery, whereas axial pain is a significant problem in the laminoplasty group⁷. Moreover, for multilevel severe CSM with a giant anterior compression mass, a single decompression procedure cannot achieve efficient decompression. Therefore, in this study circumferential cervical surgery (expansive open-door laminoplasty by splitting of spinous processes and selective anterior cervical decompression and fusion) was performed to treat multilevel severe CSM.

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Figure 1 The angle between the inferior endplate of C2 and inferior endplate of C7 (angle a) was used to evaluate cervical alignment.

Materials and methods

Patient data

Twenty-eight patients (19 men and 9 women) underwent combined expansive open-door laminoplasty (C3–C6) by splitting of spinous processes and selective anterior cervical decompression and fusion. Japanese Orthopaedic Association (JOA) scores, number of finger grip and releases (G and R) in 10 seconds, and hand-grip strength were used to assess neurological function. All patients underwent routine and dynamic X-rays, CT, and MRI before surgery. Preoperative cervical alignment was evaluated by using the C2–C7 angle (Fig. 1). The compression ratio and diameter of the anterior mass at the most severe compression level were used to evaluate the severity of compression (Fig. 2). A ten cm VAS was used to assess axial pain (with a score of 0 indicating no pain and a score of 10 representing the worst pain). The characteristics of the subjects are shown in Table 1 and Table 2.

Surgical technique

After undergoing general anesthesia, the patient was put in a prone position. Expansive open-door laminoplasty by splitting of the spinous processes of C3–C6 was performed according to Kurokawa's method² with some modifications. The paravertebral muscles were detached from the C3–C6 spinous processes and laminae through a

Figure 2 The ratio (a/b) between (a) the diameter of the anterior mass and (b) the diameter of the spinal canal at the most severe compression level was used to evaluate the severity of compression.

6–8 cm midline posterior approach. The muscles attached to the C2 spinous process were preserved without detachment. After exposing the C3–C6 spinous processes and laminae, the spinous processes were split using a 1 mm high-speed drill. Bilateral gutters were created as hinges at the borders of the laminae and facets with a 5 mm high-speed drill (Fig. 3a). After the halves of the laminae had been elevated like a French door, hydroxyapatite spacers were tied to bridge the bilateral edges of the laminae (Fig. 3b,c). In patients in whom both C2/3 and C6/7 were

Table 1 Characteristics of the subjects

Characteristics of the subjects	Data
No. of patients	28
Age (years)	51.3 ± 7.4
Duration of symptoms (months)	48.3 ± 12.1
Affected levels	3.3 ± 0.5
C2/3	3
C3/4	21
C4/5	26
C5/6	25
C6/7	16
Associated diseases	
Hypertension	4 (14.3%)
Diabetes	5 (17.9%)
Radiologic changes	
Congenital stenosis	17
OPLL	17
Giant disc herniation	7
Cervical instability	4
Hypertrophy or ossification of the ligamentum flavum	11

Table 2 Preoperative and postoperative data

Item	Pre-operation	Post-operation (last follow-up)	t value	P value
JOA scores	9.8 ± 2.1	15.9 ± 1.2	5.60	0.00
Finger grip and release	10.8 ± 1.0	18.2 ± 2.6	3.37	0.01
Hand-grip strength (Kg)	19.3 ± 7.0	45.8 ± 10.5	4.15	0.00
C2–C7 angle (°)	21.5 ± 5.7	19.6 ± 4.1	0.79	0.56
Diameter of anterior mass (mm)	5.6 ± 0.9	0	17.10	0.00
Compression ratio (%)	58.1 ± 3.4	0	21.23	0.00

affected, a lower half laminectomy of C2 and upper half laminectomy of C7 were performed, leaving the attachments of the semispinalis cervicis and multifidus muscles untouched. All cases underwent C3 to C6 laminoplasty, except for one case who underwent C3 laminectomy because of congenital fusion of the C2 and C3 laminae. Five cases underwent lower half laminectomy of C2, and 16 underwent upper half laminectomy of C7 without detachment of the semispinalis cervicis and multifidus muscles.

After expansive open-door laminoplasty, the patient was placed in a supine position with the head slightly extended. A routine anterior incision was made to expose the affected vertebral bodies and discs. Protruded discs, osteophytes, and ossified posterior longitudinal ligament were removed completely on the most severe levels (1–3 levels) to decompress the spinal cord through the interbody space or corpectomy. An autograft iliac bone was then inserted, and a constrained plate-and-screw system used to achieve anterior cervical fixation. Anterior decompression was performed on one level in 12 cases, two levels in 15 cases, and three levels in one case, through corpectomy in 9 cases and interbody space in 19 cases.

Postoperative management and follow-up

After the surgery, a Philadelphia brace was worn around the patient's neck for 2.5 months in order to induce cervical fusion. During postoperative follow-up, the patients underwent X-rays, CT, and/or MRI examination to confirm decompression of the canal, monitor the align-

ment of the cervical spine, and assess fusion of the bone graft. JOA scores, number of finger G and R in 10 seconds, and hand-grip strength were used to assess neurological function. Ten cm VAS was used to assess the severity of axial pain as described above.

Statistical analysis

A SPSS 12.0 software package (SPSS, Chicago, IL, USA) was used for statistical analysis. To assess statistical significance, an unpaired Student's *t*-test was also performed. The level of statistical significance was set at $P < 0.05$.

Results

The mean operation time, blood loss, posterior incision length, and anterior decompression levels were 6.5 ± 1.1 h, 375.6 ± 40.1 mL, 6.1 ± 0.6 cm, and 1.6 ± 0.8 , respectively.

One-year follow-up was completed on all cases. The postoperative JOA scores, recovery rate, number of G and R in 10 seconds, hand-grip strength, and C2–C7 angle of patients at the latest follow-up are shown in Table 2. The axial neck pain score was 2.0 ± 0.1 . There was no worsening of neurological symptoms due to cord injury, cerebrospinal fluid leakage, or wound infection. The JOA score, number of G and R in 10 seconds, and hand-grip strength were significantly improved ($P < 0.05$). All cases achieved satisfactory decompression according to follow-up MRI or CT scan (Fig. 4). The C2–C7 angle did no differ significantly from that found pre-operatively.

Figure 3 Schematic of expansive open-door laminoplasty. (a) The spinous processes were split using a 1 mm high-speed drill. Bilateral gutters were created as hinges at the border of laminae and facets with a 5 mm high-speed drill. (b, c) After the halves of laminae had been elevated like a French door, hydroxyapatite spacers were tied to bridge the bilateral edges of the laminae.

Figure 4 A 54 year-old man with multi-level CSM. (a) Preoperative MRI shows multi-level CSM, giant disc herniation at the C4/5 level and congenital stenosis. (b) Post-operatively, an axial CT scan view shows that efficient decompression was achieved. (c, d) At one-year follow-up, the X-ray film and MRI show satisfactory inter-vertebral fusion and efficient decompression of the spinal canal.

Discussion

Although single posterior or anterior surgical decompression can achieve multilevel severe CSM with a giant anterior compression mass in most circumstances, a single decompression procedure is occasionally not sufficient to get effective decompression. Under such circumstances, combined anterior and posterior decompression may be a better option. However, the indications for circumferential cervical decompression and fusion remains controversial^{2,7}. Aryan *et al.* have reported the clinical results of circumferential cervical fusion in 53 CSM patients who were recruited by meeting at least one of the following criteria: (i) anterior and posterior compression of the spinal cord with loss of lordosis; (ii) anterior com-

pression only with the need for corpectomy at more than two levels; and (iii) anterior compression only with poor bone quality, preoperative instability, or deformity needing correction (including pseudoarthrosis from prior fusion)². In the present series, the authors first performed C3-C6 laminoplasty for multiple cervical myelopathy and then carried out anterior decompression and fusion on those levels with a huge anterior compression mass, severe cervical kyphosis deformity, and/or instability. The method used in this study achieved efficient decompression, reduced the risk to the spinal cord, and resulted in less trauma than that caused by combined anterior and posterior surgery.

Laminoplasty or posterior decompression has been rigidly applied to all cases of multilevel cervical myelopa-

thy with satisfactory results. The common purpose of various laminoplasty procedures is to achieve posterior movement of the spinal cord. In most institutions five laminae (i.e., C3–C7) are considered to require expansion. Although the long-term outcomes of laminoplasty are consistently acceptable⁴, postoperative problems such as cervical malalignment, restriction of the range of movement, persistent axial symptoms, and segmental motor paralysis have been reported^{6,8–10}. Because of the above mentioned reasons, in this study C3–C6 and selective laminoplasty was performed in patients with compression myelopathy as an alternative to the conventional C3–C7 procedure. Hosono *et al.* have shown that C3–C6 laminoplasty can achieve clinical results equal to those achieved by the C3–C7 procedure, the former having a significantly shorter operative time, smaller operative wound, and significantly fewer cases of axial neck pain than the latter⁹. In this study, all patients underwent C3–C6 expansive open-door laminoplasty by splitting of the spinous processes, except for one case that underwent C3 laminectomy because of congenital fusion of the C2 and C3 laminae. Blood loss, length of laminoplasty incision and postoperative VAS of axial neck pain were only 375.6 ± 40.1 mL, 6.1 ± 0.6 cm, and 2.0 ± 0.1 , respectively. C5 palsy and progressive kyphotic deformities were not observed in this series.

Because posterior decompression alone can result in incomplete decompression in patients with multiple CSM and a huge anterior compression mass, continued anterior compressive pathology may contribute to further neurological deterioration. Tsuji *et al.* have reported that the size of the anterior compression mass (≥ 6 mm) is one of the risk factors for incomplete decompression in selective expansive open-door laminoplasty⁶. In this study, although the average size of the anterior compression mass selected for anterior decompression was only 5.6 ± 0.9 mm, the extent of compression of the spinal canal was almost 60% due to congenital canal stenosis and hypertrophy of the ligamentum flavum. Thus, combining with anterior decompression may be necessary to achieve better neurological recovery in these patients.

Aryan *et al.* compared patients who underwent anterior decompression alone with those who underwent circumferential decompression and demonstrated that, although patients who underwent anterior decompression alone exhibited less severe myelopathy preoperatively, the postoperative improvement in myelopathy was higher in those undergoing circumferential decompression². Moreover, when using anterior decompression alone for treating multilevel CSM, long-level fusion and internal fixation is required, and graft dislodgement, plate failure, pseudarthrosis, incomplete decompression, and halo-vest compli-

cations remain as significant concerns with regard to multilevel stabilization¹¹. Thus, posterior fusion and fixation may be necessary for stable reconstruction. In the present authors' opinion, since laminoplasty is performed first, it is not necessary to decompress all affected levels from the anterior approach. There are no reports of circumferential cervical surgery that describe how to choose the anterior decompression levels after posterior decompression. The present authors chose the most severe levels for anterior decompression and fusion, including seven cases of giant disc herniation, 17 of ossification of the posterior longitudinal ligament (OPLL), and four of cervical instability and slip; the average anterior fusion levels were only 1.5 with only one case undergoing three-level (C3–C6) fusion due to severe kyphosis deformity. Postoperative MRI demonstrated that decompression was achieved. Thus, selective anterior decompression can effectively reduce the number of anterior fusion levels, preserve more cervical motion segments, and decrease complications caused by long segment fusion, including pseudoarthrosis, breakage of internal fixation, protracted swallowing difficulty, graft site pain, and dyspnea¹¹. The follow-up results demonstrate that no complications related to the anterior approach were observed in this series.

Conclusion

Combined expansive open-door laminoplasty by splitting of the spinous processes and selective anterior cervical fusion can achieve complete spinal canal decompression. This surgical strategy is effective in improving the outcomes of surgical treatment of CSM, and has minimal morbidity.

Disclosure

No benefits of any type have been, or will be, received from a commercial party related directly or indirectly to the subject of this manuscript.

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