Discussion

There have been numerous studies regarding the choice of surgical methods for patients with cervical compressive myelopathy undergoing initial decompression surgery.[16–19] Some authors recommend ACDF, whereas others recommend ELAP or laminectomy with or without instrumentation. Yonenobu *et al*[19] and Wada *et al*[17] found no significant differences in the clinical results between patients treated by ACDF and those treated by ELAP. Edwards *et al*[18] compared the clinical results and complications of multilevel corpectomy and laminoplasty, and found that both the surgical methods reliably arrested the progression of myelopathy in cases with multilevel cervical myelopathy. However, because the patients treated by laminoplasty required less pain medication at follow up and experienced fewer complications, they believed that laminoplasty might be the preferred method of treatment for multilevel cervical myelopathy in the absence of preoperative kyphosis.

In contrast to the abundance of studies on the initial surgical treatment for cervical spondylotic myelopathy, those on cervical myelopathy developing at the adjacent segments after ACDF have been rather scarce, and no consensus has been evolved until now as to the optimal treatment method for this pathologic condition. Baba *et al*[20] reported 18 patients with myeloradiculopathy who had undergone expansive laminoplasty after ACDF; they found that the neurologic improvement was excellent in four patients, good in six cases, fair in four cases, and poor in four cases. Because more than half of their patients had a narrow spinal canal on radiograph, they recommended laminoplasty for revision surgery. Wang *et al*[21] reported 24 patients with failed ACDF who were treated by laminoplasty. They concluded that laminoplasty was the most straightforward and effective treatment strategy for failed ACDF. However, their study included not only patients with adjacent-segment disease, but also those with inadequate anterior decompression surgery; therefore, the effects of ELAP purely on patients with adjacent-segment disease could not be clearly demonstrated in that study.

On the other hand, Hilibrand *et al*[8] performed ACDF in 38 patients with adjacent-segment disc disease and found that firm arthrodesis was achieved in only 63% of the patients treated by discectomy with interbody grafting at one or more levels, whereas it was achieved in 100% of the patients treated by corpectomy with strut grafting. However, because the patients' symptoms were not clearly described in that report, it is unknown how many patients had myelopathy before revision surgery and to what extent postoperative improvement in myelopathy had been achieved. Ishihara *et al*[6] reported five cases with cervical myelopathy at an adjacent segment, of whom three were treated by ACDF and two by ELAP. In both groups, good to excellent surgical outcomes were obtained.

In the present study, moderate recovery could be achieved after ELAP in patients with cervical myelopathy resulting from adjacent-segment disc lesions. However, the recovery rate was not as satisfactory as that in the control group (37% versus 50%). This may be attributed to the irreversible damage of the spinal cord caused by persistent compression at the adjacent segment, which was suggested by the fact that the T2 high-intensity lesions of the spinal cord extended over a larger area in group A than in group B (Figure 1). Although not statistically significant, the interval between ADCF and ELAP was weakly correlated with the recovery rates. Therefore, patients undergoing ACDF should be followed up periodically, and at the first sign of neurologic deterioration, they should be promptly treated by decompression surgery.

ELAP may be one of the most suitable options for decompression surgery, because it can expand the cervi-

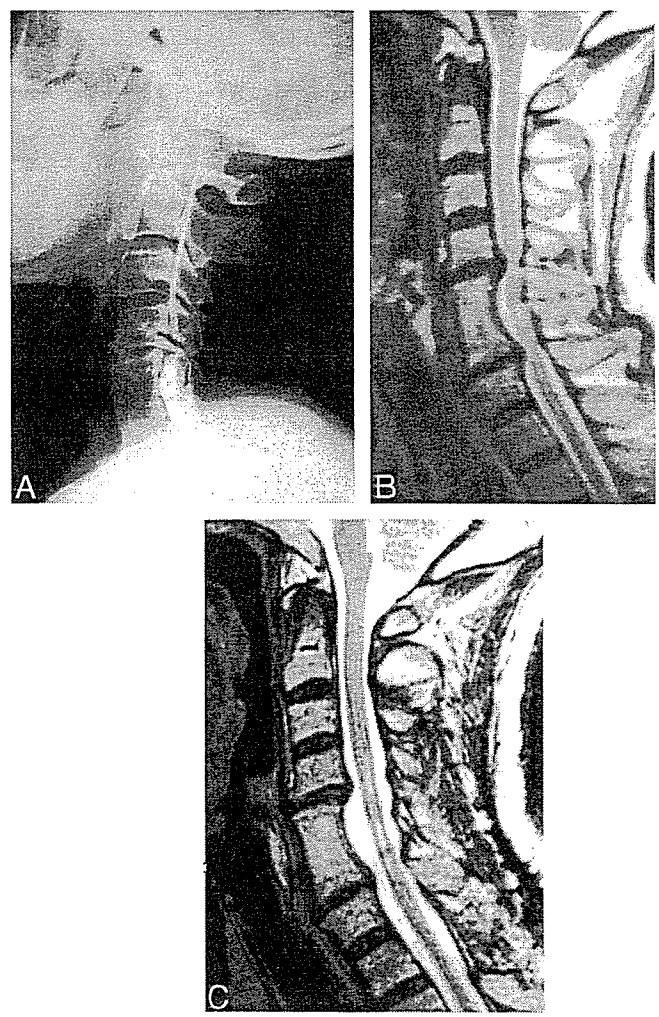

Figure 1. A 57-year-old man had undergone anterior cervical decompression and fusion (ACDF) at C5–C6 for cervical myelopathy resulting from soft disc herniation 17 years before. He had recurrence of cervical myelopathy and underwent expansive laminoplasty with improvement of his symptoms (clinical outcome; good). **(A)** Preoperative myelogram. **(B)** Preoperative magnetic resonance image (T2-weighted sagittal image). **(C)** Postoperative magnetic resonance image (T2-weighted sagittal image). Decompression of the spinal cord was good, whereas the T2 high-intensity area spread widely from the segment of ACDF to the upper and lower adjacent segments.

cal spinal canal and stabilize the motions of the adjacent segments and, thereby, allow further surgery to be avoided (Figure 2). In this study, the patients in group A had a significantly narrower spinal canal than those in group B. The angular motions at the adjacent segments were significantly decreased after ELAP in group A, indicating that ELAP effectively restrained the excessive motions of the adjacent segments.

There are, however, several limitations to this study. First, we did not compare the results of ELAP with those of ACDF for cervical myelopathy resulting from adjacent-segment disc disease. Therefore, we could not arrive at any definitive conclusion as to whether ELAP or ACDF would be the more favorable surgical option for this pathologic condition. This comparison remains to be conducted in the future, preferably in a prospective study. However, the present study was the first to be conducted on at least a moderate number of patients with myelopathy caused by adjacent-segment disease treated by ELAP and demonstrated the effectiveness and limitations of ELAP in these patients. Second, the interval between the initial ACDF and ELAP ranged widely between 1 year 4 months and 36 years 11 months. Adjacent-segment disease developing more than 30 years after ACDF may be debated as being the result of the normal aging process rather than actually representing adjacent-segment disease. Gore *et al*[22] comparatively reviewed the lateral cervical roentgenograms of 90 patients who had undergone ACDF with those of age- and sex-matched controls. The average interval from surgery to the review was 5 years. They found no difference in the incidence of degenerative changes between the operated and the control group at levels above and below the fusion with the exception of anterior entophyte formation in the ACDF group. Thus, a clear definition of adjacent-segment disease should be established, including a consideration of the appropriate interval after the ACDF and the severity of symptoms and radiologic findings.

In conclusion, ELAP, which expands the whole spinal canal and restrains the motions of the adjacent segments, is a moderately effective surgical option for cervical myelopathy developing in adjacent segments after ACDF.

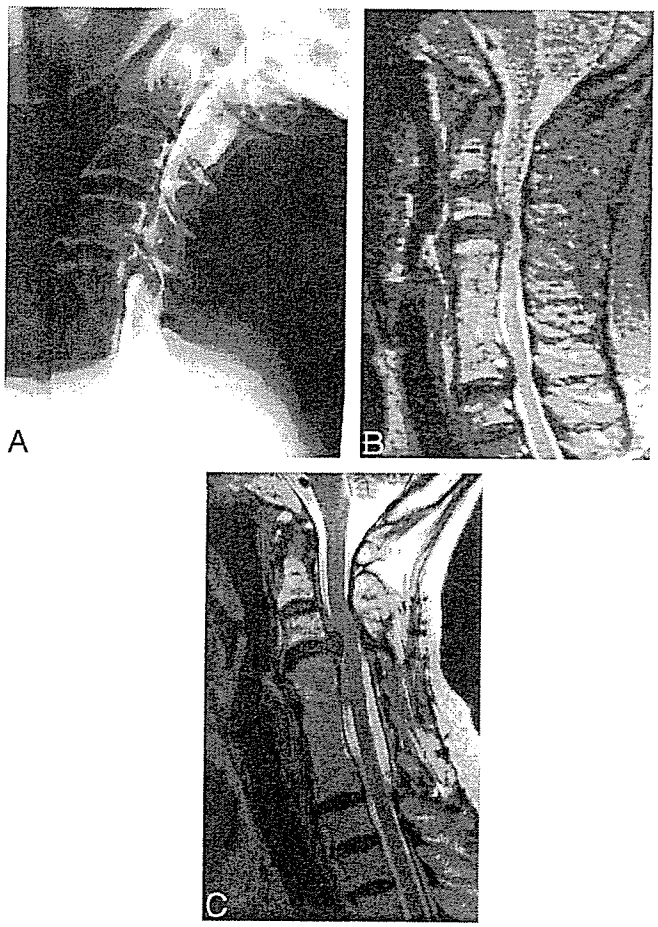

Figure 2. A female patient had undergone anterior cervical decompression and fusion (ACDF) from C5–C7 for cervical myelopathy resulting from soft disc herniation when she was 58 years old. She developed another disc herniation at C4–C5 2 years later and had ACDF again. At the age of 66 years, she developed cervical myelopathy again resulting from disc herniation at the adjacent segment (C3–C4), which was treated by expansive laminoplasty from C3–C7. She had moderate neurologic recovery after surgery (pre- and postoperative JOA scores 10 and 14, respectively). **(A)** Myelogram before the second surgery. **(B)** Magnetic resonance image before ELAP (T2-weighted sagittal image). **(C)** Magnetic resonance image at 9 years after ELAP (T2-weighted sagittal image). Although disc herniation at C3–C4 was still present, the spinal cord was nicely decompressed.

Key Points

- Moderate neurologic recovery was obtained after open-door laminoplasty in patients with cervical myelopathy resulting from adjacent-segment disease.
- The results were not as satisfactory as those in the patients without previous anterior cervical decompression and fusion.
- Open-door laminoplasty is considered to be one of the ideal surgical options to expand the cervical spinal canal and simultaneously stabilize the movements of the adjacent segments.

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Case Report

Delayed segmental motor paralysis following laminoplasty: two case reports

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Study design: Two patients who experienced the onset of segmental motor paralysis several years after laminoplasty are presented.
Objectives: To discuss the mechanism of development of delayed segmental motor paralysis following laminoplasty.
Setting: A department of orthopaedic surgery in Japan.
Methods: One patient experienced motor weakness in his deltoid and biceps muscles on the left side 5 years after laminoplasty. The other patient noticed motor weakness in his deltoid and biceps on the right side 7 years after laminoplasty. CT myelography revealed posterior spur formation and hypertrophic facet joints on the hinged side at the C4–C5 level in both patients.
Results: Posterior foraminotomy was performed at the C4–C5 level on the hinged side in both patients. Postoperatively, motor weakness in the deltoid and biceps muscles was improved in both patients.
Conclusions: Although spondylotic changes, including spur formation and disc herniation, have occasionally developed in operated segments after laminoplasty, few patients have required additional surgery for treatment of relapse of neurological deficits. It has been believed that spinal cord is rarely compressed by the spondylotic changes since it shifts posteriorly in the enlarged spinal canal. However, laminoplasty disturbs the facet joints since the medial portion of dorsal cortex and cancellous bone in facet joints is drilled out to make a trough. Facet joints disturbed in this fashion undergo degeneration over time after surgery. Nerve roots may occasionally be compressed by degenerated facet joints and spurs that have developed at the entrance of root canal, resulting in segmental motor paralysis several years after laminoplasty. Careful long-term observation is necessary after this procedure.
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Keywords: laminoplasty; segmental motor paralysis; late complication; degenerated facet joint; segmental motion

Introduction

Laminoplasty has been the treatment of choice for selected patients with cervical myelopathy due to multisegmental cervical spondylosis. The reported long-term results of this procedure have been considered satisfactory.[1–12] However, a few patients have exhibited late neurological deterioration after good recovery immediately after surgery. Numerous studies have been performed to elucidate the causes of late deterioration after this procedure.[7,10,12,13] In these studies, several factors, including progression of ossified masses, development of spondylotic changes, diminished sagittal spinal diameter, progression of instability and severe kyphosis, were considered to be associated with worsening of clinical symptoms.[7,10,12,13] Although spondylotic changes including spur formation and disc herniation have occasionally developed in operated segments after laminoplasty, few patients have required additional surgery for treatment of relapse of neurological deficits.[1–4,6–12] It is believed that the spinal cord is rarely compressed by spondylotic changes since it is shifted posteriorly in the enlarged spinal canal after laminoplasty.

In this report, two cases of segmental motor paralysis that developed several years after laminoplasty are presented. Thereafter, the mechanism of development of this paralysis is discussed and the possibility of

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degeneration of facet joints induced by this procedure as a cause of this motor paralysis is proposed.

Case reports

Case 1

A 69-year-old man noticed clumsiness in his finger motion and numbness in both his upper and lower extremities, and was admitted to our hospital. On admission, he presented with moderate quadriparesis and urinary disturbance. Plain lateral radiography of the cervical spine disclosed decrease of disc heights at C4–C5, C5–C6 and C6–C7 levels, retrolisthesis of the C4 vertebral body, posterior spur formation at the C5–C6 and C6–C7 levels, and developmental canal stenosis (Figures 1a and 2). According to White's criteria,[14] no spinal segmental instability was observed. Open door laminoplasty using the Hirabayashi method,[4,10] with C3–C7 right side open, was performed. Postoperatively, symptoms were markedly reduced, and the sensory abnormality and motor weakness in both upper and lower extremities were eliminated.

At 5 years and 6 months after the surgery, the patient experienced motor weakness in his deltoid and biceps on the left side and was readmitted to our hospital. On readmission, there was no sensory abnormality or motor weakness in either lower extremity, and no urinary disturbance or gait disturbance was observed. Motor weakness of MMT Grade 2 in the deltoid and of Grade 1 in the biceps was present on the left but not the right side. Sensory abnormality was observed in neither upper extremity. The biceps tendon reflex was diminished on the left side but normal on the right side. Other deep tendon reflexes were normal bilaterally in the upper and lower extremities. Spurling's neck compression test was negative bilaterally. On plain radiography of the cervical spine, although enlargement of the spinal canal was maintained from C3 to C7 level, spondylotic changes including decrease of disc heights, retrolisthesis of the C4 vertebral body and posterior spur formations were noted (Figure 1b). However, no spinal segmental instability was observed at the operated levels. CT myelography revealed posterior spur formation and a hypertrophic facet joint on the right side at C4–C5 level (Figure 2b).

Posterior foraminotomy was performed at the C4–C5 level on the left side. Postoperatively, motor weakness in the deltoid and biceps muscles was improved.

Case 2

A 62-year-old man suffered from sensory abnormality in both upper and lower extremities, gait disturbance and urinary dysfunction, and was admitted to our hospital. Open door laminoplasty using the Hirabayashi method,[4,10] with C3–C7 left side open, was performed. His neurological symptoms disappeared after surgery.

At 7 years after the surgery, the patient suffered from numbness and pain in his right upper extremity, which became increasingly severe. Thereafter, he noticed motor weakness in his deltoid and biceps on the right side, and was readmitted to our hospital. On readmission, there was no sensory abnormality or motor weakness in either lower extremity, and no urinary

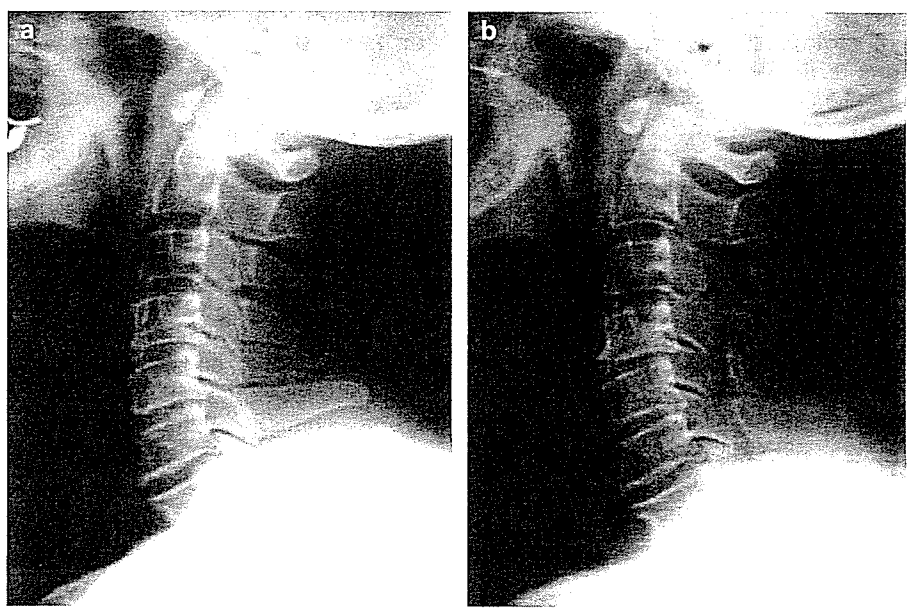

Figure 1 Plain lateral radiograms of the cervical spine in Case 1. (**a**) Before first operation. (**b**) At 5 years after first operation. Before first operation, decrease of disc heights at C4–C5, C5–C6 and C6–C7 levels, retrolisthesis of the C4 vertebral body, posterior spur formations at C5–C6 and C6–C7 levels, and developmental canal stenosis were observed. Although enlargement of the spinal canal was maintained from C3 to C7 level, spondylotic changes, including decrease of disc heights, retrolisthesis of C4 vertebral body, and posterior spur formations, were developed 5 years after the first operation

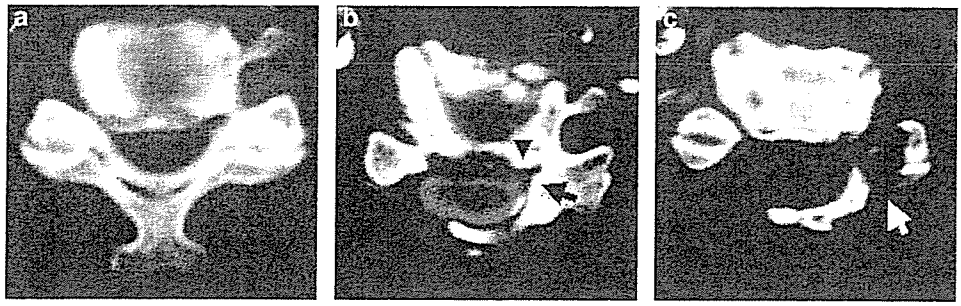

Figure 2 CT findings at C4–C5 level in Case 1. (**a**) CT myelogram before first operation. (**b**) CT myelogram 5 years after first operation. (**c**) CT 1 month after second operation. CT myelography revealed posterior spur formation (arrowhead) and hypertrophic facet joint (arrow) at the hinge side 5 years after the first operation. Posterior forminotomy was performed on the left side (white arrow)

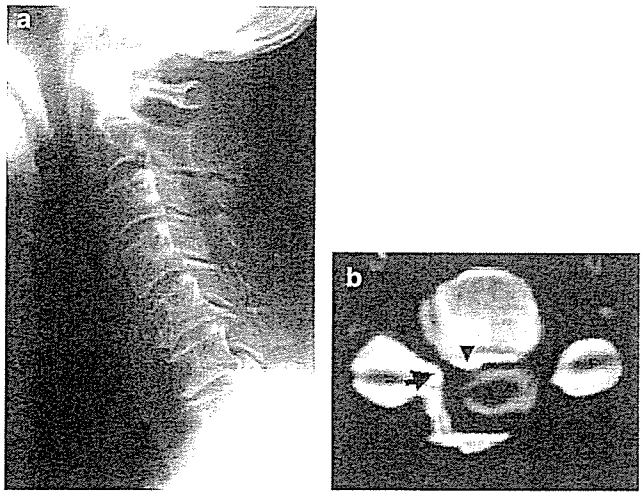

Figure 3 Plain lateral radiogram of the cervical spine and CT findings at C4–C5 level 7 years after first operation in Case 2. (**a**) Plain lateral radiogram of the cervical spine. (**b**) CT myelogram of the C4–C5 level. On the plain lateral radiogram, enlargement of the spinal canal, decrease of disc heights at C5–C6 and C6–C7 levels and posterior spur formations at C4–C5 and C5–C6 levels were observed. CT myelogram of the C4–C5 level revealed posterior spur formation (arrowhead) and hypertrophic facet joint (arrow) at the hinge side

disturbance or gait disturbance was observed. Motor weakness of MMT Grade 3 in the deltoid and biceps and sensory abnormality in the lateral aspect of the upper arm were observed on the right but not the left side. The biceps tendon reflex was diminished on the right side but normal on the left side. Other deep tendon reflexes were normal bilaterally in the upper and lower extremities. Spurling's neck compression test was positive on the right side. On plain radiography of the cervical spine, although enlargement of the spinal canal was maintained from C3 level to C7 level, decrease of disc heights at C5–C6 and C6–C7 levels and posterior spurs at C4–C5 and C5–C6 levels were observed (Figure 3a). According to White's criteria,[14] however, no spinal segmental instability was observed at the operated levels. CT myelography revealed posterior spur formation and hypertrophic facet joints on the right side at C4–C5 level (Figure 3b).

Posterior foraminotomy was performed at the C4–C5 level on the right side. Postoperatively, motor weakness in the deltoid and biceps muscles was improved.

Discussion

Segmental motor paralysis mainly involving C5 is occasionally seen in patients who have undergone laminoplasty.[7,10,16–18,20–22] This paralysis develops until 2 weeks after surgery and usually disappears spontaneously within 2 years after surgery.[10,17] Segmental motor paralysis is therefore considered to be one of the early complications of this procedure. It had long been believed that this paralysis was due to nerve root lesions caused either by inadequate surgical technique including trauma by high-speed burrs or Kerrison rongeurs or by compression resulting from dropping of a detached laminar hinge into the spinal canal.[10] However, these types of intraoperative trauma are likely to damage the posterior root rather than the anterior root, and the sensory disturbance should therefore be marked. Nevertheless, sensory disturbance was absent in most cases showing segmental paralysis after laminoplasty. Although the etiology of this paralysis remains unclear, several investigators have recently supported the hypothesis that it involves tethering of the nerve root induced by excessive posterior shift of the spinal cord after decompression.[10,15–22] In the present patients, on the other hand, degenerated facet joint and spur formation were considered as causes of paralysis and resulted in late deterioration following laminoplasty.

In general, degeneration of adjacent motion segments occurs less often after laminoplasty than after corpectomy.[17,18,20,21,23] The decreased incidence of adjacent segment degeneration observed after laminoplasty may result from maintenance of segmental motion.[23] However, preserved segmental motion may play a role in the development of spondylotic changes in operated motion segments after laminoplasty. This procedure disturbs facet joints since the medial portion of dorsal cortex and

cancellous bone in facet joints is drilled out to make a trough. Disturbed facet joints undergo degeneration over time after surgery. In patients who have undergone laminoplasty, degeneration of facet joints and uncovertebral joints may be exaggerated by preservation of segmental motion. Although the spinal cord is rarely compressed by spondylotic changes that develop because it is shifted posteriorly in the enlarged spinal canal, nerve roots might occasionally be compressed by degenerated facet joints and uncovertebral spurs that have developed at the entrance of the root canal, resulting in segmental motor paralysis several years after surgery. Therefore, concomitant foraminotomy combined with laminoplasty may be recommended for initial surgery for patients exhibiting root canal stenosis before surgery, even if they did not complain of symptoms of radiculopathy before surgery. For patients exhibiting segmental instability before surgery, fusion with posterior decompression may be selected.

In conclusion, delayed segmental motor paralysis may be considered as one of the late complications of laminoplasty. Disturbance of facet joints by drilling and development of spondylotic changes may result in development of root canal stenosis after surgery, occasionally associated with neurological deterioration. Careful long-term observation is thus necessary after this procedure.

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Ossification of the posterior longitudinal ligament of the thoracic spine in association with polycystic ovary syndrome

Sir,

A 24-year-old woman visited our hospital with a three-week history of muscle weakness and sensory disturbance of bilateral lower extremities. She exhibited moon-face, hepertrichosis, obesity and hyperglycemia, which are findings typical of Cushing's syndrome. However, this patient did not have a pituitary tumor. Tomography of the thoracic spine revealed ossification of the posterior longitudinal ligament (OPLL) at levels T6 to T9 [Figure 1] and severe compression of the spinal cord was found on magnetic resonance imaging [Figure 2]. Myelography and computer tomography were performed and OPLL was recognized at levels T3 to T9 of the spine [Figure 3]. She was diagnosed with thoracic myelopathy due to OPLL. Hypercholesterolemia and abnormally high testosterone level were found. She had also polycystic lesions in both ovaries [Figure 4] on magnetic resonance imaging and the diagnosis of polycystic ovary syndrome was established. Her neurological symptoms aggravated rapidly and she developed paraplegia. Emergency T3 to T9 laminectomy was performed [Figure 5] and her neurological symptoms were improved by surgery and she began to walk by eight weeks after surgery.

The patient presented here also had obesity and other abnormalities including hyperinsulinemia and

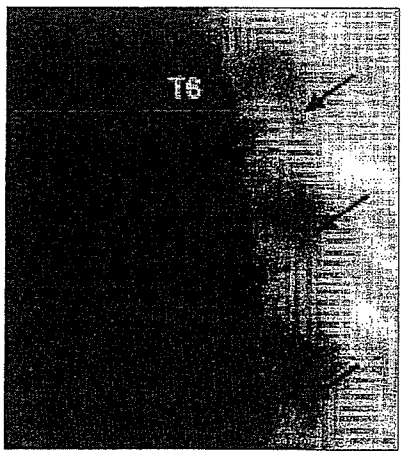

Figure 1: OPLL (arrows) was found at levels T6 to T9 on tomography

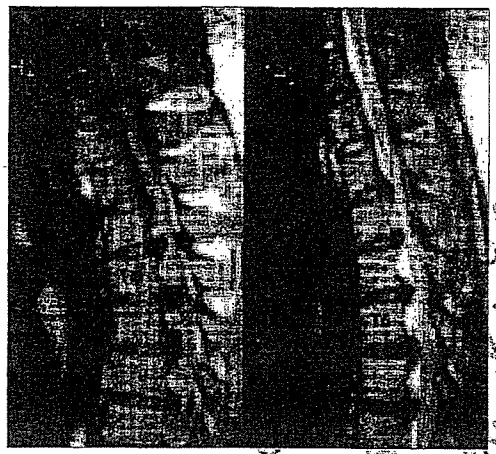

Figure 2: Severe compression of the spinal cord was found on magnetic resonance imaging. A: T1 weighted image, B: T2 weighted image

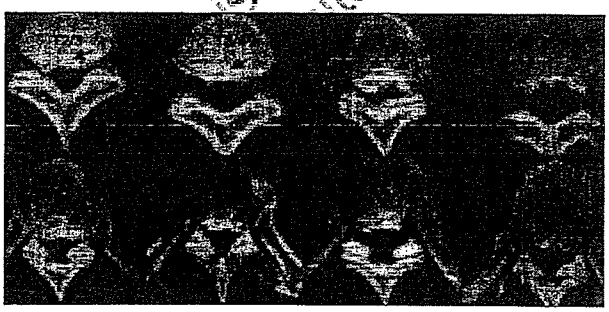

Figure 3: Computer tomography associated after myelography revealed OPLL (arrows) at levels T3 to T9

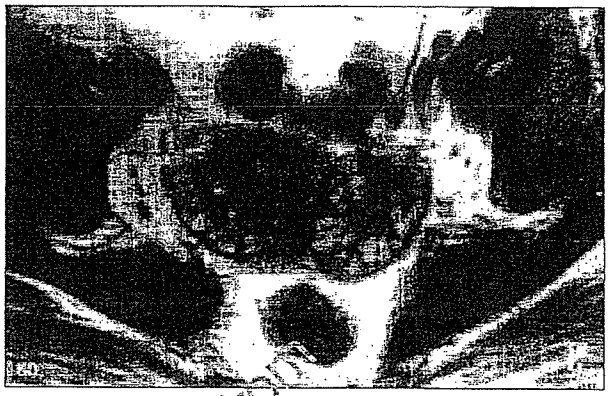

Figure 4: Magnetic resonance imaging revealed polycystic lesions (arrows) in both ovaries

Figure 5: Intraoperative finding at T3 to T9 laminectomy

hyperandrogenemia. Hyperinsulinemia has been reported as a factor possibly related to the occurrence of OPLL.[1] Polycystic ovary syndrome is characterized by polycystic lesions of both ovaries, oligoovulation, obesity, virilism, insulin resistance compensatory hyperinsulinemia and hyperandrogenemia.[2] The prevalence rates of polycystic ovary syndrome for Black and White women were reported to be 8.0 and 4.8%.[3] Our survey revealed no paper reporting the occurrence of OPLL in patients with polycystic ovary syndrome. However, the patients with polycystic ovary syndrome had been treated by gynecologists and the survey of the spine was not performed. The OPLL association with polycystic ovary syndrome might not be accidental. The characteristic findings of obesity, insulin resistance compensatory hyperinsulinemia, increased levels of free insulin-like growth factor-I (IGF-I)[4] and hyperandrogenemia in patients with polycystic ovary syndrome are suspected to be related to the occurrence of OPLL. The stature of female patients with OPLL in the thoracic spine corresponds to patients with polycystic ovary syndrome. IGF-I was reported to be involved in the development of OPLL.[5] Hormonal surveys for patients with OPLL in the thoracic spine may be useful for clarifying the pathogenesis of OPLL.

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Original article

Cervical spine disorders in farm workers requiring neck extension actions

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Abstract

Background. Cervical extension is considered a risk factor for provoking radicular and spinal cord compromise. However, there have been no reports on the relation between extension strain (ES) and cervical spine disorders: degenerative cervical spine disorders, dynamic canal stenosis (DCS), and cervical myelopathy. We performed a cross-sectional study to investigate the relation.

Methods. Orthopedic examinations were performed on 177 grape-growers (ES-exposed group) and 191 eggplant-growers (control group) between May and August 2000; and patients with degenerative cervical spine disorders, DCS, and cervical myelopathy were identified in the two groups. ES, degenerative cervical spine disorders, DCS, and cervical myelopathy were regarded as exposure variables; and age, sex, and working years were regarded as confounders. In cases where the subject was exposed to each exposure variable, multivariate-adjusted odds ratios to degenerative cervical spine disorders, DCS, and cervical myelopathy and multivariate-adjusted odds ratios regarding cervical myelopathy as the dependent variable were calculated by unconditional logistic regression analysis.

Results. Multivariate unconditional logistic regression analysis showed a significant odds ratio of ES to degenerative cervical spine disorders [2.72, 95% confidence interval (CI) 1.62–4.56]. Multivariate unconditional logistic regression analysis showed significant odds ratios for DCS (4.50, 95% CI 2.03–9.96) and age (1.07, 95% CI 1.01–1.14) regarding cervical myelopathy as the dependent variable.

Conclusions. These findings suggested that ES of the cervical spine is a risk factor for degenerative cervical spine disorders, and DCS and the aging process are risk factors for cervical myelopathy.

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Introduction

"The term degenerative cervical spine disorder" refers to vertebral osteophyte formation, apophyseal arthropathy, and intervertebral instability of the cervical spine caused by degenerative changes of the cervical intervertebral discs.[1] Degenerative cervical spine disorders have been thought to be related to age,[2] but the occurrence of such conditions at younger ages in two patients with athetoid cerebral palsy with strong involuntary movements was reported in 1962.[3] After this report, early occurrence of degenerative cervical spine disorders caused by overuse and axial pressure to the cervical spine has been occasionally reported.[4–6]

Degenerative cervical spine disorders develop without symptoms in many cases, progressing to spinal canal stenosis, which compresses the cervical spinal cord, resulting in cervical myelopathy.[1] Static compression,[7–9] dynamic compression,[10–12] and circulatory disorders[13] of the cervical spinal cord are postulated to be risk factors of cervical myelopathy, but the mechanism has not been clearly elucidated. In 1962, Penning[10] designated spinal canal stenosis caused by posterior transfer of the vertebral body associated with cervical extension as a pincers mechanism and proposed the concept of dynamic canal stenosis (DCS). Since this concept was proposed, it has been suggested that dynamic compression on the cervical spinal cord is involved in the occurrence and aggravation of cervical myelopathy.[14–16]

In routine clinical practice, we have recently noted a high prevalence of degenerative cervical spine disorders and of cervical myelopathy in farm workers who perform tasks requiring repetitive cervical extension. Thus, we performed a cross-sectional study of farm workers with and without extension strain (ES) of the cervical spine, and investigated the relation between ES and cervical spine disorders, including degenerative cervical spine disorders, DCS, and cervical myelopathy.

Subjects and methods

Subjects

In January 2000, a total of 177 grape-growers (74 men, 103 women) aged 30–69 years (mean 51.0 years) who worked in Fukuoka, Japan and who worked in a cervical extension position for 8 h per day for 8 months or more per year were selected as the study population of the ES-exposed subjects. Another group of 191 eggplant-growers (96 men, 95 women) aged 30–69 years (mean 50.8 years) who worked in Fukuoka, Japan and who did not work in a cervical extension position were selected as control subjects. All subjects were fully informed about this study and gave their consent. A self-administered questionnaire on age, sex (gender), working years, current symptoms, past history, and farm work details was administered, and an orthopedic examination was scheduled for the two groups. There had been no transfers to other districts or change of job in the two groups during the past 30 years according to documents from the agricultural cooperatives.

Orthopedic examination

The orthopedic examination was performed between May and August 2000. The current symptoms of pain in the neck, shoulders, and arms, numbness of the bilateral fingers, stiff shoulders, lumbago, and knee joint pain and the past history of all diseases were recorded; the physical examination were performed, and plain radiographs of the cervical spine were obtained at a distance of 1.5 m between the radiation source and the film tray using computed radiography-equipped Medical E-Mobile in cooperation with Fuji Medical System to produce middle and extension position images.

Diagnostic criteria for degenerative cervical spine disorders

Anterior and posterior osteophyte formation and intervertebral space narrowing at C3/4-6/7 segments (four segments) were evaluated based on plain radiographs obtained in the neck neutral position (Fig. 1). A rating of 3 or 4 by the Nathan classification was considered indicative of osteophyte formation.[17] A rating of 3 or 4 by the Lawrence classification was considered indicative of intervertebral space narrowing.[18] The presence of osteophyte formation was scored 1 and that of intervertebral space narrowing was scored 2 using Jäger's scoring system[6] (Table 1). The severity of degenerative cervical spine disorders was assessed as a total score for four segments (minimum–maximum scores 0–24) (Fig. 2). When the total score was 1 or higher, the subject was diagnosed as having a degenerative cervical spine disorder.

Table 1. Jäger's scoring system

Findings	Score
Anterior osteophyte formation	1
Posterior osteophyte formation	1
Intervertebral space narrowing	2

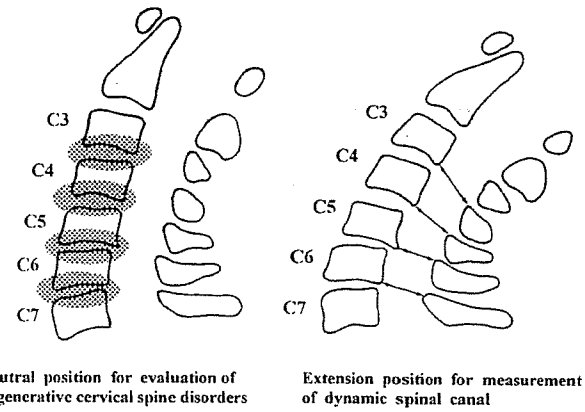

Fig. 1. Degenerative cervical spine disorders were evaluated at C3/4-6/7 segments (four segments) in the neutral position by plain radiography. In addition, the distance of dynamic spinal canal was measured at C3/4-6/7 segments (four segments) in the extension position

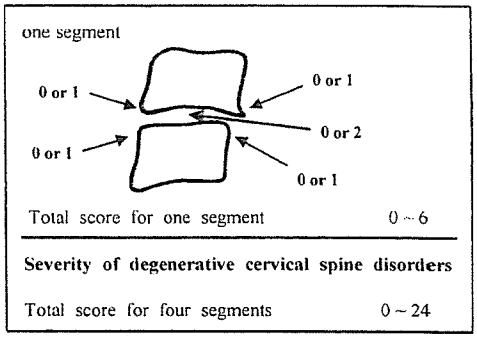

Fig. 2. Anterior and posterior osteophyte formation and intervertebral space narrowing were evaluated with regard to degenerative cervical spine disorders. The total score for one segment was 0–6. Regarding the severity of degenerative cervical spine disorders, the total score for four segments was 0–24

Diagnostic criteria for DCS

The distance between the posteroinferior edge of the vertebral body and the base of the spinous process of the vertebra below at C3/4-6/7 segments (four segments) were measured based on plain radiographs obtained in the neck extension position (Fig. 1). The shoulder was in contact with the film tray, and the distance from the radiation source to the film tray was set

at 1.5m. When the distance was less than 12mm at one or more segments, the subject was diagnosed as having DCS.

Evaluation of degenerative cervical spine disorders and measurement of dynamic spinal canal

The final diagnosis of degenerative cervical spine disorders and DCS were settled based on the majority evaluation of degenerative cervical spine disorders and the mean value of the diameter of the dynamic spinal canal determined by the five physicians (four orthopedists and one radiologist) who were blinded to the films and patients.

Diagnostic criteria for cervical myelopathy

The subject with numbness of the bilateral fingers was diagnosed as having cervical myelopathy regardless of the presence or absence of a degenerative cervical spine disorder or DCS. The orthopedic examination revealed no subjects with other diseases that might be suspected to cause numbness of the bilateral fingers, such as thoracic outlet syndrome or peripheral nerve entrapment neuropathy, nor were there subjects with a past history of peripheral neuropathy.

Statistical analysis

The χ^2 test was performed to evaluate the difference in the proportions of age and sex between the ES-exposed group and the control group. Intraclass correlation coefficients among the five physicians regarding evaluations of degenerative cervical spine disorders and measurements of the diameter of the dynamic spinal canal were calculated.

To investigate the relation between ES and cervical spine disorders, both exposure variables [i.e., ES (presence or absence), degenerative cervical spine disorders (presence or absence), DCS (presence or absence), cervical myelopathy (presence or absence)] and confounders [i.e., age (continuous number), sex (male or female), and working years (continuous number)] were regarded as explanatory variables. Unconditional logistic regression analysis was performed for the three conditions: (1) multivariate unconditional logistic regression analysis regarding ES, degenerative cervical spine disorders, DCS, and cervical myelopathy as exposure variables and age, sex, and working years as confounders and each cervical spine disorder as the dependent variable; (2) multivariate unconditional logistic regression analysis regarding all variables simultaneously as explanatory variables and cervical myelopathy as the dependent variable; and (3) multivariate unconditional logistic regression analysis regarding ES, degenerative cervical spine disorder, and DCS sequentially as explanatory variables including the confounders and cervical myelopathy as the dependent variable.

All statistical analyses were carried out using SPSS version 10.1. $P < 0.05$ was regarded as significant.

Results

There were no significant differences in the proportions of age or sex between the ES-exposed group and the control group (data not shown). The prevalence of degenerative cervical spine disorders, DCS, and cervical myelopathy tended to increase with age in both the ES-exposed and control groups (Table 2). The intraclass correlation coefficients among the five physicians for evaluations of degenerative cervical spine disorders was 0.92 ($P < 0.0001$) and that of measurements of the dynamic spinal canal was 0.91 ($P < 0.0001$), showing high consistency among the physicians.

Relation between ES and cervical spine disorders

The multivariate unconditional logistic regression analysis regarding ES, degenerative cervical spine disorders, DCS, and cervical myelopathy as exposure variables and age, sex, and working years as confounders, with each cervical spine disorder as the dependent variable showed a significant odds ratio and 95% confidence interval (CI) for ES to degenerative cervical spine disorders (2.72, 95% CI 1.62–4.56) (Table 3).

The multivariate unconditional logistic regression analysis regarding all variables simultaneously as explanatory variables and cervical myelopathy as the dependent variable showed significant odds ratios for DCS and age (data not shown).

The multivariate unconditional logistic regression analysis regarding ES, degenerative cervical spine disorders, and DCS sequentially as explanatory variables including the confounders and cervical myelopathy as the dependent variable revealed (1) there was no interaction of ES, degenerative cervical spine disorders, and DCS with the other explanatory variables; (2) that for evaluating the odds ratio of ES, degenerative cervical spine disorders, or DCS, the other five explanatory variables should be treated as confounders in the final model; and (3) only DCS (4.50, 95% CI 2.03–9.96; $P < 0.0001$) and age (1.07, 95% CI 1.01–1.14; $P = 0.02$) had significant odds ratios (Table 4).

Discussion

Because the present study was a cross-sectional one, the progression cannot be tested whether the relation

Table 2. Characteristics of study populations

Parameter, by age	ES-exposed group of grape growers			Control group of eggplant growers		
	Men	Women	Total	Men	Women	Total
Total no.	74	103	177	96	95	191
Age (years)						
30–39	10	17	27	14	13	27
40–49	23	25	48	30	32	62
50–59	22	42	64	29	26	55
60–69	19	19	38	23	24	47
No. of degenerative cervical spine disorder cases[a]						
30–39 Years	0	2 (11.8)	2 (7.4)	2 (14.3)	0	2 (7.4)
40–49	7 (30.4)	9 (36.0)	16 (33.3)	7 (23.3)	9 (28.1)	16 (25.8)
50–59	18 (81.8)	34 (81.0)	52 (81.3)	16 (55.2)	13 (50.0)	29 (52.7)
60–69	15 (78.9)	15 (78.9)	30 (78.9)	14 (60.9)	16 (66.7)	30 (63.8)
Severity of degenerative cervical spine disorders (mean score)						
30–39 Years	0	0.12	0.07	0.21	0	0.11
40–49	0.83	0.68	0.75	0.63	0.72	0.68
50–59	3.27	2.24	2.59	1.24	1.38	1.31
60–69	3.21	3.21	3.21	2.48	1.92	2.19
No. of DCS cases[b]						
30–39 Years	1 (10.0)	3 (17.6)	4 (14.8)	1 (7.1)	0	1 (3.7)
40–49	3 (13.0)	4 (16.0)	7 (14.6)	2 (6.7)	6 (18.8)	8 (12.9)
50–59	5 (22.7)	11 (26.2)	16 (25.0)	6 (20.7)	7 (26.9)	13 (23.6)
60–69	8 (42.1)	9 (47.4)	17 (44.7)	8 (34.8)	6 (25.0)	14 (29.8)
No. of cervical myelopathy cases[c]						
30–39 Years	0	0	0	0	0	0
40–49	1 (4.3)	3 (12.0)	4 (8.3)	0	2 (6.3)	2 (3.2)
50–59	2 (9.1)	4 (9.5)	6 (9.4)	1 (3.4)	3 (11.5)	4 (7.3)
60–69	4 (21.1)	5 (26.3)	9 (23.7)	4 (17.4)	4 (16.7)	8 (17.0)

There were no significant differences in the proportions of age or sex between the ES-exposed group and the control group
ES, extension strain; DCS, dynamic canal stenosis
Numbers in parentheses represent [a] the prevalence of degenerative cervical spine disorders (%), [b] prevalence of DCS (%), [c] prevalence of cervical myelopathy (%)

Table 3. Odds ratios adjusted by the other exposure variables, age, sex, and working years

Exposure variables	Dependent variables (cervical spine disorders)		
	Degenerative cervical spine disorders	DCS	Cervical myelopathy
ES	2.72* (1.62–4.56)	1.20 (0.69–2.09)	1.30 (0.58–2.88)
Degenerative cervical spine disorders	—	2.28* (1.20–4.33)	2.06 (0.73–5.81)
DCS	2.39* (1.25–4.58)	—	4.50* (2.03–9.96)
Cervical myelopathy	2.02 (0.69–5.88)	4.48* (2.03–9.87)	—

Numbers in parentheses are 95% confidence intervals
* $P < 0.05$

between ES and a cervical spine disorder is causal. However, because there had been no transfers to other districts or change of job during the past 30 years (which is longer than the mean working years: 23.5 and 25.3 years, respectively), the data may be regarded as a quasi-retrospective cohort one.

The odds ratio obtained by multivariate unconditional logistic regression analysis of ES to degenerative cervical spine disorders was significantly high: 2.72 (95% CI 1.62–4.56), indicating that ES and degenerative cervical spine disorders had a significant relation (Table 3). This finding suggested that ES of the cervical spine is a risk factor for degenerative cervical spine disorders.

Cervical myelopathy is a symptom of cervical spinal cord and roots due to protrusion of the intervertebral

Table 4. Odds ratios with cervical myelopathy as the dependent variable

	Dependent variable: cervical myelopathy		
Explanatory variables	OR	95% CI	*P*
ES	1.30	(0.58–2.88)	0.53
Degenerative cervical spine disorders	2.06	(0.73–5.81)	0.17
DCS	4.50*	(2.03–9.96)	<0.0001
Age	1.07*	(1.01–1.14)	0.02
Sex	0.70	(0.32–1.57)	0.39
Working years	1.00	(0.96–1.05)	0.89

OR, odds ratio; CI, confidence interval
*$P < 0.05$

disc or marginal prominence of the spinal body. The clinical view is complex and variable, depending on the position of the cervical spinal cord lesion; and many symptoms occur, such as numbness of the bilateral fingers, skillful movement dysfunction of the fingers, and bowel and bladder dysfunction.[1] Therefore, a definitive diagnosis of cervical myelopathy by an orthopedic examination is difficult. In the present study, numbness of the bilateral fingers was regarded as the onset of cervical myelopathy because it occurs most frequently as the initial symptom and is typical.[19,20] The diagnostic criteria for cervical myelopathy used in this study correspond to potential cervical myelopathy.

Multivariate unconditional logistic regression analysis regarding cervical myelopathy as the dependent variable revealed significant odds ratios for DCS (4.50, 95% CI 2.03–9.96) and age (1.07, 95% CI 1.01–1.14) (Table 4). These findings suggested that DCS and the aging process are risk factors for cervical myelopathy. DCS has been highlighted in past case-control studies by many researchers.[10–12,14–16] In 1956, Wolf et al.[7] reported that when the minimum sagittal diameter is <10mm cervical spinal cord compression may be predicted. In 1962, Penning[10] reported that when the diameter of the dynamic spinal canal is <11mm there is a strong suspicion of cervical spinal cord compression at this site. In 1975, Kataoka et al.[14] reported that when the diameter of the dynamic spinal canal is <12mm dynamic compression on the cervical spinal cord occurs. In the present study, the criterion of <12mm, generally used in Japan, was defined as DCS. With regard to the aging process, in 1999 Wang et al.[21] reported that the decrease of the cervical spinal cord area and decreased neurons and myelin in the cervical spinal cord occurs with age.

Because farm workers are busy and do not usually consult a hospital even when they have mild cervical spine disorders, their cervical spine disorder is often severe by the time they seek help. Therefore, prevention of cervical spine disorders is important. We propose that working conditions be improved by reducing ES, for example, by using a footstool.

Conclusions

Extension strain may be a risk factor of degenerative cervical spine disorders. Therefore, farm workers who are at risk for extension strain of the cervical spine should be provided education about cervical spine disorders and their prevention.

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Original Contribution

Kurume Medical Journal, 53, 7-12, 2006

Double-Door Laminoplasty Using Autologous Spinous Process for the Management of Cervical Myelopathy

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Summary: We describe a technique of double-door laminoplasty for the management of cervical myelopathy using the autologous spinous process instead of an artificial spacer. The aims in the present study were to determine the fusion rate and the incidence rate of breakage in the autologous spinous process, and to assess its efficacy for cervical laminoplasty. Twenty-three patients of cervical myelopathy were treated with double-door laminoplasty followed by implantation of the autologous spinous process. The spinous process from C3 to C7 was resected, at 8 mm from the basal part of the spinous process. The autologous spinous process was made from the removed spinous process, and was implanted between each expanded laminae. Post-operative CT scanning determined the fusion rate between the expanded laminae and the autologous spinous process as 70.4% at 3 months, and 93.5% at 6 months, after the operation. There was no dissociation and no breakage in the autologous spinous process during the follow-up observation period. There were certain advantages to our technique including the high fusion rate and good stability in the autologous spinous process. In addition, this technique was less expensive than other techniques using an artificial spacer. These findings indicated that this technique was a reliable procedure for effectively treating of cervical myelopathy which are caused by multisegmental cervical canal stenosis.

Key words double-door laminoplasty, autologous spinous process, fusion rate

INTRODUCTION

For the surgical treatment of multisegmental cervical canal stenosis, there are various surgical procedures available. The choice of procedure depends on many factors, including the cause of the spinal cord compression, the number of vertebral segments involved in the disease process, the cervical alignment, and the surgeon's familiarity with the technique [1]. The poor outcomes associated with cervical laminectomy have led to the development of the new technique of laminoplasty, for achieving posterior decompression, in Japan [2-8]. A number of modifications in laminoplasty have been reported. Double-door laminoplasty was introduced by Kurokawa et al. [9] in 1982, and has now been widely performed. In the original procedure, small bone blocks from the iliac crest were grafted to keep the split spinous processes separated, thereby providing a wider space for the spinal cord. However, this procedure causes some side effects such as door site pain, a long operative duration, and significant blood loss. In order to avoid these problems, laminoplasty using spacers made of artificial materials such as hydroxyapatite (HA) then became popular. However, inadequate contact between the artificial spacer and the spinous process has been reported. The inadequate contact rate between them was about 30% [10-13]. Therefore new artificial spacers are being developed for improving good fusion rate.

We have been performing double-door laminoplasty using the autologous spinous process instead

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Abbreviations: CSM, cervical stenotic myelopathy; HA, hydroxyapatite; JOA, Japanese Orthopedic Association; OPLL, posterior longitudinal ligament; ROM, range of motion.

of an artificial spacer since 1988 [14]. A short length of the spinous process is resected, and then this removed spinous process is implanted between the expanded laminae. We have previously reported that the clinical outcome from this surgical technique was satisfactory [15]. But there is no report yet on the fusion rate and the incidence rate of breakage in the autologous spinous process within 6 months after operation. The purpose of the present study was to examine the fusion rate and the incidence rate of breakage in the autologous spinous process and to assess its efficacy for cervical laminoplasty.

MATERIALS AND METHODS

Patient population

Double-door laminoplasty has been performed for 23 patients involving 12 patients with cervical stenotic myelopathy (CSM), and 11 patients with ossification in the posterior longitudinal ligament (OPLL), in Kurume University Hospital, in the 6 months from January to June 2003. There were 18 men and 5 women, with an average age of 62.1 years (range 34-80 years). All patients presented lordotic or neutral curvature in the cervical spine, and no patient showed gross spinal instability.

Operative technique

The expansive double-door laminoplasty was performed by sagittal splitting of the spinal process, as developed by Kurokawa et al. [9]. The bilateral posterior neck muscles are dissected from the laminae to enlarge the surgical field. After exposing the muscles on one side, the spinal process is separated, and the spinous process, ligaments, and posterior neck muscles are exposed en bloc. Then, each spinous process from C3 to C7 is resected at 8 mm from the basal part of spinous process. The autologous spinous process about 10 to 15 mm long is made from the removed spinous process, and then implanted between each expanded lamina [14] (Fig. 1). After reconstruction of the laminae, the grafts are held in place with sutures that are passed through holes in the laminae made using a 1-millimeter burr. The average operative duration and blood loss are recorded.

Clinical evaluation

The severity of preoperative clinical symptoms was determined using an evaluation score established by the Japanese Orthopedic Association (JOA score) (Table 1). The JOA scores were determined at just before the operation, and at 3 months and at 6 months after the operation.

Radiographic evaluation

The range of motion (ROM) between flexion and extension of the cervical spine was measured at before the operation, and at 3 months and at 6 months after the operation, using lateral-view radiographs. The angle between the two lines extending from the posterior margins of the vertebral bodies of C2 and C7 was measured in maximum flexion, and

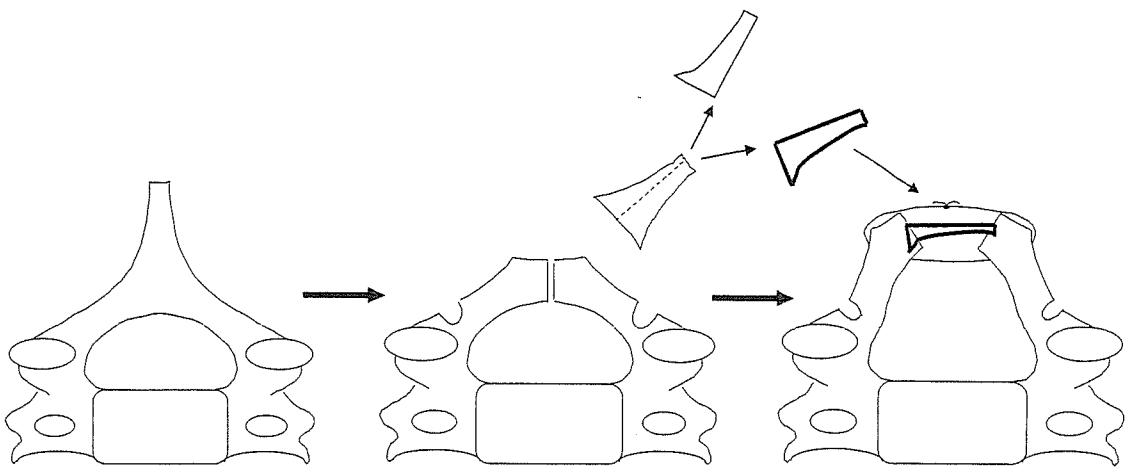


Fig. 1. The spinous processes are removed, and the remaining spinous process is split using a drill. Autologous spinous processes which are about from 10 to 15 mm long are made from the removed spinous processes and are implanted between the expanded laminae.

TABLE 1.
Japanese orthopaedic association scoring system (17-2) for cervical myelopathy

I. *Motor function*
1. Finger
0 = Unable to feed oneself with any tableware including chopsticks, spoon or fork, and/or unable to fasten buttons of any size
1 = Can manage to feed oneself with a spoon and/or fork but not with chopsticks
2 = Either chopsticks-feeding or writing is possible but not practical, and/or large size buttons can be fastened
3 = Either chopsticks-feeding or writing is clumsy but practical, and/or cuff buttons can be fastened
4 = Normal
2. Shoulder and elbow (evaluated by MMT score of the deltoid or biceps muscles, whichever is weaker)
−2 = MMT 2 or less, −1 = MMT 3, −0.5 = MMT 4, 0 = MMT 5
3. Lower extremity
0 = Unable to stand up and walk by any means
0.5 = Able to stand up but unable to walk
1.5 = Able to walk without support but with a clumsy gait
2 = Walks independently on a level but needs support on stairs
2.5 = Walks with independently when going upstairs, but needs support when going downstairs
3 = Capable of fast walking but clumsy
4 = Normal

II. *Sensory function*
A. Upper extremity
0 = Complete loss of touch and pain sensation
0.5 = 50% or less normal sensation and /or severe pain or numbness
1 = More than 60% normal sensation and/or moderate pain or numbness
1.5 = Subjective numbness of a slight degree without any objective sensory deficit
2 = Normal
B. Lower extremity
Same as A
C. Trunk
Same as A

III. *Bladder function*
0 = Urinary retention and/or incontinence
1 = Sense of retention and/or dribbling and/or thin stream and/or incomplete continence
2 = Urinary retardation and/or pollakiuria
3 = Normal

Total score for a normal individual = 17, MMT : manual muscle test

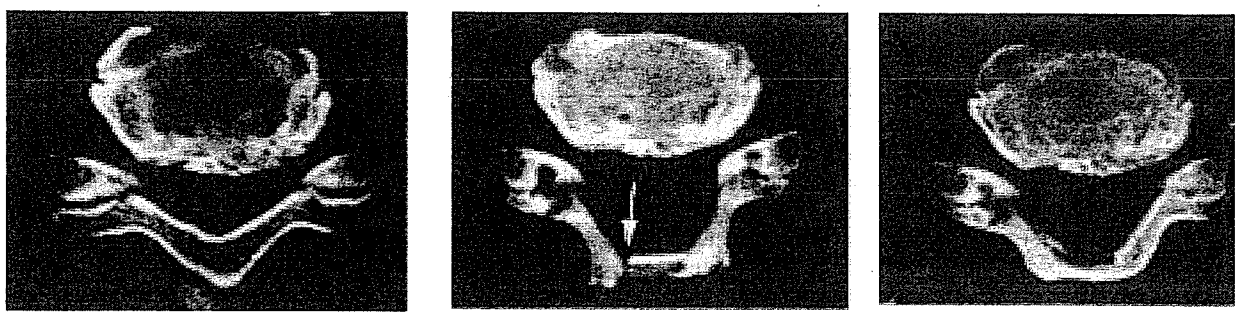
in extension. The sum of these two angles was defined as the ROM.

CT evaluation

At three months and at six months after the operation, a CT scan was taken to determine the fusion rate between each expanded lamina and the autologous spinous process. Helical CT scanning was performed to examine each expanded lamina including the autologous spinous process, with 3-mm collimation. The gantry was placed parallel to each lamina. All laminae were then divided into 2 classes; Group A with bony fusion, and Group B with non-fusion (Fig. 2). Three independent observers evaluated the bone fusion at both side of 115 opened laminae (total 230 points) from 23 patients. Bony fusion was concluded to have been achieved when 2 of the 3 observers agreed.

RESULTS

The average JOA score was 9.68±2.6 points (range from 4.5 to 13.5 points) before surgery, 12.95±2.6 points (range from 9.5 to 16.5 points) at 3 months, and, 13.06±2.4 points (range from 10.5 to 16.5 points) at 6 months after the operation (Fig. 3A). The recovery rate was 43.8±24.5 at 3 months, and 49.1±23.7 at 6 months. No postoperative



A: Preoperative B: Postoperative at 3 month C: Postoperative at 6 month

Fig. 2. Preoperative (A), postoperative at 3 months (B) and at 6 months (C) CT scans of the fifth cervical vertebral level of a patient with OPLL. The right expanded lamina of Fig. 2B shows a clear space between the autologous spinous process and the bone (arrow), and was categorized into Group B as non-fusion. The left expanded lamina of Fig. 2B and Fig. 2C show no space between them with new bone formation, and were categorized into Group A as fusion.

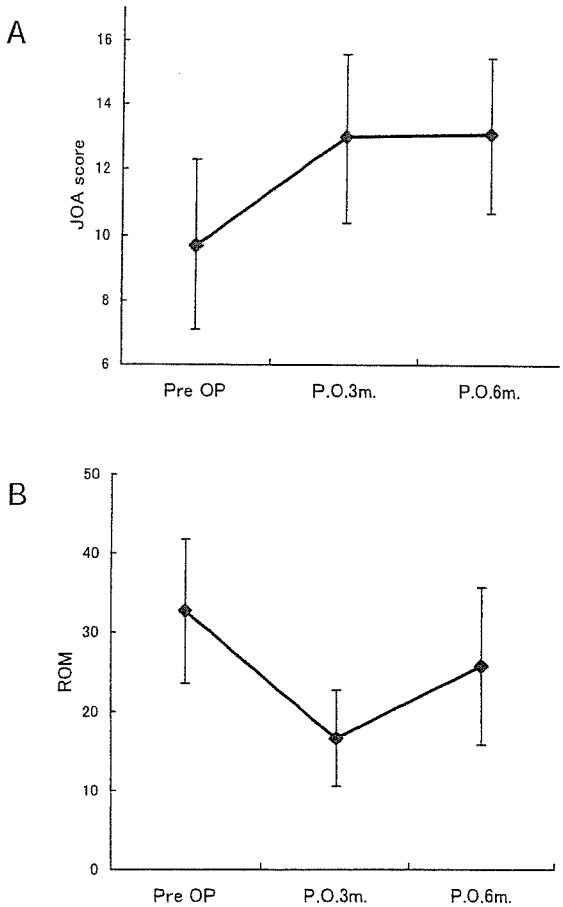


Fig. 3. A, Changes in the JOA score over time in patients. The average preoperative JOA score of 9.68± 2.6 (mean± SD) increased to 12.95±2.6 at 3 months after surgery and to 13.06± 2.4 at 6 months. B, Changes in the ROM of the cervical spine over time in patients. The average ROM of 32.7±9.1 (mean± SD) decreased to 16.7±6.1 at 3 months after surgery and then increased to 25.8±9.9 at 6 months.

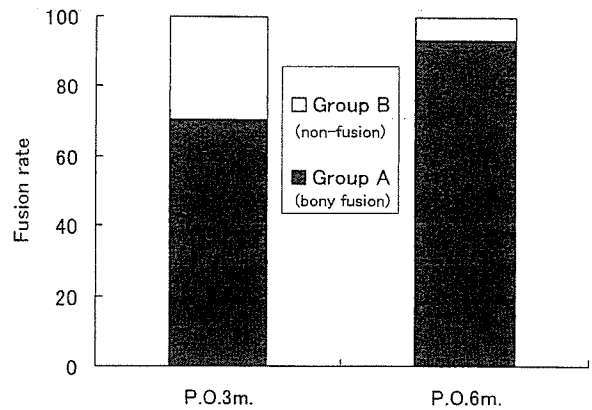


Fig. 4. The status of bone fusion after surgery. The fusion rate between the expanded lamina and the autologous spinous process was 70.4% at 3 months after the operation. The fusion rate at 6 months after the operation was 93.5%. There was no dissociation and no breakage in the autologous apinous process during the follow-up observation period.

deterioration in symptoms was seen in any patient.

The average ROM of the cervical spine was 32.7±9.1 at pre-operation. The average ROM after the operation was 16.7±6.1 at 3 months, and 25.8± 9.9 at 6 months (Fig. 3B).

Post-operative CT scanning was used to investigate the reconstructed laminae at 3 and at 6 months after the operation. The fusion rate between each expanded lamina and the autologous spinous process was 70.4% (162 of 230) at 3 months, and 93.5% (215 of 230) at 6 months (Fig. 4). There was no dissociation, and no breakage in the autologous spinous process during the 6 months of the follow-up period.