Expansive Laminoplasty by Sagittal Splitting of the Spinous Process for Cervical Myelopathy: Correlation of Clinical Results with Morphological Changes in the Cervical Spine

KAZUMASA ISHIBASHI

Department of Orthopaedic Surgery, Kurume University School of Medicine, Kurume 830-0011, Japan

Summary: Morphological changes in the cervical spine were evaluated using radiography in 140 patients with cervical myelopathy who underwent expansive laminoplasty by sagittal splitting of the spinous process. We assessed the influence of these observed changes on the postoperative clinical results. The mean follow-up period was 33±19 months. Intervertebral body union occurred in 18%, and interlaminal union in 80% of the patients. The factors influencing the bony union in these were not identified. Bony union did not significantly influence the clinical results. There were changes in cervical alignment in 29 (21%) patients after the operation. Correlation between the spinal curvature and the clinical results was the strongest for the sigmoid-type curvature. The number of patients in whom preoperative ROM was maintained was only 8 (7%). The range of cervical spine motion decreased by approximately 50%, and there was no correlation with the clinical results. The surgical method described in the current study for compression myelopathy was associated with postoperative morphological changes and decreased ROM in the cervical spine, but nonetheless provided good postoperative results unless extreme morphological abnormalities occurred. This surgical technique was safe and gave satisfactory results in patients with preoperative morphological abnormalities in the cervical spine.

Key words cervical spine, compression cervical myelopathy, cervical morphology, decompression surgery, expansive laminoplasty, cervical alignment

INTRODUCTION

Surgical enlargement in the spinal canal, also called expansive laminoplasty, for cervical myelopathy is an operative method developed in Japan. Since laminoplasty by Z-plasty (Hattori’s method) was first reported by Oyama and Hattori [1] in 1973, a number of surgical techniques for expansive laminoplasty have been developed, including extensive simultaneous multisegment laminectomy described by Kirita [2] in 1976, expansive open-door laminoplasty reported by Hirabayashi [3] in 1978, and expansive laminoplasty by sagittal splitting of the spinous process described by Kurokawa [4] in 1982. The advantage of expansive laminoplasty has been sufficient decompression of the spinal cord while maintaining the physiological status of the cervical spine. However, problems associated with this surgery have been decreased in cervical motion due to interbody or interlaminal bony union, changes in the alignment of the cervical spine as seen with laminectomy, changes in spinal cord curvature, and development of pain surrounding the neck. Sufficient clinical results following expansive laminoplasty have been reported [5-10], but detailed comparison between the clinical outcomes and the morphological changes in the cervical spine has not yet been performed in a large number of patients after expansive laminoplasty. Therefore, we have performed longitudinal studies on the radiographic changes in the cervical spine after expansive laminoplasty.
MATERIALS AND METHODS

Patients

The subjects were 140 patients who underwent expansive laminoplasty by sagittal splitting of the spinous process for compression cervical myelopathy at our Department over 11 years from 1984 to 1994, for whom clinical follow-up as well as radiographic data were available for a period of at least one year after surgery. Patients with trauma-related myelopathy, a spinal cord tumor, or reoperation after anterior fusion were excluded. The patients consisted of 87 men and 53 women aged between 36 and 83 years (mean age 63±10 years). The mean follow-up period was 33±19 months (range 12-96 months). The causes for the myelopathy included cervical spondylosis (CS) in 72 patients, intervertebral disc herniation (DH) in 6 patients, and ossification of the posterior longitudinal ligament (OPLL) in the other 62 patients.

Operative method

Expansive laminoplasty by sagittal splitting of the spinal process developed by Kurokawa et al. [4] was employed in all subjects. In 19 patients (OPLL: 12, CS: 7 patients, 12 men and 7 women) who received the operation early on the study period, interlaminal fusion at the enlargement was performed using an autologous iliac bone strut graft. In the surgical technique performed during this period, the bilateral posterior neck muscles were dissected from the laminae to enlarge the surgical field. In the 121 patients who received the operation after October 1988, we used a method for exposure that sought to preserve these muscles: after exposing the muscles on one side, the spinal process was separated, and the spinous process, ligaments, and posterior neck muscles were exposed en bloc. After that, the spinous process was shortly resected, and the removed spinous process was implanted between the expanded laminae [10,11].

Clinical assessment

Preoperative and postoperative clinical symptoms were assessed according to the scoring system proposed by the Japanese Orthopaedic Association (JOA) score (Table 1), and the recovery rate was calculated using Hirabayashi’s method [(postoperative score-preoperative score)×100/(17-preoperative score)]. A recovery rate of ≥75% was described as excellent, >74%≤50% as good, >50%≤25% as fair, <24% ≥0% as unchanged, and <0% as worsened. The relationship between the clinical results and various parameters, including age, sex, duration of disease, and sagittal diameter of the spinal canal, was analyzed statistically.

Radiographic findings

Morphological changes in the cervical spine on plain radiography were reviewed in 140 patients. Lateral-view flexion and extension radiographs were examined for the evidence of any postoperative interbody or interlaminal bony union of the vertebrae.

Alignment in the cervical spine

Curvature observed on the lateral-view radiograph in the neutral position was classified as lordotic, straight, kyphotic or sigmoid type.
EXPANSIVE LAMINOPLASTY

Fig. 1. Radiographic measurement of cervical spine.

a: Measurement method of range of motion in the cervical spine \( (\alpha + \beta) \). The sum of the angles between two lines drawn along the posterior surfaces of C2 and C7 in flexion \( (\alpha) \) and extension \( (\beta) \).
b: Range of motion of the intervertebral disc space. The ROM of the intervertebral disc space was determined as the sum of the angles between the lines extending from the inferior margins of adjacent vertebral bodies in flexion and extension.
c: Alignment of cervical spine (Ishihara’s method [12]). A line is drawn between the lower posterior margin of C2 and upper posterior margin of C7 (A). Perpendicular lines are drawn to line A from the lower posterior margins of C3-C6 to obtain their sum \((a_1 + a_2 + a_3 + a_4)\). The curvature index is calculated as \((a_1 + a_2 + a_3 + a_4 \text{ mm}) \times 100/A \text{ mm}\).

Range of motion (ROM) in the cervical spine

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 extension. The sum of these angles was defined as the ROM of the cervical spine (Fig. 1a). The ROM of the intervertebral space was determined as the sum of the angles between the lines extending from the inferior margins of adjacent vertebral bodies in flexion and extension (Fig. 1b).

Instability of the cervical spine

Patients showing slipping of more than 3 mm of the posterior margin of the vertebral body on cervical radiography in maximum flexion and extension were assessed as having instability.

Alignment of the cervical spine (Ishihara’s method [12])

In the neutral position, at first, a line was drawn on the radiogram between the posteroinferior margins of the vertebral bodies of C2 and C7. Next, perpendicular lines were drawn from the posteroinferior margins of the vertebral bodies of C3-C6 extending to the line drawn earlier. The ratio between the length of the line drawn earlier (denominator) and the sum of the perpendicular lines (numerator) was computed to obtain the Curvature Index (Fig. 1c). This index shows objectively the type of curvature in the cervical spine; in general, a ratio of \( \geq 0 \) represents the lordotic-type (the degree of lordosis increases with increasing ratio), and a ratio of \( < 0 \) indicates the sigmoid-type or kyphotic-type curvature.

Statistics

Student’s t test and repeated measures analysis of variance were used for comparison of groups and different time periods, respectively. Differences were considered significant at the level of \( p<0.05 \) for each statistical method.

RESULTS

Clinical results (Table 2)

The JOA score was 9.1\(\pm\)2.9 points (range 2 to 15 points) before surgery and 13.4\(\pm\)2.4 points (range 5 to 17 points) at follow-up, with a mean recovery rate in JOA score of 53\(\pm\)28% (range −3 to 100%) over all patients. The recovery rate was 79\(\pm\)18% (range
50 to 100%) in the 6 patients with DH, 52±28% (range -7 to 100%) in the 72 patients with CS, and 53±29% (range -33 to 100%) in the other 62 patients with OPLL. The rate of patients who were evaluated as excellent or good was 100% (6/6) of the patients with DH, 64% (45/72) of those with CS, and 61% (39/62) of those with OPLL. The difference in the recovery rate between DH and the other two groups was each significant (both p > 0.05), but difference between patients with CS and OPLL was not significant. The recovery rate in the group with preservation of the supporting posterior structures was 54±28% (−33 to 100%), and that in the patients without preservation was 49±29% (−7 to 94%), with no significant difference.

Radiographic findings

Bony union of intervertebral body (Fig. 2): During the postoperative follow-up period, bony union of intervertebral bodies occurred in 26 (18%) patients,

### TABLE 2.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Results</th>
<th>Age (years)</th>
<th>Gender (male:female)</th>
<th>Duration disease (years)</th>
<th>Follow-up (months)</th>
<th>pre JOA (points)</th>
<th>post JOA (points)</th>
<th>Recovery rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>63 ± 10</td>
<td>87 : 53</td>
<td>28 ± 39</td>
<td>33 ± 19</td>
<td>9.1 ± 2.9</td>
<td>13.4 ± 2.4</td>
<td>53 ± 28</td>
<td></td>
</tr>
<tr>
<td>DH</td>
<td>55 ± 13</td>
<td>2 : 4</td>
<td>4 ± 2</td>
<td>28 ± 13</td>
<td>8.9 ± 3.4</td>
<td>15.6 ± 1.1</td>
<td>79 ± 18</td>
<td></td>
</tr>
<tr>
<td>CS</td>
<td>66 ± 10</td>
<td>39 : 33</td>
<td>33 ± 46</td>
<td>30 ± 17</td>
<td>8.9 ± 3.0</td>
<td>13.3 ± 2.2</td>
<td>52 ± 28</td>
<td></td>
</tr>
<tr>
<td>OPLL</td>
<td>61 ± 9</td>
<td>46 : 16</td>
<td>23 ± 29</td>
<td>37 ± 21</td>
<td>9.4 ± 2.7</td>
<td>13.3 ± 2.6</td>
<td>53 ± 29</td>
<td></td>
</tr>
</tbody>
</table>

ALL: all patients; DH: disc herniation, CS: cervical spondylotic myelopathy; OPLL: ossification of posterior longitudinal ligament; pre JOA: Preoperative Japanese Orthopedic Association score (0-17 points); post JOA: Postoperative Japanese Orthopedic Association score (0-17 points)

Recovery rates were calculated using Hirabayashi’s method: (postoperative score - preoperative score) × 100/(17-preoperative score) %.

Fig. 2. The intervertebral disc level of bony union. Union of vertebral bodies was observed at one year or more after surgery in most cases, and there was no specificity to the levels involved. Interlaminal union occurred relatively early after surgery, and higher cervical spines were involved more frequently.
EXPANSIVE LAMINOPLASTY

consisting of 16 (18%) men and 10 (19%) women. Interbody bony fusion was observed in 19 (16%) of the 121 patients who did not undergo interlaminal strut bone graft and in 7 (37%) of the 19 patients who underwent interlaminal strut bone graft, with significant difference (p=0.0358). Bony union was observed in 11 (15%) patients with CS and in 15 (24%) patients with OPLL; the number of levels of vertebral body union was greater in OPLL, but the difference was not significant. Bony union occurred within 6 months in 5 (19%) patients and after 1 year in 21 (81%) patients. The extent of intervertebral body union was 1 level in 9 patients, 2 levels in 5 patients, 3 levels in 8 patients, and 4 or more levels in 5 patients. There was no specificity regarding the level involved.

The recovery rate of JOA score was 53±27% in patients with bony union, and 54±29% in those without union, with no significant difference.

Interlaminal bony union (Fig. 2): Interlaminal bony union was observed in 97 (80%) of the 121 patients (CH: 6, CS: 65, OPLL: 50 patients, men: 75, women: 46) who did not undergo interlaminal fusion, consisting 59 men (79%) and 38 (83%) women. There were 4 (67%) of 6 patients with DH, 49 (75%) of 65 patients with CS, and 44 (88%) of 50 patients with OPLL with no significant difference among these. Bony union occurred within 6 months after surgery in 46 (47%) patients, between 6 months and 1 year in 41 (42%), and after 2 years or more in 10 (10%) patients. Thus, bony union occurred within 1 year in 87 (90%) patients, indicating that interlaminal union occurred earlier than interbody union. The number of interlaminal spaces united was 1 level in 42 (44%) patients, 2 levels in 26 (27%) patients, 3 levels in 12 (12%) patients, and 4 or more levels in 17 (18%) patients. Of the intervertebral disc levels, C2/3 was most commonly involved in 65 patients (p<0.05).

The recovery rate in JOA score was 53±30% in patients with interlaminal union, and 53±28% in those without union, with no significant difference.

Factors that may be involved in interlaminal bony union were examined in 121 patients. At follow-up, of 25 (21%) patients who showed progression to apparent osteoporosis, 22 (88%) had interlaminal bony union, but there was no significant difference in the rate of bony union between patients with osteoporosis and patients without osteoporosis. Statistical analysis showed that interlaminal bony union was not significantly correlated to age, extent of laminoplasty, or to the alignment of the cervical spine.

Changes in cervical alignment and correlation to clinical results

Alignment of the cervical spine before operation: Ninety-four (67%) patients had lordotic-type, 30 (21%) had straight-type, 2 (1%) had kyphotic-type, and 14 (10%) had sigmoid-type curvature, preoperatively. No significant difference was observed in the frequency of these curvatures in terms of age, sex, or disease.

The recovery rate in JOA score was 49±29% (−33 to 100%) in the lordotic group, 60±23% (8 to 100%) in the straight group, 51±46% (18 to 83%) in the kyphotic group, and 67±32% (0 to 100%) in the sigmoid group, with no significant difference. Thus, the preoperative cervical curvature had no significant influence on the operative results (Table 3).

Alignment of the cervical spine after operation: Seventy-seven (55%) patients had lordotic-type, 37 (26%) had straight-type, 10 (7%) had kyphotic-type, and 16 (11%) had sigmoid-type curvature, postoperatively.

The recovery rate in JOA score was 43±28% (−33 to 100%) in the lordotic group, 57±26% (8 to 100%) in the straight group, 59±30% (0 to 94%) in

<table>
<thead>
<tr>
<th>Types of Alignment</th>
<th>Results</th>
<th>Age</th>
<th>Gender</th>
<th>Disease</th>
<th>pre JOA</th>
<th>post JOA</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(years)</td>
<td>(male:female)</td>
<td>(DH:CS:OPLL)</td>
<td>(points)</td>
<td>(points)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td>Lordotic (n=94)</td>
<td>63 ± 10</td>
<td>35 : 59</td>
<td>4 : 46 : 44</td>
<td>9.1 ± 2.6</td>
<td>13.1 ± 2.5</td>
<td>49 ± 29</td>
<td></td>
</tr>
<tr>
<td>Straight (n=30)</td>
<td>63 ± 9</td>
<td>11 : 19</td>
<td>1 : 18 : 11</td>
<td>9.1 ± 3.3</td>
<td>13.9 ± 1.9</td>
<td>60 ± 23</td>
<td></td>
</tr>
<tr>
<td>Kyphotic (n=2)</td>
<td>58</td>
<td>1 : 1</td>
<td>0 : 1 : 1</td>
<td>8.5 ± 3.5</td>
<td>12.0 ± 5.7</td>
<td>51 ± 46</td>
<td></td>
</tr>
<tr>
<td>Sigmoid (n=14)</td>
<td>62 ± 12</td>
<td>6 : 8</td>
<td>1 : 7 : 6</td>
<td>9.4 ± 3.5</td>
<td>14.9 ± 1.7</td>
<td>67 ± 32</td>
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</table>

There was no significant correlation with preoperative alignment of the cervical spine or any of the other factors, but the recovery rate was the highest for sigmoid-type curvature.

Kurume Medical Journal Vol. 47, No. 2, 2000
TABLE 4.  
Comparison of curvature change and recovery rate

<table>
<thead>
<tr>
<th>Preoperative Alignment of the Cervical Spine</th>
<th>Number of patients</th>
<th>Recovery rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Postoperative Alignment</td>
<td>lordotic</td>
</tr>
<tr>
<td>Lordotic (n=94)</td>
<td>76</td>
<td>13</td>
</tr>
<tr>
<td>Straight (n=30)</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Kyphotic (n=2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sigmoid (n=14)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>total (n=140)</td>
<td>77</td>
<td>37</td>
</tr>
</tbody>
</table>

*, *: p<0.05

Fig. 3. 72-year-old female with cervical spondylotic myeloradiculopathy.
B: Radiograph of immediately after expansive laminoplasty of C3-6 with segmental bone graft.
C: At 6 months after surgery, anterior fusion of C4-6 was performed (C-2) because of a localized kyphotic deformity resulting from malunion following posterior fusion (C-1). At one year after surgery, the spinal alignment has changed, and pain in the neck and shoulder persisted (C-3).
the kyphotic group, and $67\pm27\%$ (0 to 100\%) in the sigmoid group. The difference between the lordotic and straight groups was significant ($p<0.05$) (Table 4).

Changes in cervical alignment: There were changes in the cervical alignment in 29 (21\%) patients after the operation. Changes occurred in 18 (19\%) of the 94 patients with lordotic-type, 6 (20\%) of the 30 patients with straight-type, and in 5 (36\%) of the 14 patients with the sigmoid-type curvature, before surgery. Of the 76 patients with the lordotic-type curvature both before and after surgery, 54 (72\%) patients showed a decrease in the degree of lordosis. The percentage change in Curvature Index (Curvature Index at final follow-up $\times 100$/Curvature Index at initial examination) was $80\pm43\%$, showing a decrease of 20\% on average.

The recovery rate in JOA score in the 9 patients with the sigmoid-type curvature both before and after surgery was the highest at 70\% to 30\%, significantly higher in comparison with the $48\pm29\%$ in the 76 patients with the lordotic-type both before and after surgery ($p<0.05$) (Table 4). However, 2 patients with the sigmoid-type curvature presented a chin-on-chest position after surgery, and developed intractable cervical pain and shoulder stiffness. These symptoms were resolved within 6 months in 1 patient, but anterior fusion was added in the other because symptoms deteriorated with progressing deformity (Fig. 3).

Before surgery, 16 (11\%) patients had abnormal curvatures in the cervical spine with kyphosis or localized kyphosis (kyphotic-type + sigmoid-type). Their ages ranged from 44 to 81 years (mean $\pm$ SD, 62$\pm$11 years), and they consisted of 1 with DH, 8 with CS, and 7 with OPLL. The recovery rate in JOA score in these 16 patients was $65\pm32\%$ (range 0 to 100\%). The angle of kyphosis changed from $8.6\pm3.4^\circ$ (range 5 to 15\°) preoperatively to $8.2\pm4.1^\circ$ (range 0 to 15\°) postoperatively. Although the mean value decreased slightly on average, 6 (38\%) patients showed an increase in the kyphotic angle.

There were 11 (8\%) patients in whom a kyphotic or sigmoid deformity appeared after surgery. Their cervical curvature before surgery was lordotic-type in 5 patients and straight-type in 6 patients. Of these
11 patients, 9 patients had CS. The degree of the kyphotic angle was slight in all the 11 patients who developed a kyphotic deformity after operation.

Range of motion (ROM) in the cervical spine: The ROM in the cervical spine of the 121 patients excluding the 19 patients who underwent interlaminar strut bone graft was $36 \pm 13^\circ$ (range 5 to 62°), before surgery. The ROM was $19 \pm 13^\circ$ (range 0 to 55°) at one year after surgery (n=121), and $17 \pm 12^\circ$ (range 0 to 55°) at 2 years and 6 months on average after surgery (n=78), showing a decrease of about 50%. The magnitude of the decrease in the ROM was 27% in patients with DH, 50% in patients with CS, and 66% in patients with OPLL ($p < 0.05$). The ROM ratio for the cervical spine (ROM at final follow-up ×100/preoperative ROM) was >50% in 58 (48%) patients. The number of patients in whom preoperative ROM was maintained was only 8 (7%), consisting of 1 of 6 patients (17%) with DH, in 6 of 65 patients (9%) with CS, and in 1 of 50 patients (2%) with OPLL (Fig. 4).

The recovery rate in JOA score was 51±28% in 63 patients with an ROM ratio <50%, and was 56±28% in the 58 patients with an ROM ratio ≥50%, with no significant difference.

Intervertebral instability: Before surgery, instability in a total of 17 intervertebral disc spaces was observed in 16 patients, consisting of 7 men and 9 women, ranging in age between 51 and 83 years (mean age 67 years). Thirteen had CS and 3 had OPLL. The level of instability was C3/4 in 6 patients, C4/5 in 8, and C5/6 in 3. After surgery, slipping was fully resolved by the surgery in 3 patients, decreased in 5, unchanged in 4, and worsened in 2; the intervertebral ROM at the unstable segments decreased significantly from $12 \pm 7^\circ$ before surgery to $5 \pm 6^\circ$ after surgery ($p < 0.01$). The recovery rate was 57±11% and 53±23% in patients with and without instability, respectively, with the difference being not significant.

Curvature Index -Ishihara’s method - (Fig. 5): The Curvature Index was $11.4 \pm 10.2$ ($-18$ to 40) before surgery and $5.9 \pm 11.0$ ($-21$ to 34) at follow-up, showing a reduction of about 50%. The reduction rate was 38% for patients with DH, 45% for patients with CS, and 58% for patients with OPLL, showing that lordotic-type was maintained most often in patients with DH. The differences were not
significant. The number of patients who showed a decrease of more than 10 in the Curvature Index (CI) at final follow-up (CI at final follow up-CI at preoperation ≥ 10), namely, who showed a great change in curvature, was 37 (26%). They comprised 26 (28%) of the 94 patients with lordotic-type, 5 (17%) of the 30 patients with straight-type, and 6 (43%) of the 14 patients with sigmoid-type curvature, preoperatively, the differences being not significant. None of the kyphotic patients showed a great change in curvature.

DISCUSSION

Changes in curvature after laminectomy have long been a problem in spinal surgery. In 1930, Eiselsberg [13] reported kyphotic deformity following surgery in the thoracolumbar segment. With regard to the cervical spine, the change in curvature after laminectomy has been reported to be from 43% to 95% [14-17]. Expansive laminoplasty by sagittal splitting of the spinous process which was developed to avoid such problems was considered a more rational therapy for compression cervical myelopathy than simple laminectomy, but radiography revealed the induction of various morphological changes. In particular, changes in the cervical alignment, more or less similar to those observed after laminectomy, were observed [11]. Thus, various preventive methods to minimize changes in the cervical alignment have been devised. Matsuzaki et al. [18] considered that, in expansive laminoplasty by sagittal splitting of the spinous process, at the time of exposure of the facet joints, the dissection of muscles can injure the dorsal primary rami of spinal nerves, causing denervation and malfunction in the posterior neck muscles.

To minimize invasion in the facet joint, they dissected muscles only to one third medially of the facet joint, and placed the gutter of the lamina medially in the facet joint; the incidence of kyphotic deformity was minimized thereafter. We agree with the consideration of muscle injury, but cannot agree with this placement of a gutter, because the medial placement of a gutter induces weakness in the expanded lamina and leads to insufficient spinal cord and nerve root decompression. Tsuzuki et al. [19] considered that the posterior supporting structures acted as lever arms in the traction of the cervical spine. They stated that the en bloc preservation, exposure and resuturing of the posterior structures, including the spinous process, supraspinous ligament, and posterior neck muscles of one side, enabled maintenance of the degrees of lordosis. In the present study, there was no significant difference noted between before and after the introduction of the surgical method in which the posterior neck muscles were preserved, with regard to the incidence of cervical alignment changes. However, this absence of difference could be due to differences in the duration of postoperative restriction in the cervical motion by wearing the collar or the time interval to the initiation of rehabilitation in the patients investigated. Hoshino et al. [7] reported that the incidence of increased kyphosis and decreased lordosis more than 10° was reduced by reconstruction by suturing and shortening of the rectus capitis posterior major, oblique capitis inferior, and semispinalis capitis muscles, which were attached to the C2 spinous process. Kunogi et al. [11] also pointed out that a tension band (attachments of the trapezius, splenius, and semispinalis muscles) formed by the spinous process, supraspinous ligament, and interspinous ligament in the lower cervical spine as well as the semispinalis muscle attached to the C2 spinous process were important in the extension mechanism of the cervical spine.

The present author has also employed a surgical method in which the deep nuchal and cervical muscles were restored and supraspinous and interspinous ligaments were preserved. The degree of lordosis decreased in 72% of the patients, while 44% of the patients with abnormal curvature before surgery showed an increase in the curvature. However, the degree of morphological changes in the cervical spine was mild in the majority of the patients. These results suggested that preservation of the posterior neck muscles was an important point for the success of this operative method. Posterior surgery causes damage to the posterior neck muscles to some degree. Minimization of this damage requires utmost attention to the methods of exposure, gentle manipulation of the muscles during surgery, and repair of muscles after the completion of surgery.

The relationship between the postoperative bony union of the laminae and vertebrae and the alignment of the cervical spine was investigated. Aita et al. [5] reported that the prevalence of bony union of the laminae and vertebral bodies was 97%, and C2/3 was involved in 79%. In the present study, interlaminal bony union was observed in 97 (80%) patients, and C2/3 was involved in 65 (67%), showing that union was common at higher levels, as reported by Aita et al. [5]. The high incidence of union at C2/3, which is slightly lordotic, is probably due to the shortened distance between their spinous processes due to
postoperative collar wearing, and that the C2-3 interspace is a region with an originally small ROM. However, the incidence of multilevel bony union involving three or more disc spaces was low at 24% (29/121 patients), and the mean ROM of the cervical spine was decreased to 50% of the preoperative baseline values at two years and six months after the surgery; however both had little effect on the activities of daily life. The ideal surgical procedure for the cervical spine appears to be one that results in adequate decompression without affecting the cervical alignment or mobility. From this point of view, several variables were analyzed statistically to identify factors influencing interlaminal and interbody bony union after surgery, but no specific factor could be identified. We could thus not propose methods for preventing interlaminal and interbody bony union after spinal surgery. Theoretically, shortening the time wearing a postoperative collar, loosening the collar fixation to the cervical spine, and earlier initiation of cervical exercises are considered as factors that might prevent bony union.

Abnormal cervical curvature can be caused by surgical damage to the back muscles. Presumably, intraoperative crush injury and denervation in muscles caused by a retractor causes muscular degeneration, leading to muscle weakness. Kawaguchi et al. [20] reported that muscular degeneration was dependent on the retraction pressure-time product. Accordingly, the present author [21] has also investigated the relationship between postoperative changes in the transverse area of the posterior neck muscles as well as displacement of the nuchal ligament and changes in the range of the cervical spine motion and changes of the cervical spine alignment. No significant degree of correlation was detected between the morphological or quantitative changes in the posterior neck muscles and the curvature abnormalities after surgery. These findings suggested that qualitative changes in the muscles had a greater association with the degeneration of posterior neck muscles than quantitative changes, namely, changes in the area of the muscle. Recently, we have revised our postoperative program; from about three weeks after surgery, when postoperative inflammatory reaction is reduced, the collar is worn loosely to allow isometric exercises of the neck muscles within the range that causes no pain.

The benefit of expansive laminoplasty lies in the backward shift of the spinal cord associated with posterior decompression. Accordingly, it is generally considered that favorable results may not be achieved in severe kyphotic patients due to insufficient spinal cord shift. There have been several reports on the relationships between the postoperative changes in alignment of the cervical spine and the obtained clinical results. Sanaga et al. [23] reported that patients with postoperative kyphotic deformity showed poorer results. Hirabayashi et al. [24] pointed out the significance of a backward shift in the spinal cord, suggesting that the postoperative retention or acquisition of cervical lordosis was beneficial. On the other hand, Matsuzaki et al. [18] reported better results in patients with increased kyphosis. They ascribed this to the patients being relatively young (mean age, 40 years) and to hemifusion eliminating the dynamic compression factor preventing augmentation of spinal cord compression.

In the present study, good results were obtained even when the cervical spine had no physiological curvature preoperatively. In addition, when comparison was made between patients with physiological lordosis and those with curvature deformities after surgery, the latter, particularly those with the sigmoid-type curvature, showed a significantly higher recovery rate. The effectiveness of the decompression surgery was maintained even in 5 patients with a postoperative kyphotic angle of more than 10°.

These findings indicated that morphological changes in the cervical spine and the decreased range in the cervical spine motion were not major factors affecting the postoperative clinical results following expansive laminoplasty by sagittal splitting of the spinous process described in the current study for cervical myelopathy.

ACKNOWLEDGMENTS: The author would like to thank Professor Kensei Nagata and Professor Akio Inoue for their kind suggestion and encouragement during the course of this study.

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