Laminoplasty is being more frequently performed to treat multisegmental cervical myelopathy, and favorable results have been reported in many papers. Nevertheless, some complications of laminoplasty, such as transient muscle weakness of the upper extremities and axial symptoms, have been reported. We have also sometimes encountered patients who have shown a significant loss of cervical lordosis after laminoplasty. We previously reported significant loss of cervical lordosis after laminoplasty in female patients even when we had repaired the insertion of the deep extensor musculature to the C-2 spinous process. In this paper, we report the results of our study of the relationship between preservation of the insertion of the deep extensor musculature of the cervical spine at C-2 and postoperative cervical alignment, especially differences between cases involving male and female patients, as well as the relationship between the loss of cervical lordosis and neurological outcome after laminoplasty.

Clinical Material and Methods

We performed a retrospective review of 104 cases involving patients with cervical myelopathy who underwent cervical laminoplasty at our university hospital between June 1998 and September 2003. Patients who underwent laminoplasty for treatment of the continuous or mixed type of OPLL, were treated with hemodialysis, or had undergone anterior spinal fusion were excluded. Eighty-one of the remaining 89 cases involving patients with cervical myelopathy were evaluated. The underlying disorder in this series was CSM in 65 cases and OPLL in 16 cases. Of the OPLL cases, only the segmental type was included, be...
cause in the other types, the postoperative cervical alignment might not change, being maintained by the OPLL itself. Before May 2001, patients with cervical myelopathy were surgically treated with laminoplasty involving elevation of the C-3 lamina, with repair of the insertion of the deep extensor musculature to the C-2 spinous process at the end of surgery. Since June 2001, such patients were treated with laminoplasty by means of C-3 dome laminotomy (laminotomy for the caudal side of the C-3 lamina; Fig. 2A and B) or laminectomy to completely preserve the insertion of the deep extensors to the C-2 spinous process (Fig. 2C and D).

We reviewed 50 cases in which patients underwent laminoplasty to elevate the C-3 lamina, and the procedure included repair of the deep extensor musculature (Group A). There were 34 men and 16 women in this patient group, and the mean duration of follow-up was 42.1 months (range 24–84 months). The underlying disorder was CSM in 39 cases and OPLL in 11 cases. The mean patient age at surgery was 61.7 years (range 37–78 years). The patients had been instructed to wear a cervical collar for 3 to 4 weeks postoperatively.

Another 31 cases in which patients underwent laminoplasty by C-3 dome laminotomy or laminectomy were also evaluated (Group B). There were 22 men and 9 women in this group, and the mean duration of follow-up was 28.3 months (range 24–48 months). The underlying disorder was CSM in 26 of these 31 cases and OPLL in five. The mean patient age at surgery was 59.2 years (range 40–77 years). Patients in this group had been instructed to wear a cervical collar for 1 to 3 weeks postoperatively (Table 1). If the patient’s spinal canal at the C2–3 level was narrow, a C-3 laminectomy was performed (three cases). In all patients, the laminoplasty procedure was adapted from the modified method of Itoh and Tsuji (open-door type) and performed to C-6 or C-7, and none of the patients received physical therapy.

We studied the degree of cervical lordosis after laminoplasty and compared the results with preoperative values. The percentage values for neurological recovery obtained at last follow-up were also compared to preoperative values. Cervical spine lordosis was determined by measuring the angle formed by two lines extending from the inferior border of the C-2 vertebral body and superior border of the C-7 vertebral body on a lateral radiograph obtained with the patient in the neutral position (Fig. 3). The severity of neurological symptoms was assessed using the evaluation system established by the JOA (the JOA score). The percentage of recovery, which represents neurological recovery, was calculated from pre- and postoperative JOA scores using a formula proposed by Hirabayashi. Statistical analysis was performed using the Student t-test and Fisher exact test, and probability values of less than 0.05 were considered significant.

**Results**

There was no significant difference between preoperative values in the two groups (cervical lordosis, \( p > 0.24 \); JOA score, \( p > 0.58 \)).

**Radiographic Outcome**

In Group A, the overall mean values for pre- and postoperative cervical lordosis were 14.5 and 10.9°, respectively, indicating that cervical alignment was maintained after laminoplasty (\( p > 0.18 \)). There was a significant difference between pre- and postoperative measurements in female patients, however (14.4 and 3.7°, respectively; \( p < 0.004 \)). In particular, a clinically meaningful loss of cervical lordosis (defined for the purposes of this study as a loss > 15°) was seen in seven (43.8%) of the 16 female patients in this group, although there was no such finding in male patients.

In Group B, the overall mean values for pre- and postoperative cervical lordosis were 17.3 and 19.1°, respectively (\( p > 0.48 \)). There was no significant difference between the mean pre- and postoperative cervical lordosis measurements in the female patients in this group, however (15.0° compared with 14.1°, respectively; \( p > 0.83 \)). Thus, in this group, cervical lordosis was maintained even among female patients. In fact, no patient in Group B experienced a clinically meaningful loss of cervical lordosis. The between-group difference with respect to loss of cervical lordosis was statistically significant (\( p < 0.03 \)).
**Neurological Outcome**

In Group A, the mean preoperative JOA score was 9.9, and the mean score at final follow-up was 13.5, providing a 54.1% average recovery value. In Group B, the mean preoperative JOA score was 10.2, and the mean score was 13.8 at the final follow-up, providing a 54.8% average recovery value. There was no significant difference in the average percentage of recovery between the two groups (p > 0.91; Table 2).

The average percentage of recovery was 56.9% in the female patients of Group A in whom cervical lordosis was maintained (nine patients) and 51.5% in the female patients of Group A who lost more than 15° of lordosis (seven patients). There was no significant difference in the average percentage of recovery between these two subgroups (p > 0.68; Table 3).

**Illustrative Cases**

**Case 1**

This 47-year-old woman was treated with laminoplasty with enlargement of the C-3 lamina and repair of the insertion of the deep extensor musculature. Radiographic examination performed 2 years after surgery showed a change to cervical kyphosis (Fig. 4).

**Table 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>mean age</td>
<td>61.7 ± 9.8</td>
<td>59.2 ± 10.6</td>
</tr>
<tr>
<td>sex (M/F)</td>
<td>34/16</td>
<td>22/9</td>
</tr>
<tr>
<td>disorder (cases of CSM:OPLL)</td>
<td>39:11</td>
<td>26:5</td>
</tr>
<tr>
<td>mean follow-up in mos (range)</td>
<td>42.1 (24–84)</td>
<td>28.3 (24–48)</td>
</tr>
<tr>
<td>collar (wks)*</td>
<td>3–4</td>
<td>1–3</td>
</tr>
</tbody>
</table>

* Length of time during which patients wore a collar postoperatively.

**Case 2**

This 54-year-old woman was treated with laminoplasty with C-3 dome laminotomy to preserve the insertion of the deep extensor musculature to the C-2 spinous process. Radiographic examination 2 years after surgery showed that cervical lordosis was maintained (Fig. 5).

**Discussion**

Posterior procedures usually involve stripping the extensor musculature of the cervical spine. To expose and ele-
Cervical malalignment after laminoplasty

TABLE 2
Neurological recovery and cervical lordosis*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preop</td>
<td>Postop</td>
</tr>
<tr>
<td>JOA score</td>
<td>9.9 ± 3.0</td>
<td>10.2 ± 2.6</td>
</tr>
<tr>
<td>% recovery cervical lordosis (%)</td>
<td>NA</td>
<td>54.1 ± 29.5</td>
</tr>
<tr>
<td>all patients</td>
<td>14.5 ± 12.5</td>
<td>15.4 ± 12.9</td>
</tr>
<tr>
<td>M</td>
<td>14.5 ± 13.3</td>
<td>15.4 ± 12.9</td>
</tr>
<tr>
<td>F</td>
<td>14.4 ± 10.7</td>
<td>3.7 ± 15.6</td>
</tr>
</tbody>
</table>

* Data are given as means ± standard deviations. NA = not applicable.

The C-3 lamina, deep extensors inserted into the C-2 spinous process are usually disrupted, with subsequent caudal retraction of the muscle. Various authors\textsuperscript{20,21} have reported several techniques to repair these muscles. In a paper presenting the results of their biomechanical study, Nolan and Sherk\textsuperscript{12} reported that the extensor musculature acts as a dynamic stabilizer, and laminectomy with removal of the attachments of the semispinalis to the axis results in a loss of normal cervical alignment. Vasavada et al.\textsuperscript{19} also noted that most (37%) of the extension moment–generating capacity comes from the semispinalis. Fujimura and Nishi\textsuperscript{2} analyzed the cervical extensor musculature on computed tomography images and plain radiographs obtained in 53 patients who had undergone laminoplasty and noted a weak correlation between the deep nuchal muscles area and curve index. In a previous paper,\textsuperscript{6} we reported that the degree of repair of the deep extensor musculature affects postoperative cervical alignment based on the results of our analysis of coronal magnetic resonance images obtained after laminoplasty. Regarding the relationship between postoperative cervical alignment and neurological recovery, Satomi et al.\textsuperscript{13} noted that neurological recovery in patients with meaningful loss of cervical lordosis after laminoplasty was less than that in patients with no change in cervical lordosis and that the difference was statistically significant. In contrast, Guigui et al.\textsuperscript{3} noted that there was no significant between-group difference in extent of neurological recovery after cervical laminectomy in patients with or without change in the spinal curvature.

FIG. 4. CASE 1. Preoperative (left) and postoperative (right) lateral radiographs obtained in this 47-year-old woman with cervical myelopathy treated by laminoplasty with elevation of the C-3 lamina. The postoperative radiograph was obtained 2 years after surgery and shows substantial loss of cervical lordosis (12° preoperatively, −5° postoperatively).

Some problems have been reported between C-2 and C-3 in laminoplasty procedures. Takeuchi et al.\textsuperscript{16} noted that axial symptoms were improved by complete preservation of the deep extensor musculature insertion into the C-2 spinous process using a C-3 laminectomy. Moreover, in patients who underwent enlargement of the C-3 lamina, interlaminar osseous fusion occurred between C-2 and C-3 with high frequency (Fig. 6), and the postoperative range of motion of the cervical spine was significantly reduced.\textsuperscript{5} Therefore, a C-3 dome laminotomy or laminectomy that can preserve the insertion of deep extensors without elevation of the C-3 lamina has the potential to improve axial symptoms and prevent reduction of range of motion after laminoplasty. This procedure, however, could not be adapted for use in patients with OPLL in whom ossification extended to the upper cervical spine (usually those with the continuous or mixed type of OPLL).

FIG. 5. Case 2. Preoperative (left) and postoperative (right) lateral radiographs obtained in this 54-year-old woman with cervical myelopathy treated by laminoplasty with C-3 dome laminotomy. The postoperative radiograph was obtained 2 years after surgery and shows maintenance of cervical lordosis (12° preoperatively, 10° postoperatively).

TABLE 3
Neurological recovery in female patients in Group A stratified according to maintenance or loss of cervical lordosis

<table>
<thead>
<tr>
<th>Cervical Lordosis</th>
<th>Maintained</th>
<th>15° Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>JOA score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>preop</td>
<td>9.3 ± 2.4</td>
<td>9.2 ± 3.6</td>
</tr>
<tr>
<td>postop</td>
<td>13.8 ± 2.1</td>
<td>13.4 ± 1.9</td>
</tr>
<tr>
<td>average recovery (%)</td>
<td>58.9 ± 30.1</td>
<td>51.5 ± 17.4</td>
</tr>
</tbody>
</table>
We have maintained and those in whom there was a loss of more than 15°. Female patients in Group A in whom cervical lordosis was measured during the laminoplasty procedure. The measurement was clearly observed in the maximal flexion position. A: Neutral position. B: Maximal flexion.

In this study, there was a statistically significant increase in the incidence of clinically meaningful loss of cervical lordosis after laminoplasty only among female patients in Group A. We considered why we cannot fully and effectively repair the deep extensors of female patients, despite the fact that these muscles are atrophic preoperatively.\(^6\) We also showed that preserving the insertion of the deep extensors to the C-2 spinous process prevents substantial loss of cervical lordosis after laminoplasty even in female patients; furthermore, not elevating the C-3 lamina does not affect the neurological recovery. It should be noted, however, that there was no statistically significant association between neurological recovery and postoperative loss of cervical lordosis in our patients, even in comparisons between the female patients in Group A with cervical lordosis that was maintained and those in whom there was a loss of more than 15°.

In female patients, there was a statistically significant association between clinically meaningful postoperative loss of cervical lordosis and laminoplasty involving the C-3 lamina, even when we repaired the deep extensor musculature of the cervical spine during the laminoplasty procedure. Preservation of the insertion of the deep extensor musculature to the C-2 spinous process prevented such changes in cervical alignment, even among female patients who underwent laminoplasty. Neurological recovery was not affected by postoperative loss of cervical lordosis.

Conclusions

In female patients, there was a statistically significant association between clinically meaningful postoperative loss of cervical lordosis and laminoplasty involving the C-3 lamina, even when we repaired the deep extensor musculature of the cervical spine during the laminoplasty procedure. Preservation of the insertion of the deep extensor musculature to the C-2 spinous process prevented such changes in cervical alignment, even among female patients who underwent laminoplasty. Neurological recovery was not affected by postoperative loss of cervical lordosis.

References


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