Long-term results of tension-band laminoplasty for cervical stenotic myelopathy
A TEN-YEAR FOLLOW-UP

T. Motosuneya,
T. Maruyama,
H. Yamada,
N. Tsuzuki,
H. Sakai

From Saitama
Medical Center,
Saitama, Japan

We reviewed 75 patients (57 men and 18 women), who had undergone tension-band laminoplasty for cervical spondylotic myelopathy (42 patients) or compression myelopathy due to ossification of the posterior longitudinal ligament (33 patients) and had been followed for more than ten years. Clinical and functional results were estimated using the Japanese Orthopaedic Association score. The rate of recovery and the level of post-operative axial neck pain were also recorded. The pre- and post-operative alignment of the cervical spine (Ishihara curve index indicating lordosis of the cervical spine) and the range of movement (ROM) of the cervical spine were also measured.

The mean rate of recovery of the Japanese Orthopaedic Association score at final follow-up was 52.1% (SD 24.6) and significant axial pain was reported by 19 patients (25.3%). Axial pain was reported more frequently in patients with ossification of the posterior longitudinal ligament than in those with cervical spondylotic myelopathy (p = 0.027). A kyphotic deformity was not seen post-operatively in any patient. The mean ROM decreased post-operatively from 32.8° (SD 12.3) to 16.2° (SD 12.3) (p < 0.001). The mean ROM ratio was 46.9% (SD 28.1) for all the patients. The mean ROM ratio was lower in patients with ossification of the posterior longitudinal ligament than in those with cervical spondylotic myelopathy (p < 0.001). Compared to those with cervical spondylotic myelopathy, patients with ossification of the posterior longitudinal ligament had less ROM and more post-operative axial neck pain.

Posterior cervical laminoplasty may be subdivided into two categories: symmetrical double-door laminoplasty or asymmetrical open-door laminoplasty. Previous reports on mid- and long-term surgical results have demonstrated the efficacy of both types. However, only a few studies have been reported with results after ten years or more. Tension-band laminoplasty using a hydroxyapatite spacer is categorised as an asymmetrical open-door laminoplasty, and favourable results have been reported in the short term. The purpose of this study is to evaluate the long-term clinical and radiological results of tension-band laminoplasty with a follow-up of more than ten years.

Patients and Methods
Between 1991 and 1999, a total of 220 patients underwent tension-band laminoplasty at our hospital for cervical spondylotic myelopathy or compression myelopathy due to ossification of the posterior longitudinal ligament. Of the 220 patients, the clinical records of 75 patients (34.1%, 57 men and 18 women) who had been followed for more than ten years post-operatively were available for this retrospective study. The mean age of patients at surgery was 56.7 years (40 to 77). The mean follow-up period was 152 months (122 to 210). The study comprised 42 patients with cervical spondylotic myelopathy and 33 with ossification of the posterior longitudinal ligament. The affected surgical levels for cervical spondylotic myelopathy were C2-7 in 24 patients, C2-T1 in two, C3-7 in 12, and C3-T1 in four patients. The affected surgical levels for ossification of the posterior longitudinal ligament were C1-7 in 13 patients, C1-T1 in three, C1-T3 in one, C2-7 in 12, C3-7 in two and C2-T1 in two. The mean number of opened laminae was higher in patients with cervical spondylotic myelopathy (2.7) than in patients with cervical spondylotic myelopathy (2.3) (Mann-Whitney U test, p < 0.01).

Tension-band laminoplasty was indicated in patients with cervical myelopathy caused by cervical spondylosis or ossification of the posterior longitudinal ligament, which was defined as a small sagittal spinal canal. In cases...
with disc lesions with posterior spur formation or disc herniation with a normal spine canal, anterior surgery was indicated. No surgery was performed in patients with a cervical radiculopathy alone. The fundamental surgical procedure was as follows.

Under general anaesthesia all patients were placed in the prone position, with the head immobilised in slight flexion using a three-pin skull fixator. A midline longitudinal incision allowed exposure of the spinous processes of the cervical spine. The entire spinoligamentous complex was maintained while the paravertebral muscles were detached and retracted bilaterally from the laminae. The supraspinous ligament with the speculum rhomboideus was preserved in a continuous band. A longitudinal groove, 3 mm wide, was made with an air drill along the junction of lamina and facet on each side. The left side was opened, except in the cases where right-sided symptoms were more severe. The groove on the opening side was drilled out, and the lamina elevated together with the underlying ligamentum flavum using the groove on the opposite side as a hinge. When necessary, the groove on the hinged side was deepened slightly with the drill until the lamina was elevated enough to accommodate a hydroxyapatite spacer. The spacer is held in place by the tension-band effect produced at the site of the greenstick fracture on the hinged side. Post-operatively, unless contraindicated because of their general condition, patients were allowed to mobilise or sit up in bed the day after surgery. A cervical brace was applied for three weeks, and a soft cervical collar for the following three months.11

Clinical and functional evaluation. The severity of clinical symptoms was described using an evaluation score established by the Japanese Orthopaedic Association (JOA).12 The maximum score attainable was 17. The total pre-operative and post-operative JOA scores of each patient were calculated. The recovery rate, described by Hirabayashi et al,13 indicating the degree of neurological recovery after operation, was calculated as follows:

$$\text{recovery rate (\%) = } \left( \frac{\text{post-operative JOA score} - \text{pre-operative JOA score}}{17 - \text{pre-operative JOA score}} \right) \times 100$$

Post-operative axial neck pain was graded as follows: severe (painkiller or local injection required regularly), moderate (physiotherapy or compress required regularly), or mild (no treatment needed). Severe or moderate axial pain persisting for more than one month was considered as significant axial pain.14,15

Radiological evaluation. Radiological assessments were performed before and after surgery in all patients. The anteroposterior diameter of the spinal canal was measured on lateral neutral radiographs at the C4 mid-vertebral level. Alignment of the cervical spine was evaluated by measuring the Ishihara curve index at the neutral position (Fig. 1).16 The range of movement (ROM) was calculated as the difference of the C2-7 angle between lateral flexion and extension radiographs.9 The degree of preserved post-operative ROM (ROM ratio) was calculated as the ratio of post-operative ROM to pre-operative ROM. In ten patients, post-operative CT images were also obtained to confirm the status of union for the grafts and gutter on the hinge side. Statistical analysis. The results are given as mean values and one SD. As appropriate, either the Mann-Whitney U test or Yates $2 \times 2$ chi-squared test was used for statistical analysis. A p-value < 0.05 was considered statistically significant.

Results

The mean pre-operative JOA score was 9.6 (SD 2.7). This had increased to 13.8 (SD 1.9) by the first year after surgery and to 13.9 (SD 1.9) by three years, then was maintained for five years after surgery (13.9 (SD 2.0)). However, the mean JOA score at final follow-up had decreased slightly (13.4 (SD 2.1)). When comparing the pre-operative and last follow-up, the mean score improved significantly (Mann-Whitney U test, p < 0.001). The pre- and post-operative JOA score at final follow-up was 10.0 (SD 2.7) and 14.0 (SD 2.1) for patients with cervical spondylotic myelopathy (Mann-Whitney U test, p < 0.001) and 9.2 (SD 2.6) and 12.7 (SD 2.2) for those with ossification of the posterior longitudinal ligament (Mann-Whitney U test, p < 0.001), respectively. The final mean recovery rate for all patients was 52.1% (SD 24.6): 57.5% (SD 24.7) for those with cervical spondylotic myelopathy and 45.1% (SD 23.2) for those with ossification of the posterior longitudinal
ligament (Table I). The recovery rate did not correlate with the number of opened laminae.

A total of 52 patients (69%) had post-operative axial neck pain. This was severe in eight patients, moderate in 11 and mild in 33. Of the 19 patients with significant pain, six had cervical spondylotic myelopathy and 13 had ossification of the posterior longitudinal ligament. Significant pain occurred more frequently with ossification of the posterior longitudinal ligament than with cervical spondylotic myelopathy (Yates $2 \times 2$ chi-squared test, $p = 0.027$) (Table II).

The mean anteroposterior diameter of the spinal canal at the C4 level on plain lateral radiographs was 11.3 mm (SD 1.8) before surgery and 15.8 mm (SD 1.9) after. On the CT images, bony union was confirmed at the hinges and around the spacers. These spacers were not absorbed.

The mean Ishihara curve index was 5.6 (SD 6.7) pre-operatively and 4.6 (SD 5.3) post-operatively. This difference was not significant (Mann-Whitney U test, $p = 0.36$). A loss of cervical lordosis was seen in 24 patients (32%); a post-operative kyphotic deformity was not observed in patients whose pre-operative alignment was lordotic. The mean pre- and post-operative Ishihara curve index was 7.8 (SD 7.0) and 6.2 (SD 6.1) for patients with cervical spondylotic myelopathy and 2.9 (SD 3.3) and 2.6 (SD 3.2) for those with ossification of the posterior longitudinal ligament. The pre- and post-operative curve index was larger in patients with cervical spondylotic myelopathy than in those with ossification of the posterior longitudinal ligament, and the pre- and post-operative difference was not statistically significant in either group (Table I).

The mean ROM, analysed by the Mann-Whitney U test, decreased post-operatively from $32.8^\circ$ (SD 12.3) to $16.2^\circ$ (SD 12.3) ($p < 0.001$): the mean ROM ratio was 46.9% (SD 28.1). In patients with cervical spondylotic myelopathy, the mean ROM decreased post-operatively from $35.3^\circ$ (SD 11.0) to $22.1^\circ$ (SD 12.3) ($p < 0.001$): the mean ROM ratio was 59.3% (SD 23.9). In those with ossification of the posterior longitudinal ligament, the mean ROM decreased post-operatively from $30.0^\circ$ (SD 13.4) to $8.6^\circ$ (SD 7.1) ($p < 0.001$): the mean ROM ratio was 31.2% (SD 24.7). The mean pre-operative ROM was not significantly different between patients with cervical spondylotic myelopathy and those with ossification of the posterior longitudinal ligament ($p = 0.072$), but the mean post-operative ROM was greater in the former than in the latter ($p < 0.001$). The mean ROM ratio was lower in patients with ossification of the posterior longitudinal ligament than in those with cervical spondylotic myelopathy ($p < 0.001$) (Table I). All patients with a post-operative ROM of less than 2° at final follow-up were those with ossification of the posterior longitudinal ligament, for whom there had been some increase in the extent of the ossification.

The mean ROM ratio was $32.6$% (SD 25.6) in patients with significant axial pain and 51.9% (SD 27.2) in those with mild or no axial pain ($p = 0.009$). The mean number of opened laminae was 7.3 (SD 1.6) in patients with significant axial pain and 6.0 (SD 1.1) in those with mild or no axial pain ($p < 0.001$) (Table II).

### Table I. Results of clinical and radiological findings (SD)

<table>
<thead>
<tr>
<th></th>
<th>All patients (n = 75)</th>
<th>Cervical spondylotic myelopathy (n = 42)</th>
<th>Ossification of the posterior longitudinal ligament (n = 33)</th>
<th>p-value (cervical spondylotic myelopathy vs ossification of the posterior longitudinal ligament, Mann-Whitney U test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative JOA* score</td>
<td>9.6 (2.7)</td>
<td>10.0 (2.7)</td>
<td>9.2 (2.6)</td>
<td>0.290</td>
</tr>
<tr>
<td>Post-operative JOA score</td>
<td>13.4 (2.1)</td>
<td>14.0 (2.1)</td>
<td>12.7 (2.2)</td>
<td>0.066</td>
</tr>
<tr>
<td>Recovery rate (%)</td>
<td>52.1 (24.6)</td>
<td>57.5 (24.7)</td>
<td>45.1 (23.2)</td>
<td>0.081</td>
</tr>
<tr>
<td>Pre-operative curve index</td>
<td>5.6 (6.7)</td>
<td>7.8 (7.0)</td>
<td>2.9 (5.3)</td>
<td>0.034</td>
</tr>
<tr>
<td>Post-operative curve index</td>
<td>4.6 (5.3)</td>
<td>6.2 (6.1)</td>
<td>2.6 (3.2)</td>
<td>0.024</td>
</tr>
<tr>
<td>Pre-operative ROM† (%)</td>
<td>32.8 (12.3)</td>
<td>35.3 (11.0)</td>
<td>30.0 (13.4)</td>
<td>0.072</td>
</tr>
<tr>
<td>Post-operative ROM† (%)</td>
<td>16.2 (12.3)</td>
<td>22.1 (12.3)</td>
<td>8.6 (7.1)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ROM ratio (%) (SD)</td>
<td>46.9 (28.1)</td>
<td>59.3 (23.9)</td>
<td>31.2 (24.7)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

* JOA, Japanese Orthopaedic Association  
† ROM, range of movement  
‡ p < 0.001 versus pre-operative value  
§ significant difference between cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament ($p < 0.05$)

### Table II. Comparison between positive and negative axial pain

<table>
<thead>
<tr>
<th></th>
<th>Significant axial pain</th>
<th>Mild or no axial pain</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical spondylotic myelopathy (cases)</td>
<td>6</td>
<td>36</td>
<td>0.027*</td>
</tr>
<tr>
<td>Ossification of the posterior longitudinal ligament (cases)</td>
<td>13</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Range of movement ratio (%) (SD)</td>
<td>32.6 (25.6)</td>
<td>51.9 (27.2)</td>
<td>0.009†</td>
</tr>
<tr>
<td>Number of opened laminae (SD)</td>
<td>7.3 (1.6)</td>
<td>6.0 (1.1)</td>
<td>&lt; 0.001†</td>
</tr>
</tbody>
</table>

* Yates $2 \times 2$ chi-squared test  
† Mann-Whitney U test
Post-operative complications. Transient post-operative motor weakness in C5 and/or C6 segments occurred in four patients (5.3%), although their symptoms had resolved completely at final follow-up.

Discussion

Laminectomy has the potential disadvantages of losing the posterior elements of the cervical spine and causing spinal deformities such as kyphosis or slippage. In contrast, laminoplasty preserves the posterior structures of the cervical spine. Laminoplasty is the most common procedure for cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament in Japan and many different methods have been reported. Previous studies with short- and mid-term results have shown it to be a useful procedure, however, some types of laminoplasty have been shown to be less effective in preventing post-operative kyphotic deformity. Sasai et al. reported that cervical lordosis decreased significantly after surgery in 87% of the patients treated with the modified Kurokawa method, and Hirabayashi and Satomi reported that 42% of the patients treated with open-door laminoplasty showed a decrease in lordosis post-operatively. By contrast, a previous report of tension-band laminoplasty with short-term follow-up and the present study have shown that post-operative kyphotic deformity is less common.

In the present study, we focused on the long-term outcome of the surgical effects obtained in the short-term after surgery. One of the limitations of this study is the low survey rate (34.1%). However, only a few ten-year follow-up reports have been published. In each of these reports, the number of the patients was less than that of the present study. The clinical outcome of tension-band laminoplasty was similar to that described in the other reports, suggesting that the neurological recovery seen in the short-term was maintained for more than ten years.

Regarding the possible post-operative kyphotic deformity, no significant difference was seen between the pre- and post-operative curve index, and post-operative kyphosis was not seen in patients whose pre-operative alignment was lordotic. These results strongly suggest that tension-band laminoplasty prevented the progression of cervical kyphosis for a long period. We suggest that preserving the supraspinous ligaments, not splitting the spinous processes, and avoiding reclosure of the canal by using spacers may contribute to favourable long-term results.

The ROM of the cervical spine was reduced more severely after laminoplasty in patients with ossification of the posterior longitudinal ligament than in those with cervical spondylotic myelopathy. Enlargement of the ossification of the posterior longitudinal ligament and unexpected bony fusion of the facet joints and/or laminae may cause this reduction.

A well-known complication of laminoplasty is axial pain, which is an intractable form of pain around the neck and shoulder that often continues for several years after surgery, even in patients with an excellent neurological recovery. Although the aetiology of this pain remains unknown, its incidence has been reported to be as high as 60% to 80% after laminoplasty. However, no report has shown how long it continues. In our study, 69% of the patients had post-operative axial pain, consistent with previous reports which looked at the short- to mid-term follow-up. This suggests it is likely that axial pain will continue for more than ten years in most patients in whom this occurs soon after surgery. Significant axial pain also occurred more frequently in patients with ossification of the posterior longitudinal ligament than in those with cervical spondylotic myelopathy, and more frequently in patients with a lower ROM ratio. This suggests a possible relationship between post-operative axial neck pain and a decrease of the ROM due to progression of ossification of the posterior longitudinal ligament.

In the literature, less post-operative axial neck pain was seen when the C7 spinous process was preserved at laminoplasty. Tsuji et al. concluded that selective laminoplasty was less invasive than C3-7 laminoplasty and was useful in reducing axial symptoms. Sakaura et al. showed that preservation of the muscle attachments to the C2 and C7 spinous processes reduces the adverse effects after cervical laminoplasty. Ono et al. reported that C3-6 laminoplasty in which the C7 process is preserved reduces damage to the nuchal muscles. These studies show that laminoplasty which sacrifices the spinous process of C7 is not to be recommended in the absence of cord compression at C6-7 or at a lower level. In our study significant axial pain occurred more frequently in patients with ossification of the posterior longitudinal ligament and in patients in whom more laminae were opened. However, it is difficult to decide which contributes more to post-operative axial pain; the diagnosis of ossification of the posterior longitudinal ligament or the number of opened laminae, because these two factors are related. This procedure is not indicated for the patient with a severe kyphosis because a favourable recovery cannot be expected with posterior decompression alone. In such cases, anterior decompression and fusion or correction of the vertebral alignment with spinal instrumentation should be considered.

Supplementary material

A further opinion by Professor R. S. Yang is available with the electronic version of this article on our website at www.jbjs.org.uk

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