Lift-up laminoplasty for myelopathy caused by ossification of the posterior longitudinal ligament of the cervical spine

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Introduction

Ossification of the posterior longitudinal ligament (OPLL) is a common cause of cervical cord myelopathy in Asian countries, especially in Japan. Although the complete pathophysiology of OPLL is not well understood, surgical treatment by the anterior or posterior approach has been demonstrated to be effective. The anterior approach is feasible when removing segmental or circumscribed type OPLL, while the posterior approach of extensive laminectomy or expansive laminoplasty is feasible when treating diffuse type OPLL, i.e., continuous or mixed type. We have utilized a “lift-up” cervical laminoplasty, using custom-designed hydroxyapatite laminar spacers and titanium miniplates to expand and secure the cervical canal in the treatment of 10 consecutive patients with cervical myelopathy caused by OPLL. An advantage of our procedure as compared with others is that the amount of expansion of the cervical canal can be adjusted to the requirements of each patient. In the present study, our preliminary surgical outcome is presented with image analysis.

Material and Methods

Patient population

10 patients (9 males and 1 female), ranging from 56 to 74 years of age with a mean age of 62.4 years, underwent lift-up laminoplasty for cervical myelopathy secondary to OPLL at our institution from 1998 to 2003. No patient underwent surgery for cervical radiculopathy alone. The mean follow-up period was 31.1 months with a range of 8 to 52 months. All patients received a comprehensive preoperative evaluation at which it was recognized that there was no improvement in their neurological symptoms following conservative treatment and that their symptoms were worsening.

Surgical technique of lift-up laminoplasty

The surgical technique of lift-up laminoplasty of the cervical spine has been described previously. Briefly, after standard exposure of the posterior cervical spine with the preservation of the spinoligamentous complex, osteotomy of the laminae was carried out by transecting the laminae using a small cutting burr (Midas Rex Pneumatic Tools, Inc., Fort Worth, TX, USA) (Figure 1a). The yellow ligaments were sharply dissected at the upper and lower level of the laminotomy and the laminae removed en bloc. Additional resection...
of the laminar edge or posterior foraminotomy was performed in cases of myeloradiculopathy. To “lift up” the laminae to a good position, custom-designed hydroxyapatite laminar spacers were fitted to expand the spinal canal (Figure 1b). The shape of the spacer is designed so that it conforms adequately to the adjoining cut edges of the laminae. Three sizes of spacers are used: 3 mm (small), 5 mm (middle), and 8 mm (large). The width of each spacer is 6 mm, which is approximately half the width of the lamina. Large-size spacers are used when a maximum expansive laminoplasty is planned according to preoperative simulation. Combining spacers of different sizes is also possible for each side at one level. The reconstructed posterior laminae were secured with titanium miniplates (Figure 1c). The fascia of the paravertebral muscles was sutured to the spinal ligamentous complex to further stabilize the posterior elements of the cervical spine. A soft collar was used for patient comfort while mobilizing during the first week after surgery. No other external orthosis was used after surgery.

Preoperative simulation of lift-up laminoplasty

The laminoplasty was simulated in the axial plane and the expansion achieved by using spacers of different sizes was considered preoperatively. The axial section of computed tomography (CT) at the level of the largest OPLL in the anteroposterior diameter was used for simulation. As a preoperative simulation, a lamina was lifted up, divided at its base, and two spacers of the same size, either middle or large size, were inserted on both sides of the bone gap. The bone edge of the lamina on both sides, 3 mm in length along the dorsal cortex, was deleted as bone defect. The dural sac of the unaffected cervical spinal cord of the patient himself/herself was placed in the expanded spinal canal (Figure 2). If the small or middle-size spacers did not produce sufficient expansion of the spinal canal, large size spacers were selected. Based on this estimation, the appropriate size of spacer was determined preoperatively.

Clinical assessment with image analysis

Neurological function was assessed using the Neurosurgical Cervical Spine Scale (NCSS) proposed by the Japanese Society of Spinal Surgery before surgery and at 6 months after surgery (Table 1). In this scaling system, motor functions of the lower and upper extremities and sensory function can be scored separately. The recovery rate of neurological function was expressed by the following formula: (total scores after surgery - total scores before surgery) / 14 - total scores before surgery) X 100. The surgical outcome with respect to neurological function was estimated based on that at 6 months after surgery. We selected 6 months post-operation as the assessment time point because the neurological functions at an early stage after surgery (i.e., several weeks) may still be unstable and those late after surgery (more than several years) may be affected by aging factors.

Image analysis before and after surgery included plain roentgenography, CT and magnetic resonance imaging (MRI) of the cervical spine. The stenosis ratio of the cervical canal was compared before and after surgery using an image analysis computer system (Mac SCOPE, MITANI Corp., Japan). Axial images of cervical CT scans were acquired using a scanner-linked computer, and then exported to Mac SCOPE where the antero-posterior diameter of the cervical spine was measured.

### Table 1: Neurosurgical cervical spine scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Status and description</th>
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<tbody>
<tr>
<td>1.</td>
<td>Total disability: Chair bound or bedridden</td>
</tr>
<tr>
<td>2.</td>
<td>Severe disability: Needs support in walking on flat, and unstable to ascend or descend stairways</td>
</tr>
<tr>
<td>3.</td>
<td>Moderate disability: Difficulty in walking on flat, and needs support in ascending or descending stairways</td>
</tr>
<tr>
<td>4.</td>
<td>Mild disability: No difficulty in walking on flat, but mild difficulty in ascending or descending stairways</td>
</tr>
<tr>
<td>5.</td>
<td>Normal: Normal walking, with or without abnormal reflexes</td>
</tr>
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</table>

**Upper extremity motor function**

1. Total disability: Totally unable to perform daily activities
2. Severe disability: Severe difficulty in daily activities with motor weakness
3. Moderate disability: Moderate difficulty in daily activities with hand and/or finger clumsiness
4. Mild disability: No difficulty in daily activities, but mild hand and/or finger clumsiness
5. Normal: Normal daily activities, with or without abnormal reflexes

**Sensory function and/or pain**

1. Severe disturbance: Severe difficulty in daily activities with incapacitating sensory disturbance and/or pain
2. Moderate disturbance: Moderate difficulty in daily activities with sensory disturbance and/or pain
3. Mild disturbance: Normal daily activities, but mild sensory disturbance and/or pain
4. Normal: Neither sensory disturbance nor pain

**Figures 1a - 1c:** Diagram of the surgical technique of lift-up laminoplasty. 1a: En bloc osteotomy of laminae by transecting the laminae using a high-speed small cutting burr. 1b: Lift-up of the laminae into a good position with newly designed hydroxyapatite laminar spacers, so that pulsation of the dura mater overlying the spinal cord could be observed. 1c: Reconstruction of laminae with titanium miniplates

**Figures 2a - 2f:** Preoperative simulation of lift-up laminoplasty. 2a, 2b: Axial section of preoperative CT scan at the level of the largest OPLL in the anteroposterior diameter in Case 7. 2c-2f: The degree of expansion of the spinal canal was estimated by computer-assisted simulation. The lamina was lifted up, divided at its base, and two spacers of the same size, either middle (2c, 2d) or large size (2e, 2f) were inserted on both sides of the bone gap.
spinal canal and OPLL were measured in each axial section at the affected levels. The value of the stenosis ratio was expressed as a percentage by the following formula: (diameter of OPLL/diameter of spinal canal) × 100. The final value of the stenosis ratio was expressed as an average value. The postoperative stenosis ratio was obtained in the same manner at the same levels as in preoperative measurement.

Results

There were 5 cases of diffuse OPLL of continuous or mixed type and 5 cases of focal OPLL of segmental or circumscribed type associated with cervical spondylosis, disc herniation or developmental canal stenosis. All 10 patients had long-tract signs of the spinal cord, including Babinski sign, ankle clonus, hyperreflexia or posterior column dysfunction.

The average scores of preoperative lower extremity motor function, upper extremity motor function and sensory function were 2.9 ± 0.2, 3.3 ± 0.2 and 2.5 ± 0.2, respectively. Sphincter dysfunction was reported in 3 patients. Six months after surgery, the average scores of postoperative lower extremity motor function, upper extremity motor function and sensory function had significantly improved to 4.3 ± 0.2, 4.4 ± 0.2 and 3.1 ± 0.1, respectively (non-parametric analysis with the Wilcoxon signed rank test). Sphincter dysfunction was reported in 3 patients. Six months after surgery, the average scores of postoperative lower extremity motor function, upper extremity motor function and sensory function had significantly improved to 4.3 ± 0.2, 4.4 ± 0.2 and 3.1 ± 0.1, respectively (non-parametric analysis with the Wilcoxon signed rank test).

The recovery rate of neurological function ranged from 40 to 80% with a mean of 60.7 ± 4.6% (Table 2).

The preoperative stenosis ratio ranged from 22.3% to 57.8% with a mean of 34.6 ± 3.2%. The postoperative range was from 13.2% to 30.5% with a mean of 21.5 ± 1.7%. There was significant postsurgical relief of spinal canal stenosis, with a 13.1% improvement in the mean stenosis ratio (paired t-test) (Table 2). The recovery rate of neurological function did not correlate with the preoperative stenosis ratio or with the difference in stenosis ratio before and after surgery (Pearson’s correlation coefficient).

Case 7

A 54-year-old male with diffuse type OPLL presented with progressive myelopathy. On admission, he needed support to walk on level ground and was unstable to ascend or descend stairways even with support. NCSS scores before surgery were 2, 3 and 2 for motor functions of the lower and upper extremities and sensory function. CT and MRI obtained before surgery revealed a severely compressed spinal cord caused by OPLL (Figures 3a and 3d). The patient underwent lift-up laminoplasty of the cervical spine with large-size laminar spacers. Neurological symptoms improved remarkably soon after surgery except for a slight bilateral motor weakness of the shoulder joints, which disappeared gradually with conservative treatment with steroids and physiotherapy. Radiological evaluations of CT and MRI early after surgery revealed remarkable decompression of the affected cord by lift-up laminoplasty (Figures 3b and 3c). Six months after surgery, he was able to walk independently and demonstrated improvement in neurological status with NCSS scores of 4, 4 and 3. At 1 year after surgery bony fusion of the reconstructed laminae was shown to be complete with CT (Figure 3c).

Case 9

A 61-year-old male with diffuse-type OPLL presented with progressive myelopathy. On admission, he had difficulty in walking on level ground and needed support to ascend or descend stairways. NCSS scores before surgery were 3, 3, and 3 for motor functions of the lower and upper extremities and sensory function, respectively. CT and MRI obtained before surgery demonstrated a severely compressed spinal cord caused by OPLL (Figures 4a and 4b). He underwent lift-up laminoplasty of the cervical spine with mid-size laminar spacers. Neurological symptoms were remarkably improved soon after surgery. NCSS scores after surgery were 5, 5 and 3, respectively, both immediately and 6 months post-operation. Radiological evaluation after surgery revealed satisfac-

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Type of OPLL</th>
<th>Levels of laminoplasty</th>
<th>Follow-up (mos)</th>
<th>NCSS</th>
<th>Recovery rate (%)</th>
<th>% Spinal canal stenosis</th>
<th>SEM</th>
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<td></td>
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OPLL: ossification of the posterior longitudinal ligament, yrs: years, mos: months, NCSS: neurosurgical cervical spine scale, SEM: standard error of the mean
tory decompression of the affected cord by lift-up laminoplasty (Figures 4c and 4d).

Discussion

Surgery for cervical OPLL

Posterior cervical decompression by laminectomy alone or expansive laminoplasty is widely accepted as a treatment of choice for cervical myelopathy secondary to OPLL. Expansive cervical laminoplasty was principally designed to be an alternative to extensive laminectomy in cases of multilevel cervical canal stenosis. The disadvantages of extensive cervical laminectomy, including spinal instability, accelerated spondylotic changes, postoperative spinal deformity and constriction of the dura mater by formation of extradural scar tissue, are widely recognized. Various expansive laminoplasty surgical techniques have been developed to enlarge and maintain the spinal canal and hence avoid the disadvantages of extensive laminectomy. The role of laminoplasty in cervical OPLL has been well established in the past, even though some may still argue that the anterior approach is the preferred method for cervical OPLL. The posterior approach of expansive laminoplasty for cervical OPLL has been demonstrated to be safe and effective and to have an acceptable long-term outcome.

Lift-up laminoplasty

Technically, there are certain advantages of our procedures, as previously suggested. Tedious wiring or bone grafting is not necessary with our method, minimizing the possibility of iatrogenic morbidity. Our method can also provide immediate stabilization of the laminae while maintaining anatomical integrity. The firm reconstruction of laminae can minimize the necessity for external orthosis or immobilization after surgery, avoiding the contracture of paravertebral muscles that is responsible for postoperative neck pain and restriction of cervical movement. In our previous study, the postoperative range of neck motion could be preserved well at 81.4% of the preoperative range and no significant change in cervical curvature was found before and after surgery. Bony bridging between the edge of the lateral mass and the resected lamina was usually found at 6 to 9 months after surgery. In regard to surgery-related complications, we unexpectedly encountered a single case with radiculopathy of the C5 nerve, however, the patient in Case 7 showed a full recovery early after surgery, as demonstrated in the case presentation. Although the pathological mechanism of C5 radiculopathy after decompression of the cervical spine is still poorly understood, it could happen after anterior or posterior decompression of the cervical spine. The importance of prophylactic posterior foraminotomies to prevent the tethering damage of nerve roots after extensive laminectomy has been advocated. In our procedure, prophylactic posterior foraminotomies could be per-
formed easily regardless of the side of foraminotomy.

**Degree of expansion**

The greatest advantage of our procedure for surgical treatment of OPLL is that the degree of expansion is controllable by the selection of spacer sizes at each side of each level, which can be tailored to the stenosis ratio in each individual case. This is not possible in other reported procedures.6,10-13 However, the optimal amount of cervical canal expansion in the cases of OPLL remains uncertain. Our procedure can contribute to research on this subject since the degree of expansion is adjustable with spacers of different sizes.

Several studies found that the anteroposterior compression ratio of the spinal cord correlated with the pathological damage.26-29 A reduced sagittal canal diameter might be the real culprit inflicting the repetitive mechanical trauma, resulting in myelopathy. The most important factor in relieving spinal cord compression in those patients with cervical stenotic myelopathy. Postoperative growth of ossified lesions may influence the long-term results of cervical expansive laminoplasty or laminectomy.7,8,19 OPLL tends to progress postoperatively and neurologically improving is related to the volume or anteroposterior diameter of the enlarged osseseal canal.28-30 It may be necessary to expand the sagittal canal to some degree in cases of OPLL, although excessive opening of the cervical canal may not always correlate with long-term neurological outcomes because of the occasionally induced reconstruction of the spinal canal due to epidural scar formation. Because what constitutes sufficient expansion of the cervical canal varies with each individual case, an individually configurable procedure of lift-up laminoplasty may be optimal for OPLL.

**Conclusion**

Although analysis using a larger population and an extensive postoperative follow-up period needs to be undertaken, our technique of lift-up laminoplasty appears to be an efficient method of stabilizing the posterior elements and maintaining sufficient decompression to treat patients with cervical OPLL and to be a good choice for standard posterior cervical approaches. The optimal extent of expansion should be further clarified in order to obtain functional recovery in the short term and to determine the progression of OPLL in the long term.

**References**