Surgical experience with symptomatic thoracic ossification of the ligamentum flavum

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Object. Symptomatic thoracic ossification of the ligamentum flavum (OLF) is rare, and its prognostic factors remain unclear. The authors retrospectively studied 24 patients with surgically treated thoracic OLF to delineate its prognostic factor.

Methods. The clinical manifestations, radiological studies, surgical records, and pathological findings were reviewed. Preoperative and postoperative neurological data were reappraised using the American Spinal Injury Association and modified Japanese Orthopaedic Association (JOA) scoring systems. Spearman rank-correlation coefficients and nonparametric tests were used to analyze the correlations between the variables of patient characteristics, preoperative duration of symptoms, preoperative neurological status, associated spinal disorder(s) other than thoracic OLF, and the final functional outcome.

Conclusions. Decompressive surgery is indicated in patients in whom symptomatic thoracic spinal cord compression is caused by intruding OLF. Magnetic resonance imaging can provide sufficient clues for the diagnosis of thoracic OLF. Higher preoperative modified JOA scores of 3 and 4 are positively correlated with better postoperative functional recovery than lower scores. Surgery should be performed as soon as possible before independent ambulatory function is impaired.

KEY WORDS • ossification • ligamentum flavum • thoracic spine • myelopathy

SYMPTOMATIC spinal canal stenosis is common in the cervical and lumbar spine, but it is rare in the thoracic spine.1 Clinical symptoms of thoracic spinal cord compression usually develop in the canal in which the anteroposterior diameter is narrower than 10 mm.2 It usually occurs in cases involving vertebral trauma, herniated thoracic disc, spondylosis, osseous overgrowth secondary to general bone and joint disorders, metabolic disease, ankylosis, and hypertrophy of posterior spinal elements.3,5 Of these, thoracic OLF is a relatively rare cause of thoracic myelopathy.2,12 In Japan, the authors of a hospital-based study found that OLF accounted for 2% of all spinal disorders and 2.3% of all spinal surgery.7 Although a portion of cases involving thoracic OLF were asymptomatic and could be treated conservatively,17 it was thought that surgical intervention was needed when the OLF became symptomatic secondary to spinal cord compression.5,4,12,14 Because of the low prevalence of this disorder, small patient populations, and the rarity of large clinical reports, the treatment guidelines and surgical prognoses in patients with this disease remain unclear and worthy of further investigation.17 In the present study we retrospectively assessed the clinical features of patients with symptomatic thoracic OLF treated surgically in our institute. We compared the associated factors and the surgical results to delineate more clearly the effects of this surgically treatable disease.

Clinical Material and Methods

We retrospectively reviewed the charts, imaging studies, and pathological reports obtained in patients with symptomatic thoracic canal stenosis secondary to OLF treated at Chang Gung Memorial Hospital. Imaging, surgical, and pathological findings were used to establish a diagnosis of OLF. Histopathology records confirmed the diagnosis of OLF with endochondral ossification in all excised ligamentum flavum specimens (Fig. 1). The initial symptoms, presenting signs, surgical indications, and postoperative results were analyzed. The initial symptoms refer to the patient’s first complaint, which could be the result of intruding ligamentum flavum–induced compression. The presenting signs indicate the clinical neurological deficits documented on the patient’s chart. We classified the presenting signs into local irritation (backache), thoracic radiculopathy (dermatomal numbness), and myelopathy (hyperreflexia, paraparesis, or
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Fig. 1. Photomicrograph of an ossified ligamentum flavum specimen demonstrating the pattern of endochondral ossification with a transitional layer of cartilaginous tissue (C) located between the degenerative ligamentum flavum (L) and well-formed woven bone (B); H & E, original magnification × 200.

sphincter dysfunction) with or without radiculopathy. Associated spinal disorders, including cervical, lumbar, and thoracic stenoses other than those affecting the operative segments, were also documented. Preoperatively and postoperatively, neurological conditions were reappraised using the five-tier ASIA scores, and the ambulatory status was reappraised using a modified JOA scoring system proposed by Palumbo, et al. (Table 1). Ambulatory status was recorded at the time of surgery, at 3 months postoperatively, and at the last follow-up examination. In cases with a modified JOA score of 3 and 4, a functionally independent recovery was achieved.

Spearman rank-correlation coefficients and nonparametric tests were used to analyze the correlations between the following variables: patient characteristics, preoperative duration of symptoms, preoperative ASIA and modified JOA scores, associated spinal disorders, and the final functional outcomes. For all statistical tests, a probability value less than 0.05 (two-tailed test) was considered significant.

Results

Patient Population and Presentation

Twenty-four patients (14 men and 10 women) with thoracic myelopathy or radiculopathy secondary to symptomatic OLF were treated and followed at our institution between January 1994 and December 2003. Patients ranged in age from 45 to 77 years (mean 58.2 years, median 60.5 years). The mean follow-up duration was 3.5 ± 2.2 years (range 1–8.5 years, median 3.45 years). The most frequent initial symptom, combined numbness and weakness of the lower limbs, was observed in 19 patients (79.2%); this was followed by backache at the involved spinal level, which occurred in six patients. Other subjective symptoms included gait unsteadiness in two patients, pure motor weakness of lower limbs in two patients, and lower-extremity numbness without motor weakness in two patients; intermittent claudication was demonstrated in one patient. Objectively, thoracic myelopathy was diagnosed in 23 patients (95.8%) and thoracic radiculopathy in one patient (4.3%). Sixteen patients experienced voiding difficulty. In all patients signs of thoracic cord or nerve root compression occurred in varying periods (range 1 month–20 years, median 1 year; and 95% confidence interval of mean 2.2–5 years) before they were examined.

Neuroimaging Diagnoses

Magnetic resonance imaging was used to establish the diagnosis of symptomatic OLF in 21 patients, postmyelography CT scanning was conducted in two, and both were performed in one patient. The ossified ligamentum flavum displays the density of cortical bone on CT scans (Fig. 2) and demonstrates triangular protrusion with a low-signal intensity resembling cortical bone on T1-weighted MR images (Fig. 3).

The pathological ligamentum flavum involved one segment in 11 patients, two segments in eight, three segments in three, four segments in one, and six segments in one patient. In all patients the ossification involved at least one segment of the ligamentum flavum between T 9 and T 12. Figure 4 displays the distribution of vertebral segments. In 19 patients in whom the MR imaging signal of OLF-involved spinal cord could be clearly visualized, intramedullary hyperintense T2-weighted signals, representing damage or edema in the compressed spinal cord, were observed in 11 patients. Six (54.5%) of 11 patients with an intramedullary hyperintense signal and one (12.5%) of eight without an abnormal signal on MR images did not exhibit functionally independent recovery at the study's censoring time. Although the neurological recovery seemed poorer in the patients with T2-weighted intramedullary hyperintense signal, the difference was not significant enough to draw the conclusion that the cord damage or demyelination led to poorer neurological recovery (p = 0.15, Fisher exact test). Twenty-three patients (95.8%) suffered from degenerative spinal diseases other than thoracic OLF and 14 (58.3%) harbored anterior spondylotic lesions (osteophyte and herniated intervertebral disc) at the corresponding levels of the ossified ligamentum flavum. Table 2 provides a summary of the other coexisting spinal disorders. Additional spinal operations included one cervical laminoplasty for continuous ossified PLL, five cervical discectomies with interbody fusion, and 11 lumbar laminectomies with three combined lumbar discectomies. All the additional spinal procedures were performed before surgical treatment of the thoracic ossified ligamentum flavum.

Surgical Treatment and Outcome

All patients in the present study underwent posterior tho-
racic laminectomy to remove the intruding ossified lesion. Efforts were made to preserve the lateral two thirds of the facet joints as much as possible to maintain the segmental stability. Thirteen patients underwent rehabilitation for a median period of 3 months (range 0.5–6 months) before operation, but neurological improvement failed to occur in all cases. Operative indications in all patients were deterioration of the clinical neurological deficits secondary to OLF. Although 16 patients harbored anterior spondylotic pathological entities (two with ossified PLLs and 14 with osteophytes and herniated discs) at the corresponding levels of the ossified ligamentum flavum, only two patients underwent concomitant resection of the intruding anterior lesions (unilateral transpedicular approach to excise an eccentric disc and osteophyte in one and transthoracic interbody fusion to remove an ossified PLL in the other). Internal instrumentation was not applied in these two patients because of adequate postoperative segmental stability. After 6 months of external body-jacket immobilization, both were free from delayed deformity and neurological deterioration for follow-up periods of 7 and 3.5 years, respectively. Decisions of whether anterior decompression should be performed were based mainly on preoperative MR imaging evaluation of the extension of anterior compression. There was no surgery-associated death, but there were five cases of surgery-related morbidity: one wound infection (4.2%), two unintended intraoperative spinal cord manipulations that resulted in postoperative acute neurological deterioration (8.4%), and two cases (21%) in which unintended intraoperative durotomies led to postoperative cerebrospinal fluid leakage. Initially, the latter two patients underwent supplementary suturing of the surgical wound but, because of persisting cerebrospinal fluid leakage, one patient underwent reopening of the wound to allow for patching with fascia graft and tissue glue. There were two cases (8.4%) of disease-associated delayed-onset death: one patient died of a pressure sore and aspiration pneumonia 2 years postoperatively, and the other died of necrotizing fasciitis arising from a wound in the anesthetic limb 6 months postoperatively. The interval between the onset of subjective initial symptom and surgery ranged from 1 week to more than 10 years (median 1 year; 95% confidence interval of mean 0.88–4.97 years). The duration of preoperative symptoms did not affect the functional recovery at the censoring time (p = 0.93, Mann–Whitney U-test).

Before surgery, function in three patients was classified as ASIA Grade C and 21 as ASIA Grade D. Postoperatively, only one patient with thoracic radiculopathy exhibited improved ASIA motor function (from Grade D to E). Because of unintended intraoperative cord manipulation (with associated inadequate OLF decompression in one patient), two patients suffered immediate postoperative neurological deterioration. Function in one patient deteriorated from ASIA Grade D to C with complete loss of ambulatory ability (modified JOA score from 3–0). Although the ASIA grade of the other patient was unchanged postoperatively (Grade D), lower-limb muscle strength deteriorated from 5/5 to 3/5 and the patient lost independent ambulation after surgery (modified JOA score decrease from 3 to 2). Neither patient regained independent ambulatory abilities after 1.5 and 2 years of rehabilitation, respectively. The ASIA grades in the other patients remained unchanged.

There was no significant difference between the pre- and postoperative ASIA grades in all patients (p = 1.00, Wilcoxon signed-rank test); however, surgery significantly improved the ambulatory status (based on modified JOA scores) of the patients 3 months after surgery (p = 0.006, Wilcoxon signed-rank test). In addition, the neurological recoveries represented by the modified JOA scores at the 3-month and final follow-up examinations were not statistically different (p = 0.854, Wilcoxon signed-rank test). Table 3 provides a summary of the modified preoperative and 3-month follow-up JOA scores. Postoperative JOA scores were higher in 16 patients than at baseline; function in six remained the same, but in two status worsened (decreased postoperative modified JOA score). In six patients modified JOA scores were unchanged: in one patient with a preoperative modified JOA score of 4 refractory painful thoracic radiculopathy was completely relieved postoperatively; in the other five, subjectively improved lower-limb sensorimotor function was present. The preoperative modified JOA score was positively correlated with the recovery of ambulatory independence at 3 months after surgery and at the censoring time (Spearman rank-correlation coeffi-
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Discussion

Clinical and Radiographic Manifestations of Thoracic OLF

Thoracic OLF is rare and usually asymptomatic. The disease usually has an insidious onset and very slow progression. Analysis of previously published epidemiological data revealed that thoracic OLF most commonly involves the vertebrae between T-9 and T-12, where greater mobility and vulnerability (due to spinal motion) may result in frequent mechanical injury. In the present study a similar distribution was observed. Although there was no sound evidence to conclude that the OLF shared the common pathogenesis of spondylotic degeneration, the high prevalence of coexisting anterior osteophytes and herniated intervertebral disc at the symptomatic OLF segments led to the hypothesis that ossification may be a degenerative response to the microinjury of the ligamentum flavum. Barnett, et al., have suggested that the hypermobility of the lower thoracic spine, as in the cervical and lumbar spine, may promote degeneration and canal stenosis. The hypothesis was histologically supported by Okada and colleagues who found that OLF formed in the hypertrophic ligamentum flavum with fibrocartilage proliferation, and this was thought to be a phenomenon of mechanical injury. Therefore, it is thought that the development of OLF may be secondary to the specific fiber reconstruction of the ligamentum flavum in response to mechanical stress.

Before the early 1990s, when MR imaging was not commonly used for neurological diagnosis, spinal CT myelography was considered the best diagnostic tool to detect OLF-induced thoracic cord compression. This CT study yields artifacts, however, that interfere with interpretation of intraspinal lesion in the upper thoracic spine because of the high contrast of intensity between the lung and surrounding osseous architectures. Although an ossified ligamentum flavum does not exhibit specific signal intensity on MR imaging, it can be detected by the typical

Fig. 3. Sagittal T2-weighted MR images revealing a triangular protrusion with a low signal intensity resembling cortical bone. A: An irregularly nodular-shaped ossified ligamentum flavum affects the upper thoracic spine. B: The lesion involves two segments associated with an anterior thoracic herniated disc and spontaneous fusion of the L-1 and L-2 vertebral bodies. C: The ossified lesions involved multiple segments of the thoracic spine.
appearance of a triangular or rectangular protrusion with a hypointense signal on both T1- and T2-weighted sequences beneath the spinous processes. In addition, MR imaging can clearly define coexisting anterior vertebral lesions and more accurately predict the significance of spinal canal compromise and the severity of spinal cord compression. Moreover, sagittal MR imaging can delineate the cephalo-caudal extension of the symptomatic ossified lesion, which is important in preoperative surgical planning. Intramedullary hyperintense T2-weighted MR signals were frequently demonstrated in the compressed spinal cord in cases of various intruding spinal lesions. Although the intramedullary hyperintense T2-weighted signal may be correlated with more severe cord compression, its correlation with poor neurological outcome remains controversial. In acute spinal cord injury, the abnormal signal represents damage to the spinal cord such as edema, necrosis, and hemorrhage. In cases involving long-standing compression of the spinal cord and attendant chronic neurological deterioration, the intramedullary T2-weighted signal may represent demyelination and microcavitation that are associated with a poorer neurological recovery despite surgical decompression. Although the patients with intramedullary hyperintense T2-weighted signal seemed to exhibit worse functional outcomes compared with those in whom this signal was absent, the current data were not statistically significant and thus do not indicate that the intramedullary hyperintense signal can be used as a prognostic factor to predict outcome after surgery for thoracic OLF.

**Prognostic Factors for Thoracic OLF**

Conservative treatment involving external orthosis or medication is not effective in preventing disease progression and neurological deterioration. Decompressive surgery (excision of the intruding ossified ligamentum flavum) is recommended when thoracic myeloradiculopathy has developed secondary to the canal compromise. The prognostic factors contributing to optimal postoperative neurological recovery, however, are unclear. A shorter duration of preoperative symptoms, thoracic canal less affected by stenosis, and the absence of proximal stenosis would be correlated with a better postoperative neurological recovery. These results indicate that exacerbation of preoperative neurological symptoms over a long period may be largely irreversible. It seemed, however, that the preoperative neurological status itself did not adequately predict postoperative neurological recovery. In the present study, preoperative neurological performance (independence of ambulation [modified JOA scores of 3 and 4]) was the only significant prognostic factor contributing to independent functional recovery (p = 0.033, Fisher exact test). The duration of symptom progression did not reach the statistical significance to be correlated with surgical outcome (p =

### TABLE 2

Coexisting spinal disorders stratified by spinal region in 24 patients

<table>
<thead>
<tr>
<th>Spinal Region</th>
<th>Disorder</th>
<th>Cervical</th>
<th>Thoracic</th>
<th>Lumbar</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ant osteophyte or HIVD</td>
<td>6</td>
<td>14</td>
<td>3†</td>
<td>23 (95.8)</td>
<td></td>
</tr>
<tr>
<td>OPLL</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>3 (12.5)</td>
<td></td>
</tr>
<tr>
<td>canal stenosis</td>
<td>4</td>
<td>0</td>
<td>14</td>
<td>18 (75)</td>
<td></td>
</tr>
<tr>
<td>spondylolysisis</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>4 (16.7)</td>
<td></td>
</tr>
<tr>
<td>compression fracture</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2 (8.3)</td>
<td></td>
</tr>
<tr>
<td>spontaneous vertebral fusion</td>
<td>0</td>
<td>0</td>
<td>2‡</td>
<td>2 (8.3)</td>
<td></td>
</tr>
<tr>
<td>ankylosing spondylitis</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1 (4.2)¤</td>
<td></td>
</tr>
</tbody>
</table>

* HIVD = herniated intervertebral disc; OPLL = ossification of the PLL.
† All patients with lumbar stenosis had coexisting lumbar disc herniation, but only those requiring postlaminectomy lumbar disectomy were considered to be symptomatic.
‡ In both patients there was spontaneous L-1 and L-2 fusion.
§ In this patient, the disease involved all spinal regions.

### TABLE 3

Modified JOA scores obtained in 24 patients before and 3 months after surgery

<table>
<thead>
<tr>
<th>JOA Score</th>
<th>Preop Score</th>
<th>Postop Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
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</tbody>
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0.93). This might be due to the insidious onset of clinical symptoms and the high incidence of coexisting spinal disorders, which biased and confused the patient’s recognition of initial presentations and the symptom progression of thoracic OLF. Therefore, in patients with symptomatic thoracic OLFs, it is better to perform decompressive surgery in an early stage of disease progression while neurological symptoms are mild and ambulatory function is not impaired. Although the incidence of coexisting spinal disorder was high (perhaps due to the small patient population) it was not correlated with outcomes after surgery; however, the high incidence of coexisting spinal disorder in thoracic OLF makes whole-spine MR imaging necessary.

Immediate postoperative neurological deterioration occurred in cases in which there was unintended intraoperative cord manipulation with or without incomplete decompression. As documented in earlier reports,1,14,15 we observed two cases of postoperative kyphotic deformities and three of spondylotic degenerations at the surgical segments; however, there was no late-onset deterioration after neurological recovery. Adequate spinal cord decompression, careful resection of the ossified lesion, and limited destruction of the medial third of the facet joints can preserve segmental stability and prevent late-onset neurological deterioration.17 In recent reports, preoperative three-dimensional CT scanning13 and intraoperative neuronavigation16 have been used for surgical planning to increase safety and make possible the precise resection of a thoracic ossified ligamentum flavum after laminotomy, which might increase the postoperative segmental stability; however, surgery performed soon after OLF causes mild clinical symptoms, adequate spinal cord decompression, and meticulous surgical intervention remain the most important strategies by which to minimize spinal cord manipulation and ensure postoperative neurological recovery.

Conclusions

Symptomatic OLF-induced thoracic cord compression is rare. Magnetic resonance imaging can provide sufficient clues for establishing the diagnosis of thoracic OLF. A high incidence of coexisting spinal disorders in patients with thoracic OLF makes preoperative whole-spine examinations necessary. Decompressive surgery is safe, but excessive intraoperative cord manipulation can cause harm and should be avoided if possible. Higher preoperative modified JOA scores of 3 and 4 are positively correlated with better postoperative functional recovery than the lower scores. Thus, surgery should be performed as soon as possible before ambulatory function is lost.

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