Management of ossification of the posterior longitudinal ligament of the thoracic spine

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The management of thoracic ossification of the posterior longitudinal ligament has been studied by many spinal surgeons. Indications for operative intervention include progressive radiculopathy, myelopathy, and neurological deterioration. The ideal surgery for decompression remains highly debatable as various methods of surgical treatment of ossification of the posterior longitudinal ligament have been devised. Although numerous modifications to the 3 main approaches have been identified (anterior, posterior, or lateral), the indication for each depends on the nature of compression, the morphology of the lesion, the level of the compression, the structural alignment of the spine, and the neurological status of the patient. The authors discuss treatment techniques for thoracic ossification of the posterior longitudinal ligament, cite case examples from a single institution, and review the literature.

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KEY WORDS • ossification of the posterior longitudinal ligament • thoracic myelopathy • thoracic spine

Ossification of the posterior longitudinal ligament is an epidemiological event that often affects the cervical spine. Tsukimoto was the first to describe OPLL of the cervical spine in 1960. However, the condition may involve the thoracic spine and produce myelopathy through anterior spinal cord compression. Ossification of the posterior longitudinal ligament is rarely seen in patients until the third decade of life. This disease process is most commonly seen in the Japanese population. The prevalence of thoracic OPLL seen in a Japanese community has been reported to be 0.8%, compared with 3.2% seen for cervical OPLL. The incidence of cases of OPLL of the thoracic spine with clinical symptoms is lower than that of the cervical spine. According to Epstein, 70% of OPLL is found in the cervical spine, 15% in the upper thoracic spine, and 15% in the proximal lumbar spine. Ossification of the posterior longitudinal ligament in the thoracic spine usually occurs in the upper- and midthoracic spines of women who are older than 40 years of age.

Symptoms are the result of stenosis that is usually progressive and unaffected by conservative management. Surgery is the only effective treatment option. For patients with thoracic myelopathy, the most effective method of treatment is relieving pressure off the spinal cord and removing the OPLL. Although surgical outcome of thoracic OPLL compares unfavorably with that of cervical OPLL, early intervention is imperative. A review of the literature, limited to the English language, was performed for surgical management of thoracic OPLL and is summarized in Table 1.

Anatomical Considerations

There are multiple classification schemes in the literature. A classification based on form and morphology includes a continuous or mixed type with a flat shape (“flat-type”) and a segmental type with sharp protrusions located behind the disc spaces (“beak-type”). Ossification of the posterior longitudinal ligament can also be described morphologically as linear, beaked, continuous waveform, continuous cylindrical, segmental, continuous, or mixed. Patterns of ossification can be divided into 4 major subgroups as follows: 1) focal ossification at the posterior margin of the vertebral body; 2) segmental ossification over multiple levels; and 4) mixed ossification. Kurosa et al. defined a classification system based on the location of the OPLL in the sagittal plane as follows: 1) central part of the S-curve of the cervicothoracic spine (the inflection point often in the upper thoracic spine where the plane shifts from cervical lordosis to thoracic kyphosis); 2) just above the thoracic apex or apical vertebrae; and 3) below the apical vertebrae, typically combined with OLF.

In spinal hyperostosis, OPLL and OLF are the main

**Abbreviations used in this paper:** JOA = Japanese Orthopaedic Association; OLF = ossification of the ligamentum flavum; OPLL = ossification of the posterior longitudinal ligament.
causes of compressive myelopathy. In the thoracic spine, OPLL and OLF can compress the spinal cord anteriorly and posteriorly, respectively, or they may fuse to circumferentially compress the spinal cord on all sides. Unlike OPLL in the cervical spine, thoracic myelopathy due to ligament ossification may be overlooked, misdiagnosed, or treated inappropriately. Unlike cervical myelopathy, thoracic myelopathy is not as common as cervical myelopathy. 

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Disease &amp; Surgical Procedure (no. of patients)</th>
</tr>
</thead>
</table>
| present study 2010 | OPLL  
pst decomp & fusion (2) |
| Matsuyama et al., 2005 | flat-type OPLL  
ant decomp & fusion (1)  
ant decomp via pst approach (3);  
laminoplasty (3)  
beak-type OPLL  
ant decomp & fusion (2)  
ant decomp via pst approach (6)  
laminoplasty (6) |
| Takahata et al., 2008 | OPLL  
circumferential decomp via pst approach (30) |
| Park et al., 2008 | OPLL  
thoracic (5) |
| Min et al., 2008 | OPLL  
ant decomp w/ discectomy (3)  
ant decomp w/ partial corpectomy (9)  
ant decomp w/ corpectomy (5)  
ant decomp w/ discectomy & partial corpectomy (2) |
| Matsumoto et al., 2008 | linear-type OPLL  
laminectomy (5)  
ant decomp via pst approach (3)  
beaked-type OPLL  
laminectomy (8)  
laminoplasty (16)  
ant decomp via ant approach (12)  
ant decomp via pst approach (5)  
circumferential decomp via combined ant & pst fusion (2)  
sternum splitting approach (2)  
continuous waveform OPLL  
laminectomy (9)  
laminoplasty (19)  
ant decomp via ant approach (4)  
ant decomp via pst approach (12)  
circumferential decomp via combined ant & pst fusion (2)  
continuous cylindrical OPLL  
laminectomy (7)  
laminoplasty (11)  
ant decomp via ant approach (2)  
ant decomp via pst approach (6)  
mixed-type OPLL  
laminectomy (7)  
laminoplasty (5)  
ant decomp via ant approach (7)  
ant decomp via pst approach (3)  
circumferential decomp via combined ant & pst fusion (4)  
sternotomy approach (3)  
continuous cylindrical OPLL  
laminectomy (7)  
laminoplasty (5)  
ant decomp via ant approach (7)  
ant decomp via pst approach (3)  
circumferential decomp via combined ant & pst fusion (4)  
sternotomy approach (3)  
continuous waveform OPLL  
laminectomy (9)  
laminoplasty (19)  
ant decomp via ant approach (4)  
ant decomp via pst approach (12)  
circumferential decomp via combined ant & pst fusion (2)  
continuous cylindrical OPLL  
laminectomy (7)  
laminoplasty (11)  
ant decomp via ant approach (2)  
ant decomp via pst approach (6)  
mixed-type OPLL  
laminectomy (7)  
laminoplasty (5)  
ant decomp via ant approach (7)  
ant decomp via pst approach (3)  
circumferential decomp via combined ant & pst fusion (4)  
sternotomy approach (3)  
Kawahara et al., 2008 | pst decomp w/ dekyphosis stabilization (4)  
circumferential decompression via initial pst decomp w/ dekyphosis stabilization followed by ant interbody (11) |

(continued)
Radiographic evaluation consists of the location and extent of OPLL, the type of OPLL, signs of dural penetration, the degree of compression, the presence of cord signal change, and the presence of “tandem ossification” in the cervical spine or the ligamentum flavum. Signs of dural penetration are based on their morphology in relation to the OPLL. Signs of dural ossification include 2 CT findings represented as the “single-layer sign,” consisting

**TABLE 1: Literature review of surgical treatment for thoracic OPLL** (continued)

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Disease &amp; Surgical Procedure (no. of patients)</th>
</tr>
</thead>
</table>
| Aizawa et al., 2007     | OPLL laminctomy (15)  
                         | laminctomy w/ fusion (2)  
                         | ant decom via diagonal ant/pst approach (2)  
                         | ant decom via pst approach (2)  
                         | OPLL, OLF laminctomy (9)  
                         | ant decom via pst approach (1)  |
| Hanai et al., 2002      | OPLL transthoracic approach for ant decom & fusion, occasional use of the scapula-releasing approach (10)  
                         | thoracoabdominal approach for ant decom & fusion (2)  |
| Yang et al., 2010       | OPLL pst decom & ant decom via posterolat approach  |
| Fujimura et al., 1997   | OPLL ant decom via manubrium splitting approach (2)  
                         | ant decom via extrapleural approach (30)  
                         | combined (1)  |
| Yamazaki et al., 2010   | OPLL pst decom w/ fusion (24)  |
| Min et al., 2007        | segmental-type OPLL partial corpectomy (6)  
                         | discectomy (3)  
                         | partial corpectomy w/ discectomy (2)  
                         | corpectomy (3)  
                         | continuous-type OPLL partial corpectomy (3)  
                         | corpectomy (2)  
                         | mixed-type OPLL partial corpectomy (1)  |
| Tokuhashi et al., 2006  | OPLL pst decom (5)  
                         | pst decom w/ fusion (11)  
                         | pst decom w/ fusion via posterolat approach (4)  
                         | ant decom w/ fusion (2)  |
| Yonenobu et al., 1987   | OPLL pst decom (12)  
                         | pst decom then ant decom (4)  
                         | pst decom then pst decom (3)  
                         | ant decom (5)  
                         | ant decom then pst decom (2)  |
| Tomita et al., 1990     | OPLL & OLF circumspinal decom (10)  |
| Tsuzuki et al., 2001    | OPLL extensive cervicothoracic laminoplastic decom (3)  
                         | extensive cervicothoracic laminoplastic decom, pst longitudinal durotomy (5)  
                         | extensive cervicothoracic laminoplastic decom, pst longitudinal durotomy root release w/ total laminofacetectomy, anterolat dural release (4)  
                         | extensive cervicothoracic laminoplastic decom, pst longitudinal durotomy root release w/ total laminofacetectomy, anterolat dural release, & OPLL excision or ant transfer, & posterolat fusion (5)  |

(continued)
of a single homogeneous ossified, focal, uniformly hyperdense OPLL mass, and the “double-layer sign,” characterized by anterior and posterior hyperdense ossified rims separated by a centrally hypertrophied, hypodense nonossified posterior longitudinal ligament (more specific for absent dura).\(^7\),\(^18\) Min et al.\(^18\) found no statistically significant difference between the double- and single-layer sign group regarding the frequency of dural penetration. Dural defects were present in 60% of patients with a double-layer sign, and in 50% of patients with a single-layer sign.

During evaluation, spinal surgeons perform a detailed history and physical examination. Patients may present with symptoms of lower-extremity numbness, lower-extremity weakness, ambulatory difficulty/gait disturbance, thoracic radiculopathy, urinary retention, bladder and/or bowel incontinence, or myelopathy. Patients may also complain of continuous chest wall or vague back pain. Diagnostic imaging often consists of plain films, myelography, CT scanning, and/or MR imaging. Stenosis can be identified by CT myelography or MR imaging. Computed tomography is helpful to identify the extent of ossification of the ligaments. Surgical outcomes may be assessed using the JOA score for thoracic myelopathy (total of 11 points), which is derived from the JOA scoring system for cervical myelopathy minus the motor and sensory scores for the upper extremity.\(^1\) This scoring system is shown in Table 2. Intraoperative neuromonitoring should be a mainstay of perioperative management.

Items studied during initial evaluation consist of the morphology of the thoracic OPLL, the level of the ossified lesions, the level of maximum ossification, presence of tandem ossification, intramedullary hyperintensity on T2-weighted MR imaging, and the kyphotic angle of the involved thoracic vertebrae. Tandem ossification is important to recognize in patients with myelopathy who plan to undergo surgical intervention for OPLL.\(^2\)\(^3\) Tandem ossification refers to ossification of other spinal ligaments—cervical OPLL or OLF. Park et al.\(^2\)\(^3\) reviewed 68 cases of cervical OPLL and found a frequency of tandem lesions in 23 patients (33.8%)—5 with thoracic OPLL. Patients with symptomatic cervical OPLL frequently had tandem ossification at the upper and mid thoracic spine.\(^2\)\(^3\) Aizawa et al.\(^1\) reviewed a subset of a larger group of 132 patients with thoracic myelopathy. There were 21 patients with OPLL and 10 patients with combined ossification of ligamentum flavum and OPLL. It is often the case that there is ossification of ligamentum flavum with thoracic OPLL.\(^2\)\(^3\),\(^27\)

The vascular supply to the thoracic spine is important for the spinal surgeon treating pathology in this region. The midthoracic region is supplied mainly by a single thoracic radicular branch (often from T-7) that is poorly collateralized, making this region more susceptible to the effect of hypotension.\(^5\) The upper thoracic spinal cord is nourished by the blood supply from the cervical vertebral artery and the lumbar artery of Adamkiewicz. There is a concern that since the thoracic cord is in a relative watershed zone of the spinal circulation, the thoracic cord may not recover as well as the cervical cord, even after sufficient decompression.\(^1\) Because of the combination of reduced vascularity and larger occupancy of the spinal canal, the thoracic cord may be subjected more to severe damage by compressive entities.\(^1\),\(^2\)\(^6\),\(^34\)

### Advantages and Disadvantages With Indications and Limitations of Various Surgical Approaches

Surgical decompression is the treatment of choice in cases of compressive myelopathy.\(^1\) The surgical management of thoracic OPLL consists of a multitude of options:

![Image](https://example.com/image.png)

### Table 1: Literature review of surgical treatment for thoracic OPLL (continued)

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Disease &amp; Surgical Procedure (no. of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurosa et al., 1996</td>
<td>OPLL, central part of S-curve</td>
</tr>
<tr>
<td></td>
<td>laminectomy (3)</td>
</tr>
<tr>
<td></td>
<td>laminoplasty (6)</td>
</tr>
<tr>
<td></td>
<td>circumferential decomp (1)</td>
</tr>
<tr>
<td></td>
<td>ant decomp &amp; floating (1)</td>
</tr>
<tr>
<td></td>
<td>ant decomp &amp; floating via manubrium splitting approach (1)</td>
</tr>
<tr>
<td>OPLL, just above apical vertebra</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ant decomp via thoracotomy (9)</td>
</tr>
<tr>
<td></td>
<td>laminectomy (1)</td>
</tr>
<tr>
<td></td>
<td>laminoplasty (1)</td>
</tr>
<tr>
<td>OPLL, combined with ossification of ligamentum flavum below apical vertebra</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ant decomp via pst approach (3)</td>
</tr>
<tr>
<td></td>
<td>laminectomy (1)</td>
</tr>
<tr>
<td>Kojima et al., 1994</td>
<td>OPLL</td>
</tr>
<tr>
<td></td>
<td>transthoracic anterolateral approach (2)</td>
</tr>
<tr>
<td></td>
<td>transsternal approach (1)</td>
</tr>
<tr>
<td>Ohtani et al., 1982</td>
<td>OPLL</td>
</tr>
<tr>
<td></td>
<td>ant decomp including partial vertebrectomy (4)</td>
</tr>
<tr>
<td></td>
<td>ant decomp &amp; subtotal vertebrectomy via manubrium splitting approach (1)</td>
</tr>
</tbody>
</table>

* ant = anterior; decomp = decompression; pst = posterior.
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TABLE 2: Evaluation of thoracic myelopathy*

<table>
<thead>
<tr>
<th>Function</th>
<th>Point Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>motor in lower extremity</td>
<td></td>
</tr>
<tr>
<td>unable to stand up &amp; walk</td>
<td>0</td>
</tr>
<tr>
<td>unable to walk w/o a cane or other support on a level surface</td>
<td>1</td>
</tr>
<tr>
<td>walks independently on a level surface, but needs support on stairs</td>
<td>2</td>
</tr>
<tr>
<td>capable of fast walking but clumsy</td>
<td>3</td>
</tr>
<tr>
<td>normal</td>
<td>4</td>
</tr>
<tr>
<td>sensory in lower extremity</td>
<td></td>
</tr>
<tr>
<td>apparent sensory loss</td>
<td>0</td>
</tr>
<tr>
<td>minimal sensory loss</td>
<td>1</td>
</tr>
<tr>
<td>normal</td>
<td>2</td>
</tr>
<tr>
<td>sensory in trunk</td>
<td></td>
</tr>
<tr>
<td>apparent sensory loss</td>
<td>0</td>
</tr>
<tr>
<td>minimal sensory loss</td>
<td>1</td>
</tr>
<tr>
<td>normal</td>
<td>2</td>
</tr>
<tr>
<td>bladder</td>
<td></td>
</tr>
<tr>
<td>urinary retention &amp;/or incontinence</td>
<td>0</td>
</tr>
<tr>
<td>sense of retention &amp;/or dribbling &amp;/or thin stream</td>
<td>1</td>
</tr>
<tr>
<td>urinary retardation &amp;/or pollakiuria</td>
<td>2</td>
</tr>
<tr>
<td>normal</td>
<td>3</td>
</tr>
<tr>
<td>total</td>
<td>11</td>
</tr>
</tbody>
</table>

* Based on the JOA scoring system.

spine may be accomplished via an anterior (manubrium splitting), posterior (transpedicular, costotransversec- tumy, or lateral extracavitary), or lateral approach (tho- racotomy). The transthoracic extrapleural or transthoracic approaches can successfully approach the anterior column via a lateral approach. The combined anterior and posterior approach is an option for treatment of OPLL. Circumferential decompression improves neurological function more efficiently than posterior decompressive laminectomy alone. However, this is technically more sophisticated than a posterior decompression.

Matsumoto et al. conducted a multiinstitutional retrospective study involving 34 institutions in which detailed analysis of a survey was performed on patients who underwent surgery for thoracic OPLL. Analysis revealed the following: linear-type OPLL was most frequently treated by laminectomy; beak-type by laminoplasty and anterior decompression and fusion by an anterior approach; continuous waveform type and the continuous cylindrical type by laminoplasty; and mixed type by laminectomy and anterior decompression and fusion through an anterior approach. When the procedures selected for different levels of maximum ossification were assessed, laminoplasty was conducted in 50% of all patients with maximum ossification at the level of T1–4; laminectomy, laminoplasty, and anterior decompression and fusion via anterior approach were conducted at almost the same frequency in patients with maximum ossification at the level of T5–8; and laminectomy was conducted in 52% of all the patients with maximum ossification at the level of T9–12. There was no statistically significant difference in the surgical outcomes among patients treated by different surgical methods. Kurosa et al. thought that that posterior or anterior decompression for the S-curve location OPLL is effective; an anterior approach regardless of the kyphosis is effective for the above apical vertebra OPLL; and a transthoracic anterior decompression is the best for the below apical vertebra OPLL.

Min et al. reviewed 19 patients who underwent anterior decompression for thoracic OPLL and found a significant percentage did not improve clinically and that the nature of the procedure is fraught with a high complication rate (42.1% overall). Results of surgery from thoracic OPLL causing myelopathy are not as satisfactory compared with those for cervical OPLL. Reported rates of postoperative neurological deterioration in patients undergoing anterior decompression range from 2.7% to 18.8%. Surgical complications can range from early to late. The most important perioperative complications noted by spine surgeons include neurological deterioration, infection, epidural hematoma, and CSF leak. Other complications can result that are similar for all surgical procedures. The true etiology of early neurological deterioration has not been fully elucidated.

Laminectomy and Laminoplasty

Posterior decompression of the spinal cord in the thoracic spine can be achieved by laminectomy with or without fusion or laminoplasty. Favorable surgical outcomes can be seen with laminoplasty for lesions with maximum ossification at the upper thoracic spine. The use of instru-
mentation should be considered with posterior decompression for thoracic OPLL in the middle and lower thoracic spine.\textsuperscript{15} This is due to the presence of physiological kyphosis in the thoracic spine, which can lead to unfavorable outcomes for decompression alone. The spinal cord will have limited shift backward with decompression alone due to the kyphosis in the thoracic spine.\textsuperscript{1} The spinal cord is more vulnerable at the site of compression due to the relative avascularity of the thoracic spine by being in a watershed zone of spinal circulation.\textsuperscript{16,17} Adherence of an ossified ligament to the ventral aspect of the dura makes direct removal difficult and risks spinal cord injury during decompression maneuvers.\textsuperscript{14,27} Yamazaki et al.\textsuperscript{35} reported a case of postoperative paraparesis after laminectomy that was reversed after posterior instrumented segmental fusion for a case of thoracic myelopathy due to combined OPLL and OLF. The Cobb angle was unchanged between preoperative and postoperative studies.

Tokuhashi et al.\textsuperscript{29} described measuring the ossification-kyphosis angle in the thoracic spine as a predictor to neurological outcome. This represents the angle of kyphosis from the posterosuperior margin at the cranial vertebral body of the decompression site, and from the posterosuperior margin of the caudal vertebral body of the decompression site to the prominence of the maximum OPLL.\textsuperscript{29} There were no patients with postoperative deleterious paralysis with echo-free space seen between the OPLL mass and the spinal cord on intraoperative ultrasoundography.\textsuperscript{29} The ossification-kyphosis angle most reflected the presence of echo-free space on ultrasonography.\textsuperscript{29} A 23° ossification kyphosis angle is thought to be the critical point for presence of echo-free space and effective posterior decompression. Thus, if the ossification-kyphosis angle is more than 23° on the sagittal view of an MR image, surgical options should be explored other than posterior decompression alone.\textsuperscript{29} In the 4 patients with posterior decompression, the ossification-kyphosis angle progressed by an average of 4.0°, and in the 11 patients with posterior decompression with fusion, the ossification-kyphosis angle changed by an average of 0.04°.\textsuperscript{29}

Yamazaki et al.\textsuperscript{37} performed intraoperative ultrasonography in 24 patients treated with decompression and fusion showed no subarachnoid space between the OPLL and the cord. Although there was persistent impingement of the spinal cord from the anterior direction after decompression, all patients showed neurological recovery after surgical treatment.\textsuperscript{37} Posterior instrumented fusion has some positive effect on myelopathy after laminectomy for thoracic OPLL.\textsuperscript{37} Also, posterior instrumented fusion and suppression of spinal column mobility was more powerful than correction of kyphosis for producing neurological recovery after posterior decompression and fusion.\textsuperscript{37}

Tsuzuki et al.\textsuperscript{34} evaluated the extent of posterior shift of the spinal cord after extensive cervicothoracic laminoplasty. If patients were without OPLL, spinal cord separation (signifying lack of anterior decompression of the spinal cord from the OPLL), additional procedures including posterior longitudinal durotomy and others to eliminate the axial inhibiting factors were performed. Complication after cervical decompressive laminoplasty included loss of range of motion of the cervical spine by 10%–30% in all patients.\textsuperscript{34} Although CSF leakage was noted to be self-limiting in this series, it took a minimum of 3 months to resolve.\textsuperscript{34}

**Cervicothoracic or Sternotomy Approach**

The spinal curvature at the cervicothoracic junction is usually lordotic or only slightly kyphotic, thereby making laminoplasty and posterior decompression of the spinal cord relatively safe.\textsuperscript{13} However, anterior approaches to the cervicothoracic junction have been described in detail.\textsuperscript{20} It is believed that the transternal approach is successful for access lesions at the upper 3 thoracic vertebrae.\textsuperscript{12} Ohtani et al.\textsuperscript{20} thought that an anterior approach to the upper thoracic spine through partial median sternotomy and dividing the manubrium is effective and allows for direct decompression of OPLL.

**Transthoracic Approach**

Anterior approaches to the middle and lower thoracic spine can be performed thorough tranpleural or transthoracic extrapleural dissection. However, these anterior decompression approaches have a relatively high rate of postoperative complications.\textsuperscript{18,36} Anticipation of dural ossification and dural penetration by the OPLL mass is important in avoiding CSF leakage and accidental damage to the spinal cord or nerve roots in planning anterior procedures to treat this condition.\textsuperscript{18} Kojima et al.\textsuperscript{32} thought that the transthoracic anterolateral approach is effective for extensive OPLL involving more than 2 thoracic vertebral bodies below T-4. Ohtani et al.\textsuperscript{20} agreed that an anterior approach through thoracotomy for pathology below T-4 is optimal. Anterior decompression is ideal for spinal cord recovery to treat thoracic myelopathy caused by OPLL on the concave side of the spine.\textsuperscript{15} It is the optimal procedure for the best chance of recovery from thoracic myelopathy.\textsuperscript{4,10,11,30,31,41} However, anterior decompression and interbody fusion through thoracotomy was less than satisfactory when performed as rescue surgery in patients with thoracic OPLL whose myelopathy worsened after laminectomy.\textsuperscript{20,38}

Many authors advocate a circumsplinal approach for complete decompression. However, there is always the potential that removal of the OPLL off the anterior cord might result in spinal cord injury during surgery. Extensive involvement of the thoracic spine with OPLL and consideration of circumferential decompression should be closely analyzed by the spine surgeon. Involvement of the dura mater in OPLL is an important issue as leakage of CSF through the resected portion of the dura is a common complication encountered during surgery. Tomita et al.\textsuperscript{34} described staged circumsplinal decompression consisting of a posterior or lateral decompression followed by anterior decompression via thoracotomy for middle or lower thoracic spine. They recommended drilling a deep gutter bilaterally into the vertebral body after extended laminectomy from a posterior approach, followed by thoracotomy for anterior decompression which features partial vertepectomy, removal of OPLL, and anterior interbody fusion. Kawahara et al.\textsuperscript{11} highlighted 13 of 15 patients who underwent a 2-staged posterior decompression.
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and stabilization followed by the anterior decompression via thoracotomy and interbody fusion.

**Lateral Extracavitary, Costotransversectomy, and Transpedicular Approaches**

Removal of the OPLL may be the most effective method of relieving pressure off the spinal cord in patients with thoracic myelopathy caused by OPLL. Factors affecting surgical outcome from an anterior approach in the thoracic spine include the following: duration and severity of myelopathy; extent of anterior decompression; combined procedure for cervical OPLL and/or ossified ligamentum flavum; and type of OPLL. The use of the anterior decompression via a posterior corridor includes the transpedicular, costotransversectomy, and lateral extracavitary approaches. Tomita et al. advocated the use of a posterior decompression via extensive laminectomy followed by costotransversectomy for upper thoracic spine. Takahata et al. performed a retrospective analysis in patients receiving circumferential decompression through a posterior approach for thoracic OPLL between 1992 and 2003. Surgical complications included dural tear, deep infection, and postoperative neurological deterioration. Further analysis demonstrated that more than 5 levels for circumferential decompression was associated with unfavorable surgical outcomes. At final follow-up, 20 of 30 patients recovered or had improved ambulatory function with or without assistive devices. Matsuyama et al. reviewed 21 patients (10 men and 11 women; mean age 54 years) with thoracic OPLL who underwent surgical treatment between 1985 and 2000. They found a lower mean operative time and blood loss in patients who received anterior decompression via a posterior approach compared with anterior decompression with fusion for both flat-type and beak-type OPLL.

**Minimally Invasive Approaches (Direct Lateral Interbody Fusion, Minimally Invasive Posterior Decompression With or Without Fusion)**

Some authors have tried to prevent postoperative or postlaminectomy kyphosis by laminoplasty or fusion anchored by segmental instrumentation. Posterior decompression without fusion or anterior decompression from a posterior approach without posterior fusion increases risk of kyphotic deformity. These procedures do not address the OPLL plaque. Minimally invasive posterior decompression with or without fusion preserves the posterior tension band. In addition, recent advances in technology have allowed for the direct lateral approach to be used in the lower thoracic spine.

**Case Illustrations**

Institutional review board approval was obtained to review all patients undergoing operative intervention for thoracic myelopathy caused by OPLL.

**Case 1**

This 60-year-old woman had a history of stroke, diabetes mellitus, and hypertension and presented with bilateral lower-extremity weakness and ambulatory difficulty. She had been transferred from an outside facility to our institution for formal evaluation. On examination, she had evidence of bilateral lower-extremity weakness and upgoing toes. The patient had trouble with ambulation, including a fall, thought to be caused by myelopathy. The patient also complained of mild back pain without a radicular component. Magnetic resonance imaging revealed multiple levels of central stenosis with evidence of cord signal change. Computed tomography scanning demonstrated multiple levels of OPLL involving the upper and midtho-
racic spine. The patient was taken to the operating room for T3–9 laminectomy with T2–10 posterior spinal fusion and segmental instrumentation. Postoperatively, the patient did well and maintained stable strength in her lower extremities. The patient was discharged to a rehabilitation center in stable condition 9 days postoperatively (Fig. 1).

Case 2

This 43-year-old woman presented with ambulatory difficulty, back pain, and numbness in her thighs and legs. Additionally, she had evidence of bladder and bowel incontinence. On examination, she had proximal lower-extremity weakness and decreased sensation to light touch and pin prick in the T-11 to L-1 distributions. Magnetic resonance imaging revealed compression of the cord at the upper, middle, and lower thoracic levels with cord signal change. Computed tomography demonstrated that stenosis was related to OPLL at multiple levels. The decision was made to take the patient to the operation room as her symptoms were getting progressively worse. The patient underwent T2–10 decompressive laminectomies with T2–11 posterior spinal fusion and segmental instrumentation in 2 stages. The patient was sent to a rehabilitation facility in stable condition. She required an inferior vena cava filter for development of deep venous thrombosis (Fig. 2).

Conclusions

Thoracic OPLL can present radiographically with complex morphology. The safety of the spinal cord should be at the forefront in deciding the surgical approach for decompression. The ultimate goal provides a subarachnoid space around the spinal cord at the level of OPLL and improvement in the patient’s neurological condition. Although there is much debate regarding the approach for decompression, ultimately, each case is different. Regardless of whether an anterior or posterior approach is performed, the main goals every spinal surgeon attempts to achieve are adequate decompression and maintenance or restoration of stabilization in the hopes of improving long-term neurological outcome.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: McClendon. Acquisition of data: Ganju. Analysis and interpretation of data: Sugrue. Drafting the article: McClendon, Sugrue, Ganju. Critically revising the article: McClendon, Ganju, Koski, Liu. Reviewed final version of the manuscript and approved it for submission: Ganju, Koski, Liu.

References

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32. Tsukimoto H: [A Case report: autopsy of the syndrome of compression of the spinal cord owing to ossification with the spinal canal of the cervical spine.] Nihon Geka Gakan 29:1003–1007, 1960 (Jpn)

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