Ossification of the posterior longitudinal ligament (OPLL) is a complex multifactorial disease process combining both metabolic and biomechanical factors. The role for surgical intervention and choice of anterior or posterior approach is controversial. The object of this study was to review the literature and present a single-institution experience with surgical intervention for OPLL.

Methods. The authors performed a retrospective review of their institutional experience with surgical intervention for cervical OPLL. They also reviewed the English-language literature regarding the epidemiology, pathophysiology, natural history, and surgical intervention for OPLL.

Results. Review of the literature suggests an improved benefit for anterior decompression and stabilization or posterior decompression and stabilization compared with posterior decompression via laminectomy or laminoplasty. Both anterior and posterior approaches are safe and effective means of decompression of cervical stenosis in the setting of OPLL.

Conclusions. Anterior cervical decompression and reconstruction is a safe and appropriate treatment for cervical spondylitic myelopathy in the setting of OPLL. For patients with maintained cervical lordosis, posterior cervical decompression and stabilization is advocated. The use of laminectomy or laminoplasty is indicated in patients with preserved cervical lordosis and less than 60% of the spinal canal occupied by calcified ligament in a “hill-shaped” contour. (DOI: 10.3171/2010.12.FOCUS10283)

Key Words • cervical stenosis • cervical spondylitic myelopathy • ossification of the posterior longitudinal ligament • laminoplasty • corpectomy
Four types of OPLL have classically been described:10,25 1) segmental—confined to the area posterior to the vertebral bodies without crossing the disc spaces; 2) continuous—extending from vertebral body to vertebral body including the disc space and spanning multiple levels; 3) mixed: combined aspects of both segmental and continuous types that maintains some skipped areas; and 4) other: limited to area behind the disc space with some extension to the posterior vertebral body endplate or focal punctate areas of hypertrophy/calcification of the posterior longitudinal ligament.

Although OPLL is the result of multiple processes, there have been numerous studies addressing the genetic and metabolic basis of this disease. While the details of those studies are beyond the scope of this manuscript, there are a few details that bear mentioning. The role of repeated mechanical stress to the cervical spine has been proposed as an agent in the formation of OPLL. Studies looking at the importance of dynamic repeated stress have demonstrated an increase in BMP-2, BMP-4, prostaglandin I2 synthase, and osteoblast specific transcription factors in patients with OPLL compared with those without OPLL.11,12 The increase in these cytokines suggests, as the authors point out, that the mechanical stress induces a biochemical response that leads ultimately to osteogenic induction in the ligament cells leading to OPLL. The importance of this finding with respect to surgical intervention is important to point out in terms of the role of surgical stabilization as opposed to decompression alone.

Matsunagra et al.21 studied the natural history of untreated OPLL and found that 17% of patients who were found to have OPLL without signs of myelopathy went on to progress to the development of myelopathy. Likewise, 64% of patients with signs of myelopathy at the time of presentation who did not undergo surgery experienced neurological deterioration. This clinical study helps to highlight the fact that the development and progression of OPLL is a dynamic process. Epstein2 describes OPLL as part of a continuum that begins with increased vascular fibrosis of the PLL and progresses to focal calcification, proliferation of periosteal cartilage, and ultimately ossification. Early ossification is often seen in patients in the 5th decade of life in the area posterior to the disc space alone, making it difficult to distinguish from degenerative spondylitis. The rate of ossification is variable among different patient groups but Harsh et al.8 found an annual growth rate of 0.67 mm in the anterior-posterior direction and 4.1 mm in the cranial-caudal direction. In another study, Matsu-naga et al.21 confirmed these findings, demonstrating that nearly 20% of patients with untreated OPLL experienced an increase of 2 mm or more in PLL thickness and 86% experienced an increase in the cranial-caudal extent of the disease. Murakami et al.20 likewise report a case of a patient who progressed from asymptomatic segmental OPLL to a mixed-type OPLL as his neurological condition deteriorated, developing myelopathy over the course of 4 years. The progressive nature of OPLL suggests that most patient will ultimately require some sort of surgical intervention.

Surgical Management

Nonoperative management of OPLL is reserved for patients who have few neurological symptoms or for those whose overall medical health precludes them from surgical treatment. Pharmacological pain management with the guidance of multidisciplinary pain specialists is recommended. Nonsteroidal antiinflammatory medications and steroid injections are the mainstays of nonoperative therapy. Unfortunately, despite the inflammatory nature of the disease, there have been few pharmacological advances in the specific antiinflammatory agents designed for OPLL, as compared with other inflammatory disease such as rheumatoid arthritis or ankylosing spondylitis.

Nearly 70% of cases of OPLL involve the cervical spine.5 Most patients with cervical OPLL come to the attention of spine surgeons because of clinical findings of myelopathy, radiculopathy, or both and thus require surgical intervention. The questions that often face the surgeon involve the appropriate surgical approach: anterior versus posterior and decompression alone versus decompression and stabilization. The location of the OPLL, in conjunction with the patient’s clinical symptoms, guides the surgeon in formulating a surgical plan. There are different treatment options available for OPLL of the cervical spine, compared with OPLL of the thoracic or lumbar spine. In the cervical spine, the anterior spinal column is much more accessible and often carries less morbidity than the thoracicotomy that would be required for anterior access to the thoracic spine. Many patients with OPLL harbor other medical comorbidities or are of advanced age such that thoracotomy is not an ideal choice. On the other hand, older patients undergoing multilevel cervical corpectomy have been shown to have an increased rate of significant dysphagia postoperatively. Posterior decompression via laminectomy or laminoplasty is an option at any level of the spine. The need for stabilization is often greater in the cervical spine than in the thoracic spine, the latter being supported by the thoracic cage. However, kyphosis of the thoracic spine may increase the need for instrumented stabilization to minimize the risk of a progressive kyphotic deformity in the setting of a disrupted posterior tension band. There are many factors that influence the surgical plan for OPLL, and in this manuscript we analyze our single-institution experience with surgically treated cervical OPLL.

Methods

After obtaining institutional review board approval, we retrospectively analyzed our own patient experience with cervical OPLL. Individual surgeon case logs and billing records were reviewed for the previous 10 years (2000–2010). We retrospectively identified 18 patients (Table 1) who underwent surgery for symptomatic cervical myelopathy secondary to radiographically confirmed OPLL. The different types of OPLL as classified by Hirabayashi et al.10 were evenly distributed among our patients: continuous in 6, segmental in 6, and mixed in 6. Twelve patients underwent laminectomy and instrumented stabilization (Figs. 1 and 2), 3 patients underwent 2-level corpectomy, 2 patients underwent 1-level corpectomy (Figs. 3 and 4), and 1 patient underwent 1-level corpectomy with adjacent-level anterior cervical disectomy and fusion. Medical record chart review was performed
to obtain both preoperative and postoperative neurological examination status as well as presenting complaints. The type of procedure was recorded as well as findings of pre- and postoperative neurological examinations and follow-up imaging. Any intraoperative or postoperative complications documented in the medical record were also recorded. The average follow-up time was calculated. Any change in neurological examination findings documented in the medical record was recorded.

**Results**

Follow-up data were available in 16 cases. One patient suffered a massive pulmonary embolus 1 month after surgery and died as a result. In another case, there was no record of the patient’s ever returning to clinic after discharge and the patient was thus classified as lost to follow-up. Of the 16 patients for whom follow-up data were available, 31% demonstrated a significant improvement in strength on objective physical examination; 69% remained neurologically stable; and 12.5% experienced some transient weakness in 1 or more muscle groups during the immediate postoperative period. The average duration of follow-up was 9 months (range 1–36 months). There was no radiographic evidence of instrumentation loosening or failure in the short term for any patients 3 months after surgery. There was no evidence of CSF leak.

**Discussion**

When evaluating patients with OPLL, preoperative planning is essential. Careful assessment of the imaging studies includes determining the extent of ossification and the direction of the surgical approach (anterior vs posterior). Diagnostic imaging in OPLL is usually multimodality. Typically, when patients present for neurosurgical evaluation, an MR imaging study has already been performed for evaluation of neck pain or arm pain. The

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**TABLE 1: Summary of demographic and clinical characteristics in 18 patients**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Type of OPLL†</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62, F</td>
<td>continuous</td>
<td>C5–6 corpectomy, C4–7 ASF</td>
</tr>
<tr>
<td>2</td>
<td>60, M</td>
<td>continuous</td>
<td>C5–6 corpectomy, C4–7 ASF</td>
</tr>
<tr>
<td>3</td>
<td>51, F</td>
<td>continuous</td>
<td>C-4 corpectomy, C5–6 ACD, C3–6 ASF</td>
</tr>
<tr>
<td>4</td>
<td>79, M</td>
<td>continuous</td>
<td>C-5 corpectomy, C4–6 ASF</td>
</tr>
<tr>
<td>5</td>
<td>59, F</td>
<td>continuous</td>
<td>C3–7 laminectomy, C3–T2 PSF</td>
</tr>
<tr>
<td>6</td>
<td>86, M</td>
<td>continuous</td>
<td>C4–7 laminectomy, C3–T2 PSF</td>
</tr>
<tr>
<td>7</td>
<td>58, M</td>
<td>mixed</td>
<td>C3–6 laminectomy, C3–6 PSF</td>
</tr>
<tr>
<td>8</td>
<td>84, M</td>
<td>mixed</td>
<td>C3–5 laminectomy, C3–5 PSF</td>
</tr>
<tr>
<td>9</td>
<td>74, M</td>
<td>mixed</td>
<td>C3–7 laminectomy, C3–T2 PSF</td>
</tr>
<tr>
<td>10</td>
<td>59, M</td>
<td>mixed</td>
<td>C4–7 laminectomy, C4–T2 PSF</td>
</tr>
<tr>
<td>11</td>
<td>51, F</td>
<td>mixed</td>
<td>C3–6 laminectomy, C3–6 PSF</td>
</tr>
<tr>
<td>12</td>
<td>42, M</td>
<td>mixed</td>
<td>C4–6 laminectomy, C3–T2 PSF</td>
</tr>
<tr>
<td>13</td>
<td>31, F</td>
<td>segmental</td>
<td>C-6 corpectomy, C5–7 ASF</td>
</tr>
<tr>
<td>14</td>
<td>64, F</td>
<td>segmental</td>
<td>C3–7 laminectomy, C3–7 PSF</td>
</tr>
<tr>
<td>15</td>
<td>68, F</td>
<td>segmental</td>
<td>C3–6 laminectomy, C3–7 PSF</td>
</tr>
<tr>
<td>16</td>
<td>56, M</td>
<td>segmental</td>
<td>C3–5 laminectomy, C3–T2 PSF</td>
</tr>
<tr>
<td>17</td>
<td>42, F</td>
<td>segmental</td>
<td>C5–6 corpectomy, C4–7 ASF</td>
</tr>
<tr>
<td>18</td>
<td>54, M</td>
<td>segmental</td>
<td>C3–7 laminectomy, C3–7 PSF</td>
</tr>
</tbody>
</table>

* There was no CSF leak or postoperative neurological deficit. Abbreviations: ACD = anterior cervical discectomy; ASF = anterior spinal fusion; PSF = posterior spinal fusion.
† As classified by Hirabayashi et al.
appearance of OPLL on MR imaging differs depending on the extent of progression of the ossification process. For example, early OPLL is often confined to the area behind the disc space with some extension to the adjacent vertebral bodies or end plates; in such a case, OPLL appears very similar to spondylosis or disc herniation. Hypertrophied and calcified ligament appears hypointense on unenhanced MR images, but following the administration of gadolinium, ossified PLL enhances. Disc herniations do not enhance. In fact, particularly advanced cases of OPLL will display evidence of fat deposition and signs of bone marrow production. Advanced continuous OPLL may demonstrate the development of a Haversian canal system within the calcified ligament. Wang et al. studied T2 signal intensity ratios between intramedullary areas posterior to compressive ossified PLL compared with the intramedullary signal behind the C7–T1 disc space where there was no compression in patients with myelopathy prior to laminoplasty. They concluded that patients with low signal-intensity ratios had better surgical outcomes than those with high signal-intensity ratios and evidence of pyramidal signs. Given the likely progression of untreated OPLL we advocate for early surgical intervention.

Computed tomography can help to confirm OPLL first suspected on MR imaging; CT can often help to better define the extent of disease seen on MR imaging and identify any foraminal component or the degree of stenosis. Likewise, OPLL in its early stages may be missed on CT sagittal reconstructions and these images should be correlated with axial imaging. Ossification of the ligamentum flavum can also be associated with OPLL and can be seen best on CT. The longitudinal extent and circumferential location of both anterior and posterior ossification and subsequent canal or foraminal stenosis aid in formulating the appropriate surgical plan. CT myelography often helps to define the extent of spinal cord compression and the urgency of surgical intervention. Dynamic flexion-extension imaging can also play a role when the surgeon is considering stabilization. It is important to point out the importance of utilizing CT reconstructions in assessing OPLL to best understand the 3D anatomy of the disease. Chang et al. have demonstrated the increased intra- and interobserver reliability of CT reconstructions compared with plain radiographs or even axial CT alone.

Patient age and medical comorbidities also influence the decision to use an anterior or posterior approach and whether to perform stabilization. Epstein reports that in comparison to stand-alone posterior procedures, anterior procedures produce better short- and long-term improvement in neurological outcomes. The work of Kawano et al. provides support for this notion, demonstrating improved outcomes in the short-term and long-term for patients undergoing anterior corpectomy compared with those undergoing posterior procedures. Anterior decompression of the spine seems to be the definitive surgical approach for a compressive lesion ventral to the spinal cord. However, OPLL can often present as segmental or continuous type of lesion spanning multiple levels. Good results have been reported for 1- and 2-level cervical corpectomies; however, corpectomies of 3 levels or more are fraught with complications including graft fracture, graft pistoning, graft dislodgement, instrumentation failure, and pseudarthrosis. Dalbayrak et al. have introduced the idea of the “skip” corpectomy, whereby the C-5 vertebral body is left intact.
and C-4 and C-6 corpectomies are performed for cervical spondylitic myelopathy and OPLL. They conclude that the C-5 body adds additional stability to the anterior cervical construct and the procedure still provides adequate decompression. The biomechanical complications are compounded by high rates of postoperative dysphagia in patients who have undergone multilevel cervical corpectomy.

Anterior corpectomy has been shown to have significant benefits for these patients, but many surgeons are concerned about the risk of durotomy and postoperative CSF leak due to the adherent ossified PLL and the potential for continued neurological deterioration due to insufficient decompression. In the series reported by Chen et al., only 4 patients suffered a CSF leak, and there was no evidence of neurological decline in patients who underwent anterior corpectomy. The authors conclude that these outcomes are the result of a lack of traumatic manipulation of the spinal cord and protection of the epidural vascular plexus. They used specially designed microdissectors to separate the ossified PLL from the dura and they also used the popular “floating” technique when there was evidence of dural ossification. Hida et al. studied the CT characteristics of patients with OPLL and demonstrated some key findings that help determine the amount of dural ossification and thus the potential risk of durotomy and CSF leak at the time of surgery. They studied 21 patients with radiographic evidence of OPLL and correlated their findings with intraoperative evidence of dural defect. They describe double- and single-layer OPLL. Twelve patients were found to have a double layer of ossification on CT at the level of the thickest ossified PLL and 10 patients were found to have a single calcified layer. Of the 12 patients with double-layer OPLL, 10 of them were found to have dural defects, whereas 9 of the 10 patients with single-layer OPLL had intact dura. Utilizing these findings on preoperative CT can help determine which areas of the ossified PLL should be left in place at surgery. In our experience, calcified ligament can be removed safely. When removing the calcified ligament, one must be careful to dissect in the appropriate plane. That plane can often be found by sliding a blunt nerve hook under the lateral aspect of the ligament. Utilizing the appropriate plane minimizes the risk of neurological injury, CSF leak, and injury to the engorged epidural venous system. In the event that the ligament is adherent to the dura, certain “bone islands” can be left in place. If the area of adherent calcified ligament is totally disconnected circumferentially, then it is unlikely to impose any compression on the spinal cord. Repair of an anterior durotomy can be challenging, particularly in the setting of calcified dura. If a CSF leak occurs it should be repaired immediately. If CSF drains from the thecal sac, the engorged epidural venous plexus will likely bleed significantly, making the procedure even more technically challenging.

Although in our experience anterior decompression and reconstruction can be done effectively and safely for 2-level disease, 3-level corpectomies are often not well tolerated due to postoperative dysphagia as well as the biomechanical challenges of such a large construct. With that in mind, we find that the most important factor in choosing an anterior or posterior approach is cervical lordosis. In particular, patients who lack cervical lordosis may benefit from an anterior approach when possible. In cases in which posterior decompression is required, however, we typically perform a stabilization procedure in our institution due to concern about progression of OPLL as a result of dynamic instability or progression of sagittal deformity. Posterior decompression alone has been shown to accelerate progression of OPLL ventrally. Takatsu et al. demonstrated an increase in the rate of deterioration of patients who underwent posterior decompression alone—laminectomy or laminoplasty—compared with those who did not undergo any surgical intervention for OPLL. Likewise, when the decompression extends to the cervical-thoracic junction, stabilization should extend across the cervical-thoracic junction to T-2 to minimize the risk of a junctional kyphosis.

In the US, most cases of OPLL are treated using a posterior approach, as it can be a less technically than an anterior corpectomy. However, the need for posterior stabilization is controversial. Laminoplasty has been used to achieve posterior decompression while preserving motion, but patients with a straight or kyphotic cervical spine are at risk for progression of cervical kyphosis, and laminoplasty is contraindicated in this population. Patients with reversal of cervical lordosis who undergo laminoplasty have been shown to experience progression of kyphotic deformity as well as progression of ligamentous ossification postoperatively.3,13,17,22

Laminectomy without stabilization or laminoplasty can be an effective surgical option in specific circumstances. Iwasaki et al. have studied long-term outcomes in patients who underwent cervical laminoplasty for OPLL and concluded that the most significant predictors for poor neurological outcome following laminoplasty are “hill-shaped” ossification, lower preoperative JOA score, postoperative change in cervical alignment, and older age at time of surgery. Likewise, they report worse neurological outcomes for patients with an occupying ratio of 60% or greater.

Matz et al. performed a detailed analysis of the literature and concluded that there is Class III evidence to support the use of laminoplasty in cervical spondylitic myelopathy or OPLL. They report 55%–60% JOA score improvement compared with nonoperative therapy. Furthermore, while the most common complication of laminoplasty is the development of a C-5 nerve palsy due to cord shift and nerve root stretch, there is preserved range of motion and Class III evidence of equivalence in functional improvement between laminoplasty, anterior cervical decompression and fusion, and laminectomy with arthrodesis. For our patient population, laminoplasty or laminectomy alone are rarely used due to the concern about progression of OPLL or development of cervical kyphosis. Many patients with OPLL also have DISH. The combination of OPLL and DISH may provide some anterior stability to the construct and thus reduce the risk of developing progressive kyphosis in the setting of laminoplasty or laminectomy. However, we have not had that experience at our institution, and thus all patients with multilevel cervical decompression in the setting of a straight or kyphotic cervical spine also undergo stabilization.
The technique we employ for posterior cervical decompression typically involves an en bloc laminectomy. Using a high-speed drill, bilateral troughs are created at the junction of the lamina and lateral mass or lamina-facet line, thus releasing the lamina from the lateral mass. Once the troughs are drilled, a nerve hook is used to define the epidural space. Disconnection of the osteoligamentous structures is performed by using Kerrison punches to systematically complete the disassociation of lamina from the facets. Similarly, disconnection of the osteoligamentous structures must also be performed at the cephalad and caudal ends to remove the lamina en bloc. This process of removing the ligamentum flavum must be done carefully to avoid any tearing of the dura. Both the ligamentum and the dura may be calcified or adherent to one another. The lamina can later be used as autograft for fusion. Throughout the procedure, the mean arterial blood pressure is maintained above 80 mm Hg to provide appropriate spinal cord perfusion. Instrumentation is typically placed prior to decompression using a modified Magerl technique for placement of lateral mass fixation and the free-hand technique described by Lenke is used for thoracic pedicle screw placement when necessary. Complete arthrodesis of the facet complex is essential to optimize fusion. The use of osteobiologic agents is a controversial topic and is left to the discretion of the surgeon. While osteobiologics can enhance fusion rates in the posterior cervical spine, their use in the anterior cervical spine is not recommended due to the intense inflammatory response generated and the concern for compromising the patient’s airway. The fusion rate in our case series is high and likely on a par with other institutions’ series in large part due to the inflammatory nature of OPLL and high propensity for calcification and fusion.

Overall, the decision to use an anterior or posterior approach is a complicated one involving many factors. In our series, 67% of the patients underwent posterior decompression and fusion. Posterior stabilization is often a less technically demanding procedure that can be done safely and effectively. Chen et al. retrospectively studied radiographic and clinical outcomes in 75 patients with severe OPLL as defined by 3 or more levels of OPLL with at least a 40% compromise of the cervical canal. The patients underwent anterior corpectomy and reconstruction, laminectomy and posterior instrumented stabilization, or laminoplasty. In this study they demonstrated a few important points. First, patients who underwent anterior corpectomy or laminectomy and instrumentation maintained a significantly greater cervical lordosis compared with those who underwent laminoplasty. Also, Chen et al. demonstrated that neurological improvement measured by the JOA scale was significantly greater in patients who underwent anterior corpectomy than in those who underwent laminoplasty. For example, the mean JOA improvement percentage (± SD) for those in the 3 groups was as follows: anterior corpectomy 63.2 ± 15.2, laminectomy and stabilization 43.5 ± 12.7, and laminoplasty 25.1 ± 8.5. None of the patients in the anterior corpectomy group or the laminectomy and fusion group experienced neurological deterioration postoperatively, but 4 of 25 patients who underwent laminoplasty suffered neurological deterioration and progressive kyphotic deformity. The fact that some of the patients in the laminoplasty group experienced worsening neurological deficits helps support the idea that there is indeed an impact from a repeated mechanical stress and potential instability that may contribute to development of OPLL. The patients in this study who underwent instrumented stabilization did not suffer the same neurological decline. Whether the deterioration was from progressive kyphosis or from OPLL progression is not completely clear, but may be due to both processes leading to continued or worsening stenosis/compression. Although the literature suggests improved outcomes for anterior decompression and reconstruction, both groups of patients in our series who underwent anterior or posterior procedures did well neurologically. The decision to use an anterior or posterior approach was based on the number of levels involved, cervical lordosis, medical comorbidities, and patient age.

Conclusions

Ossification of the PLL is a complex multifactorial disease process that requires an understanding of the etiology of the disease as well as the role for surgical intervention. Most patients who present with symptomatic OPLL will eventually require surgery. The natural history of OPLL is that of progressive neurological decline resulting from enlargement of the ossified ligament and resulting stenosis. Clinical myelopathy is further worsened by a dynamic process whereby mechanical stress is transferred into reactive inflammation. The role of surgery is to decompress and stabilize the spine. For patients who demonstrate appropriate lordosis, laminoplasty or laminectomy may be a viable option. However, studies suggest that despite preservation of cervical lordosis, patients with myelopathy secondary to OPLL require stabilization. The decision to use an anterior or posterior approach is left to the discretion of the surgeon. Both anterior and posterior approaches have been shown to be safe and effective in our experience. Due to the ability to create lordosis in the cervical spine, outcomes from anterior decompression and reconstruction have been shown in the literature to be superior to the posterior decompression and stabilization. We have demonstrated successful decompression and fusion from both an anterior and a posterior approach. The choice of which approach to use is based on a number of factors that influence patient outcomes.

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: Sugrue, McClendon, Liu, Koski, Ganju. Acquisition of data: Sugrue, McClendon. Analysis and interpretation of data: Sugrue, McClendon. Drafting the article: Sugrue, McClendon. Critically revising the article: all authors. Reviewed final version of the manuscript and approved it for submission: all authors.

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