Invited Review

Surgical Management of Cervical Myelopathy

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Abstract

Although general consensus exists regarding the need for surgery in patients with cervical myelopathy, there remains considerable debate regarding the optimal approach. Common choices include anterior decompression and fusion, or posterior approaches such as laminoplasty, laminectomy, or laminectomy and fusion. Aside from laminectomy alone, which has proven to be less favorable than its alternatives for a number of reasons, the available literature suggests that any of the other options provide similar rates of neurologic recovery. However, anterior versus posterior approaches come associated with very different sets of pros and cons. Depending on a number of factors -- such as host biology, host bone quality, kyphosis, coexisting axial neck pain symptoms, number of motion segments involved in the genesis of the cord compression, and the desire to either preserve or limit motion – either approach can yield satisfactory outcomes. In general, when cord compression arises from three or less motion segments and any associated kyphosis is mild to moderate, anterior surgery may be preferable. If it arises from three or more segments in the absence of significant kyphosis, laminoplasty may be preferable. If cord compression coexists with significant kyphosis or deformity, anterior and posterior surgery may be necessary. Regardless, the approach chosen must be tailored to the specifics of the individual patient so as to achieve adequate spinal cord decompression, which remains the sine qua non of surgery.

Servikal Myelopatinin Cerrahi Tedavisi

INTRODUCTION

Cervical myelopathy describes a constellation of symptoms and signs arising from cervical cord compression. Because the presentation of the myelopathic patient can be quite subtle in its early manifestations, the diagnosis may easily be missed or wrongly attributed as a “normal” epiphenomenon of aging. However, because the natural history is typically one of stepwise progression (22), early recognition and treatment is essential for optimal outcomes before the onset of irreversible spinal cord damage.

CLINICAL EVALUATION

History

Myelopathic patients present with neurologic complaints whose origin may seem obvious in those who are younger or have had rapid progression, but these symptoms can also mistakenly be attributed to “aging” in those who are older or in whom the symptoms are mild or insidious in onset. Upper extremity symptoms include a generalized feeling of clumsiness of the arms and hands, “dropping things,” inability to manipulate fine objects such as coins or buttons, trouble with handwriting, and diffuse (typically non-dermatomal) numbness. Lower extremity complaints include gait instability, imbalance, and “bumping into walls” when walking. Family members may comment that the patient walks as if he/ she is intoxicated. Patients with severe cord compression may also complain of Lhermitte’s symptoms: electric shock-like sensations that radiate down the spine or into the extremities with certain offending positions of the neck.

Contrary to what the unsuspecting clinician might expect, myelopathic patients often do not present with many of the symptoms commonly attributed to spinal column degeneration. For example, despite advanced degrees of spondylosis, many floridly myelopathic patients have no neck pain. Although radicular complaints such as radiating arm pain may coexist with myelopathy if the patient also has symptomatic nerve root compression, many myelopathic patients have no radicular symptoms or signs despite imaging studies which clearly demonstrate root compression. It is this painless patient who is particularly at risk of going undiagnosed until the myelopathy becomes severe. Many with myelopathy also deny any loss of motor strength until the later stages of the condition. Subtle bowel and bladder symptoms, such as urinary urgency, can be elicited with a careful history, but frank incontinence is relatively rare and typically occurs in the later stages of disease.

Neurologic Examination

A full neurologic examination should be performed, but, just as pain is not a sensitive predictor of myelopathy, neither does a completely normal neurologic exam preclude the diagnosis of myelopathy. The motor exam may be completely normal or demonstrate only subtle degrees of weakness. A careful sensory exam including pin-prick should be performed but again may be normal. The neurologic exam should also include an assessment of gait to test for instability. Bowel and bladder or dorsal column (proprioceptive) dysfunction on exam generally occurs with advanced disease and carries a poor prognosis. Hyperreflexia may be present in the upper and/or lower extremities and is suggestive of spinal cord compression. However, because peripheral nerves must be functioning properly in order to transmit
the hyperreflexia of myelopathy, patients with concomitant myelopathy and peripheral nerve disease from conditions such as diabetes, peripheral neuropathy, or severe multi-level cervical foraminal stenosis can have diminished or absent reflexes. In addition, patients with cervical myelopathy who have coexisting lumbar stenosis may exhibit brisk upper extremity reflexes yet diminished lower extremity reflexes because of the root level compression in the lumbar spine.

Provocative tests suggestive of cord compression can be elicited in the myelopathic patient. The Babinski response and sustained clonus in the lower extremities may be present. The Lhermitte’s sign is positive when certain positions of the neck cause an electric shock–like sensation down the arm, legs, and/or spine. A Hoffman’s sign occurs when flicking the volar surface of the flexed middle finger distal phalanx results in pathologic flexion of the thumb and index finger. An inverted radial reflex is seen when the brachioradialis reflex itself is diminished but causes spastic contraction of the finger flexors instead. The finger escape sign describes the inability to maintain the ulnar digits in an extended and adducted position. Patients with high cervical cord compression may demonstrate the scapulohumeral reflex, in which tapping the tip of the scapula results in brisk scapular elevation and humeral abduction. Because some of these upper motor signs can arise from either brain or cervical spinal cord pathology, one method of determining the etiology of the findings is to perform a jaw jerk test. If this test is positive, such that tapping the lower jaw leads to opening of the mouth, the origin of the upper motor neuron findings may be in the brain rather than the spinal cord.

Differential diagnosis

The most common cause of cervical myelopathy in patients over the age of 50 is spondylosis (degenerative changes), leading to the condition known as cervical spondylotic myelopathy (CSM). Anterior structures, such as bulging, ossified, or herniated discs, as well osteophytic bone spurs, are the usual causes of cord compression in CSM. Degenerative spondylolisthesis of the cervical spine can also exacerbate or cause compression. Less commonly than their anterior counterparts, posterior structures, such as ligamentum flavum hypertrophy or, rarely, ossification of the ligamentum flavum, may also contribute to cord compression.

CSM commonly arises in the setting of a congenitally narrowed spinal canal (Figure 1). In these patients, the cord may have had sufficient space and escaped compression during relative youth until the accumulation of a threshold amount of space-occupying degenerative changes. Although CSM tends to be a disorder seen in the older patient, depending on the degree of congenital stenosis and the magnitude of the accumulated spondylotic changes, it can be seen in patients who are younger as well.

Ossification of the posterior longitudinal ligament (OPLL) is another major cause of cervical myelopathy and will be discussed separately below. Less common causes of cervical myelopathy include various etiologies of cervical cord compression, such as tumor, epidural abscess, osteomyelitis/discitis, and trauma. Kyphosis, whether primary or post-laminectomy, can also cause cord compression and myelopathy. Finally, whenever evaluating patients with myelopathic complaints, it is important to keep in mind a broad differential diagnosis, including non-spinal conditions such as stroke, movement disorders, and multiple sclerosis.

Imaging of cervical myelopathy

Plain radiographs can provide useful information but are not sufficient to diagnose cord compression. Routine evaluation may include upright anteroposterior and lateral, as well as flexion-
extension views. The lateral radiograph can be particularly useful and can be used
to determine the degree of congenital cervical stenosis present. A Pavlov ratio
(AP diameter of canal/ AP diameter of vertebral body) of less than 0.8 is
suggestive of congenital stenosis. In most but not all cases, the disc space(s)
demonstrating the greatest amount of degeneration will turn out to be the ones
associated with the greatest cord compression.

In order to confirm spinal cord compression, advanced imaging in the
form of MRI or CT-myelography is necessary. MRI is noninvasive and
provides sufficient images in the majority of patients. A closed MRI is preferred over
an open study whenever possible because of superior image quality. Signal changes
within the cord may be demonstrated on MRI and are suggestive of severe
compression. If a patient cannot obtain an MRI for medical reasons (e.g., cardiac
pacemakers aneurysm clips, or severe claustrophobia), or if metal or scar from
prior cervical surgery precludes adequate visualization on MRI due to artifact, then a
CT-myelogram may be considered. Although invasive and therefore not the
best screening tests, CT-myelograms provide outstanding resolution of both
bony and neural anatomy for surgical planning. Alternatively, if a high quality
MRI is present but questions remain regarding bony anatomy for the purposes
of surgical planning, a non-contrast CT can provide complementary information. CT
may, for instance, diagnose the presence of OPLL that may be difficult to see on plain
radiographs or conclusively indentify on MRI but which can have a profound effect
on surgical treatment.

**TREATMENT**

Surgery is generally recommended for patients who have both clinical and
radiographic evidence consistent with cervical spondylotic myelopathy, as the
disorder is typically progressive without surgery. Cord compression may cause
myelopathy either by an ischemic effect secondary to compression of the anterior
spinal artery, or by a direct mechanical effect on the cord. Surgical management
has been shown to improve functional outcomes, pain, and neurologic status in
prospective studies of patients with CSM (30). It has also been demonstrated that
early intervention improves ultimate prognosis before permanent damage occurs
within the spinal cord. Therefore, surgery is the treatment of choice for cervical
myelopathy unless the patient is unwilling or unable to have surgery due to
prohibitive medical comorbidities.

It is not so clear, however, how best to
treat patients with imaging evidence of
cord compression but no clinical symptoms
or signs. This scenario can occur, for
example, in patients who underwent
advanced imaging for neck pain or
numbness which then subsequently
resolved. On the one hand, asymptomatic
cord compression may eventually become
symptomatic, particularly if the compression is severe or the patient sustains an injury such as a fall or a car accident. On the other hand, it is possible, especially with milder degrees of stenosis, that the patient may never develop problems. Ultimately, this decision rests in the informed consent of the patient and an understanding of the risks and benefits of surgical versus non-surgical care. Depending on the degree of cord compression or presence of cord signal changes, however, it can be entirely reasonable to recommend surgery even in the absence of symptoms. If non-surgical care is elected in the patient with documented cord compression, careful and frequent follow-up should be performed.

Significant debate exists regarding the best surgical approach for treating cervical myelopathy. There are a number of options, including anterior decompression and fusion, laminectomy, laminectomy and fusion, and laminoplasty. Each approach carries its own set of pros and cons, and there is no one procedure which is clearly favorable in all circumstances. Considerations which may favor one approach versus another include: 1) the number of stenotic levels present; 2) patient factors, such as comorbidities; and 3) desire to either limit or preserve motion.

**Laminectomy with or without fusion**

Laminectomy without fusion for the treatment of cervical myelopathy has a minor role in the modern surgical armamentarium due to its numerous downsides. An often quoted complication associated with laminectomy alone is post-laminectomy kyphosis (Figure 2). Although the true incidence in the adult population is unknown, estimates range from 11-47%. (16,21) Recurrent myelopathy may occur if the cord becomes draped and compressed over the kyphosis, but the incidence of clinically apparent neurologic problems resulting from this complication is unclear (7,8). In addition to potential neurologic sequelae, the kyphosis itself can be a source of neck pain or deformity. If an over-aggressive facetectomy is performed along with laminectomy, spondylolisthesis may develop and contribute to cord compression. Finally, if a patient requires a subsequent posterior operation, the exposed dura over the length of the laminectomy can make the revision more tedious, difficult, and risky to perform.

A posterior fusion can be added in order to avoid the problems seen with laminectomy alone. Laminectomy and fusion is typically performed along with lateral mass screws. Fusion has several potential benefits, including improvement of spondylotic neck pain and prevention of post-laminectomy kyphosis. In addition, moderate degrees of preexisting kyphosis can be improved after laminectomy by positioning the neck in extension prior to securing the instrumentation, although for higher degrees of kyphosis an anterior-posterior approach is generally recommended. Despite advantages over laminectomy alone, the literature has demonstrated that laminectomy and fusion

![Figure 2: Post laminectomy kyphosis. This patient had a prior anterior cervical discectomy and fusion at C6-7. Subsequently she underwent laminectomy C5-6 with development of post laminectomy kyphosis. A spondylolisthesis is also present at C4-5.](image)
is outperformed by alternative procedures. In a non-randomized study of laminoplasty versus laminectomy and fusion \(^{(9)}\), laminectomy and fusion had a trend toward an inferior rate of neurologic improvement based on objective evaluation of the Nurick score as well as patient-reported outcomes. In addition, laminoplasty had a much lower complication rate: fourteen complications arose in thirteen patients in the laminectomy and fusion group, compared with no complications in the laminoplasty group. The majority of complications was fusion related and included nonunion, significant donor site pain, implant failure, and adjacent segment degeneration. In light of these findings, laminectomy and fusion with lateral mass instrumentation may be considered an alternative to anterior surgery in certain myelopathic patients with multilevel myelopathy and severe coexisting mechanical neck pain or mild amounts of kyphosis requiring correction with fusion. However, if fusion is not necessary, laminoplasty may be a better posterior alternative.

Skip laminectomy is a modified procedure that was designed to limit posterior muscle trauma, neck pain, and instability. With this approach, two consecutive stenotic disc levels are decompressed via a standard laminectomy of the lamina between the stenotic levels combined with a partial laminectomy of the lower adjacent vertebra. Thus, a C3-7 decompression can be achieved by total laminectomy of C4 and C6, with partial laminectomies at other levels. At the “skipped” lamina (C3, C5, and C7 in this example), the muscular attachments to the spinous processes are left intact, preventing kyphosis. One study demonstrated similar neurologic outcomes to open door laminoplasty with less postoperative neck pain and better range of motion \(^{(33)}\). However, this procedure should be limited to patients with moderate stenosis or ossification of the yellow ligament, as it may not sufficiently decompress those with severe stenosis, congenital stenosis, or extensive OPLL.

**Anterior decompression and fusion**

The major advantage of the anterior approach for cervical myelopathy is the ability to directly decompress structures most commonly responsible for cord compression (e.g., herniated discs, spondylotic bars, ossification of the posterior longitudinal ligament). Anterior decompression can also directly relieve neural compression resulting from kyphosis by removing the vertebral bodies over which the cord is draped. In addition, the fusion procedure associated with anterior decompression helps to relieve spondylotic neck pain, can improve kyphosis, immobilizes and therefore protects the segment of decompressed cord, and prevents recurrent stenosis from occurring at the fused segments. Excellent neurologic recovery rates have been reported with anterior surgery for myelopathy. \(^{(4)}\)

For myelopathy arising from one or two disc spaces, a one level ACDF, two level ACDF, or a single level corpectomy and fusion (if retrovertebral cord compression exists) will be the treatment of choice for most patients. For patients with stenosis at three or more disc segments, however, the supremacy of an anterior approach, which traditionally involves multilevel corpectomy and reconstruction with a long strut graft, is not so clear cut, particularly in the absence of significant kyphosis or spondylotic neck pain. Although effective in treating neural compression, this approach has been associated with a high rate of graft-related complications. Pseudarthrosis rates after multilevel anterior corpectomy and fusion range from 11-40\% \(^{(1,5,32,35)}\), and rates of graft dislodgement range from 7-20\%. \(^{(18,27,32,45)}\) Although one might suspect that anterior cervical plating might reduce the incidence of graft-related complications in multilevel strut graft reconstructions, clinical series of plated multilevel
corpectomies \(^{(38)}\) have actually had higher graft complication rates than those without plates.\(^{(4)}\) In an early study, graft displacement rates were 9% for a two level corpectomy and 50% in three level corpectomies despite anterior plating \(^{(38)}\). Biomechanical studies suggest that plating a long strut graft construct may be mechanically unfavorable because such constructs rapidly lose stability under fatigue loading \(^{(13)}\) and reverse load transfer through the strut graft \(^{(2)}\). Buttress plating has been advocated as an alternative means of stabilizing long anterior strut grafts while avoiding the undesirable biomechanics of long plated reconstructions. Whereas a spanning plate fixed to the vertebral body above and below a long strut graft can prevent graft settling and thereby act as a “distraction device,” a buttress plate is fixed only at one end of the construct and allows for settling to occur while preventing graft kickout. Although theoretically appealing, buttress plates as stand alone anterior fixation devices have not been exempt from the usual cadre of strut graft complications, such as dislodgment and pseudarthrosis \(^{(27)}\).

Dynamic plates represent another alternative to rigid plate fixation of long strut grafts (Figure 3). Like buttress plates, they also allow for settling to occur but provide greater stability both to the top and bottom of the construct. However, clinical evidence regarding efficacy in stabilizing long strut grafts is currently lacking. Undesired or excessive settling of dynamic plates can potentially lead to plates overlapping and injuring adjacent disc spaces, as well as kyphosis, foraminal stenosis, and construct failure. Another alternative is to avoid plates altogether. Non-plated corpectomies with long strut grafts have shown good clinical results but require cumbersome rigid external immobilization and have been associated with the morbidity of autologous fibular harvest. Supplemental posterior fixation and fusion may be considered if a long anterior strut graft anteriorly is necessary, particularly if the patient has preexisting kyphosis, deformity, or prior laminectomy.

In addition to the graft problems associated with multilevel corpectomy, it is important to keep in mind that all anterior fusion operations carry relatively small but definite risks intrinsic to the anterior approach, such as speech and swallowing disturbance, airway obstruction, esophageal injury, and vertebral artery injury. These risks are probably higher when performing multilevel reconstructions than for a one or two level ACDF due to greater operative times and number of levels exposed. Another potential downside to any fusion procedure is the potential for accelerated adjacent segment degeneration. However, it remains to be determined whether adjacent segment

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**Figure 3:** Dynamic plating. AP radiograph status post multilevel anterior decompression and fusion with dynamic plate. Notice that the holes in the plate are slotted, allowing the construct to settle.
degeneration is truly a by-product of fusion or, rather, a progression of natural history in patients who demonstrate, by virtue of their need for their index cervical surgery in the first place, a propensity towards cervical spine degeneration\textsuperscript{(10)}.

**Alternative anterior corpectomy constructs**

In order to avoid problems associated with long strut grafts, there are several alternative corpectomy constructs that can be done instead if an anterior approach is chosen in the myelopathic patient with multilevel (≥ three disc space involvement) stenosis (Figure 4). These constructs can be used if the pattern and location of the patient’s stenosis are appropriate to the procedure. Multilevel ACDF is one alternative that can be performed if the stenosis is disc-based and retrovertebral decompression is not necessary. Advantages over a single long strut include the ability to achieve better fixation with screw placement into every vertebral body within the construct, as well as better preservation or even recreation of lordosis. ACDF grafts, in comparison to long struts, are also less likely to dislodge. One disadvantage may be a higher pseudarthrosis rate due to the increased number of bony surfaces requiring healing (e.g., six bony surfaces for a three level ADCF from C4-7 versus two surfaces for a two level corpectomy with single strut graft from C4-7), but the literature is not uniform on this point\textsuperscript{(11,29)}.

Another alternative when treating compression arising over three disc levels is to perform a single level corpectomy at two disc levels, then an ACDF at the other level (i.e., corpectomy–discectomy). The corpectomy–discectomy construct represents a compromise solution which avoids the biomechanical issues of a single long strut while decreasing the number of healing surfaces by two versus the equivalent number of ACDFs. Segmental plate and screw fixation can be obtained at every level except for the corpectomy level.

**Figure 4:** Alternative corpectomy constructs. If the compressive pathology allows, alternatives to multilevel corpectomy and single, long strut graft reconstruction strike a compromise between a greater number of healing surfaces required for fusion versus better preservation of lordosis, segmental screw fixation, and avoidance of long strut graft biomechanics. In addition to multilevel ACDF, options include (A) corpectomy-discectomy and (B) double corpectomy constructs.

If the pattern of the compressive pathology does not dictate otherwise, the corpectomy is performed at the upper two levels in order to avoid the mechanical disadvantage of having a corpectomy at the bottom end of the construct, where it would be more likely to dislodge.

A final alternative if the compression spans four disc levels is to perform a double corpectomy, i.e., two single-level corpectomies separated by an intact intervening vertebra. This construct achieves fewer healing surfaces versus the equivalent number of multilevel ACDFs while avoiding long strut graft biomechanics. Fixation is obtained at the top, bottom, and middle of the construct.

**Laminoplasty**

Laminoplasty was designed as an operation to achieve multilevel posterior cord decompression while avoiding problems associated with laminectomy, such as post-laminectomy kyphosis. In the majority of
cases, a C3-7 procedure is performed. There are several ways of performing laminoplasty, but the open door and French door are the most common. The common theme in all types of laminoplasty is the creation of a hinge at the junction of the lateral mass and lamina by thinning the dorsal cortex but not cutting completely through the ventral cortex. In the open door technique, the hinge is created unilaterally; in the French door version, the hinge is created bilaterally. The opening is performed by cutting through both the dorsal and ventral cortices on the opposite lateral mass-laminar junction in an open door procedure, or in the midline with the French door variation. Once the openings have been made, the hinges are cracked open by creating greenstick type fractures. Opening the laminoplasty increases the space available for the spinal cord, which drifts away from anterior compressive lesions into the space created. The “door” can then be held patent with bone (e.g., autologous spinous process or rib allograft), sutures, suture-anchors, or specially designed plates (24). (Figure 5) Laminoplasty was initially designed in Japan, where it has enjoyed a long track record of success and is currently gaining wider acceptance in North America in light of proven benefits. Particularly if the cord is compressed over three or more motion segments (and the greater number of.

**Figure 5:** Laminoplasty. Sagittal MRI (A) demonstrating multilevel cervical stenosis with thickening of the posterior longitudinal ligament consistent with OPLL behind the bodies of C3-5, along with spondylotic bulge at C5-6. This patient had painless cervical myelopathy. Open door laminoplasty with segmental plate fixation (B, C) provided complete relief of spinal cord symptoms without necessitating fusion and preservation of range of motion. Postoperative CT scan (D) demonstrates healed hinge side of the laminoplasty and significant enlargement of the space available for the cord.
motion segments that are involved), the benefits of laminoplasty over anterior surgery seem to outweigh its downsides in the properly selected patient.

In addition to its benefits over laminectomy, laminoplasty possesses several advantages over anterior decompression and fusion. First, because an indirect decompression is performed, it is in general a safer and technically easier operation to perform than multilevel anterior corpectomy, especially in patients with severe stenosis or OPLL that requires resection. Second, laminoplasty is a motion preserving procedure. No fusion is required, but a fusion and instrumentation can be done in association with laminoplasty if needed. Thus, all fusion related complications can be eliminated. Third, laminoplasty allows the surgeon to decompress segments at future risk in one operation without substantially increasing patient morbidity. With a laminoplasty, a C3 to C7 decompression is performed in one operation. In contrast, if a patient had significant stenosis from C4-C6, a surgeon may hesitate to include mildly stenotic levels at C3-4 and C6-7 anteriorly for fear of increasing complications and morbidity, but then leave the patient vulnerable to subsequent disease at those adjacent levels over time. Fourth, a laminoplasty does not preclude a later anterior procedure. If a patient has persistent stenosis after laminoplasty, anterior decompressions can subsequently be directed toward any needed levels. In addition, laminoplasty can be performed as part of a two stage operation in patients requiring anterior and posterior surgery. The extra space for the cord provided by the laminoplasty (which is performed with the neck in a neutral to slightly flexed, canal enlarging position) can make the subsequent anterior decompression (which is performed with the neck in an extended, canal narrowing position) safer to accomplish.

The advantages of laminoplasty have been borne out in head to head clinical trials with multilevel anterior corpectomy, which have demonstrated that laminoplasty and anterior surgery yield similar rates of neurologic improvement, but laminoplasty has a much lower complication rate. Yonenobu (43) compared 42 patients who underwent laminoplasty versus 41 patients who had multilevel anterior corpectomy for cervical spondylotic myelopathy. Neurologic outcomes were similar between the two groups, with both demonstrating good improvement in Japanese Orthopaedic Association myelopathy scores. However, the laminoplasty group demonstrated a significantly lower complication rate than the corpectomy group (7% versus 29%). The majority of complications in the corpectomy group were graft related. In the laminoplasty group, the only complications were three cases of C5 root paresis, all of which resolved with observation. Similar results were seen in a North American study (3). Despite its benefits, laminoplasty is certainly not a perfect operation, is not appropriate in all cases, and does have its share of disadvantages. Segmental root level palsy remains a potential concern, with reported incidences ranging from 5-12% (37). It usually affects the C5 root, resulting in deltoid and biceps weakness, but other roots can also be affected. The palsies are generally motor-dominant, although sensory dysfunction and radicular pain are also possible. The problem may arise at any point postoperatively, from immediately to 20 days later (37), complicating what otherwise appeared to be a successful spinal cord decompression. Recovery usually occurs over weeks to months in the majority of patients, but has been reported to take up to 6 years (31).

Neck pain can also be an issue in patients who have had laminoplasty. First, it must be understood that because no arthrodesis is performed, laminoplasty is not a procedure that should be undertaken with the intent to treat a patient’s painful spondylosis. Understanding that fact, controversy remains as to whether the neck pain associated with laminoplasty reflects
new-onset postoperative symptoms or simply persistent preoperative spondylotic pain. On the one hand, Hosono (12) found postoperative axial symptoms in 60% of open door laminoplasty versus 19% of anterior fusion patients, a significant difference. 75% of those reporting postoperative neck and shoulder pain in the laminoplasty group had new onset pain. In contrast, Yoshida (44) found that French door laminoplasty had no effect on either the development or resolution of axial neck and shoulder symptoms. The exact etiology for postoperative neck pain after laminoplasty is unclear, but may be related to stiffening of the facet joints or denervation and injury to the nuchal musculature. As noted above, however, because pain is often not a major issue in the myelopathic patient preoperatively, it usually remains a relatively minor issue postoperatively, particularly if patient expectations have been appropriately aligned preoperatively.

Another limitation of laminoplasty is the potential for loss of motion, despite the fact that it is considered to be a “motion-sparing” procedure. Even when laminoplasty is performed without fusion, some loss of motion can occur. The cause may be multifactorial but may include facet joint injury with spontaneous stiffening or fusion, or alterations in tissue and muscle elasticity after posterior surgical exposure. Prolonged postoperative immobilization may also contribute to the problem. In addition, placing bone graft along the hinge side to assist in healing of the hinge may lead to undesired intersegmental fusion or stiffening, and is neither recommended nor necessary. One study demonstrated less loss of motion with early cervical mobilization and avoiding bone grafting of the hinge (40). The patient with preoperative kyphosis presents a relative contraindication to laminoplasty. As most of the compressive structures that lead to cervical myelopathy, such as disc herniations, spondylotic bars, and OPLL, arise anteriorly, laminoplasty and other posteriorly-based procedures for spinal cord decompression rely on the ability of the cord to drift away from the anterior lesions as a result of releasing the posterior structures (laminae, ligamentum flavum). Although drift back reliably occurs in a lordotic or neutral cervical spine, it may not occur in the setting of significant kyphosis. However, the absence of lordosis is not an absolute contraindication to laminoplasty. Suda et al. reported that laminoplasty could be performed with acceptable neurologic recovery when the local kyphosis measured 13 degrees or less(34). Furthermore, in kyphotic patients who also have compressive lesions arising posteriorly, laminoplasty may also achieve a direct decompressive effect despite kyphosis.

Combined anterior and posterior surgery
Combined approaches are strongly recommended in patients with post-laminectomy kyphosis. In this setting, if a multilevel corpectomy is performed in order to decompress the cord, an extremely unstable biomechanical environment results, as the right and left sides of the spine become disconnected from each other (26). Likewise, in patients with significant kyphosis or deformity requiring multilevel anterior decompression, supplemental posterior fixation and fusion should be considered to optimize fusion rates, prevent implant pullout, and maintain deformity correction.

OSSIFICATION OF THE POSTERIOR LONGITUDINAL LIGAMENT (OPLL)
OPLL is another cause of cervical myelopathy, although this diagnosis is not as common as CSM (Figure 6). Although OPLL related myelopathy has mainly been described in Japan and the prevalence in the North America population is not known, the disorder is not limited to the Asian population. The cause of OPLL remains unclear, but is most likely multifactorial and related to genetic, hormonal, and environmental influences. Various
factors have been implicated, including diabetes, obesity, a high salt and low meat diet (41), poor calcium absorption (36), mechanical stress on the posterior longitudinal ligament; and even sleep habits (42). OPLL has been noted in approximately 50% of patients with diffuse idiopathic skeletal hyperostosis (DISH) (25) and may be related to a predilection for ossification. There also appears to be a familial basis to the disorder, but the exact mechanism of inheritance is not clear. In Japan, epidemiologic studies have demonstrated a 44% prevalence of OPLL in siblings of patients with known OPLL (28). More specifically, biochemical studies have linked OPLL to a variety of molecular factors, including estrogen (39), collagen XI (19), transforming growth factor beta-1 (15), BMP-4 (6), and nucleotide pyrophosphatase (17).

Depending on the severity of OPLL and the amount of associated cord compression, patients may be completely asymptomatic or have severe myelopathy. The pattern of ossification can be segmental, continuous, localized to the disc space, or mixed. As with cervical spondylotic myelopathy, OPLL is typically a surgical disorder. However, surgeons planning to operate on OPLL must take into account two unique variables not usually encountered when treating spondylotic myelopathy. The first variable is that, depending on the amount and extent of OPLL, direct resection via an anterior approach may be more difficult than in the spondylotic myelopathy patient. OPLL can sometimes erode through the dura, leaving dural deficiencies with attempts at removal. If preoperative imaging is suggestive of dural ingrowth or erosion, one way to avoid troublesome dural tears is to allow the adherent OPLL to float anteriorly after corpectomy without necessarily removing it (20). Another approach is to perform interbody fusion only without decompression. This procedure has been suggested for the patient with dynamic myelopathic symptoms and has been reported to have surprisingly good results (23), but advocates of this approach are few. The rationale for this approach is that by immobilizing and fusing the stenotic areas, repeated trauma to the cord by the ossified mass can be avoided. A final means of achieving cord decompression without resection of OPLL is to take a posterior approach instead and perform a laminoplasty.

However, posterior approaches which avoid OPLL resection introduce the second unique variable in surgical management of OPLL versus spondylotic myelopathy: namely, the potential for growth of OPLL postoperatively. Anterior approaches with floating of OPLL or complete excision have been touted to avoid postoperative growth of OPLL (20), in contrast to studies of posterior procedures which report a tendency towards radiographic enlargement of OPLL postoperatively. Thankfully, OPLL growth postoperatively may be more of a theoretical than practical issue, as the occurrence of recurrent myelopathy from this cause has been rare (14,16). Progressive longitudinal growth of OPLL may lead to stenosis at adjacent segments that have not been decompressed, but typically does not cause recurrent stenosis at levels that have been
decompressed. It may be that the extensive enlargement of the spinal canal via laminoplasty is sufficient to keep the cord decompressed as long as growth of OPLL remains modest.

As is the case for CSM, the optimal surgical procedure for OPLL remains to be determined. The same general guidelines govern the choice of approach in OPLL as in CSM. However, if the OPLL is severe, a posterior approach may be preferable and safer, regardless of the number of stenotic levels involved.

CONCLUSION

Cervical myelopathy is typically considered to be a surgical disorder. Early treatment before the onset of permanent cord injury is recommended. For patients with myelopathy arising from one or two disc segments, the anterior approach is generally preferred. If three or more motion segments are involved, variables such as significant kyphosis or substantial spondylotic neck pain may steer the surgeon to choose an anterior approach. If anterior surgery is chosen in this setting, consideration should be given to alternative corpectomy constructs which achieve the goals of anterior surgery while minimizing the graft-related complications associated with long strut grafts. In other patients with three or more disc space involvement, laminoplasty may be a better option over anterior surgery because it results in fewer complications with equivalent rates of neurologic recovery, particularly in patients with minimal spondylotic neck pain, no or mild kyphosis, and in whom fusion is undesirable or difficult to achieve due to poor healing potential or severe osteoporosis. In patients with multilevel stenosis and kyphosis, or those with post-laminectomy kyphosis, a combined anterior-posterior approach may be best. Regardless of the approach chosen, the surgical procedure must be tailored to the patient’s specific pattern of stenosis, comorbidities, and symptoms, and strict adherence to an algorithmic protocol cannot be relied upon.

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