Poster cervical decompression and fusion is a commonly performed surgery used to treat neurologic compression and spinal instability. Cervical laminectomy, once popular, has diminishing utilization as a stand-alone procedure secondary to its potential to lead to kyphotic deformity and recurrent symptoms (Fig. 10-1) (8,9). Early attempts at stabilization after laminectomy with wiring constructs were fraught with difficulty, required rigid postoperative orthoses, and had a poor capacity to maintain correction. Modern lateral mass and pedicle screw instrumentation has, however, enabled stable reconstruction of the unstable spine even after laminectomy. These newer stabilization techniques are simpler to implement and safer, have better clinical results, and decrease the need for postoperative orthoses when compared with prior methods of fusion.

**INDICATIONS**

Posterior laminectomy and fusion is indicated when posterior decompression is required for the treatment of spinal cord compression syndromes in combination with instability or kyphotic deformity. Most commonly, this is for the treatment of cervical spondylotic myelopathy associated with degenerative spondylolisthesis or kyphotic deformity. Other conditions include intradural pathology (e.g., spinal cord tumor) needing to be accessed and the potential for the creation of iatrogenic instability (22,31). In some cases of traumatic central cord syndrome requiring decompression, fusion is added if there is concomitant discoligamentous injury (Table 10-1).

There is currently no consensus on the definition of cervical instability. Although rigid radiographic criteria for cervical instability have been proposed, including more than 3.5 mm of subluxation and 11 degrees of angulation on dynamic x-rays (28), more broadly encompassing definitions are often cited. White and Panjabi defined clinical instability of the spine as the loss of the spine’s ability to maintain its patterns of displacement under physiologic loads so there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain (27). Broader definitions such as this extend the indications for fusion to patients with significant axial neck pain and/or deformity who do not present with mobile listhesis.

In cases of cervical spondylotic myelopathy, it is postulated that both motion and compression are contributors to the myelopathic process (30). As such, a fusion may be more strongly considered for this indication. A recent systematic review of the literature did suggest that there is strong evidence to support the utilization of cervical laminectomy and fusion in the treatment of cervical spondylotic myelopathy (1). In cases of cervical kyphosis, fusion should be performed with a goal of reestablishing at least neutral alignment. Irreducible kyphosis may be better treated through an anterior or combined approach.

Advantages of a posterior approach over an anterior approach include surgeon familiarity, ease of exposure, shorter operative times, and reduced risk of dysphagia and recurrent laryngeal nerve palsy (14). Patients with multilevel disease are particularly well suited for posterior approaches as well as patients with ossification of the posterior longitudinal ligament (OPLL), who are at greater risk for complications, including cerebrospinal fluid (CSF) leak and neurologic injury, with an anterior approach (1). The disadvantages of the posterior laminectomy and fusion approach are
the limited area for bone graft placement, need for costly instrumentation, and higher risk of infection.

CONTRAINDICATIONS

Posterior decompression and fusion is contraindicated as a stand-alone procedure in cases of significant anterior compressive pathology or in patients with irreducible kyphosis. Relative contraindications include patients at particularly high risk for infection (e.g., s/p radiation, malnutrition, prior posterior approach) who may be adequately treated through an anterior approach.

<table>
<thead>
<tr>
<th>TABLE 10-1 Indications for Posterior Cervical Fusion</th>
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<tr>
<td><strong>Instability</strong></td>
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<tr>
<td>• &gt;3.5-mm subluxation or &gt;11-degree angulation</td>
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<tr>
<td>• Inability to maintain patterns of displacement under physiologic loads so there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain</td>
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<tr>
<td>• Unstable traumatic injury pattern</td>
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<tr>
<td><strong>Cervical myelopathy with kyphosis or loss of lordosis</strong></td>
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<tr>
<td><strong>Cervical myelopathy with neck pain</strong></td>
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<tr>
<td><strong>Iatrogenic instability</strong></td>
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<tr>
<td>• Tumor resection</td>
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<tr>
<td>• Adjacent level disease</td>
</tr>
<tr>
<td><strong>Augment long (&gt;3 level) anterior constructs</strong></td>
</tr>
<tr>
<td>• Tobacco users</td>
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<tr>
<td><strong>Pseudoarthrosis treatment</strong></td>
</tr>
</tbody>
</table>
TECHNIQUE

Anesthesia

The anesthesiologist must be made aware of the nature of the patient’s condition. In cases with significant canal stenosis, specific anesthetic considerations include intubation, positioning, and hemodynamic support, each of which may compromise the patient’s neurologic integrity. Intubation should be performed with in-line stabilization of the neck, and we recommend consideration of awake endotracheal intubation. This has the advantage of allowing for confirmation of neurologic stability after endotracheal tube placement. Care should be taken to avoid neck hyperextension in patients with significant stenosis, as this may contribute to further canal narrowing and neurologic injury. In myelopathic and significantly stenotic patients, careful monitoring of blood pressure is essential, and intra-arterial lines for continuous blood pressure monitoring are routinely used. We maintain a mean arterial pressure of greater than 85 mm Hg to ensure cord perfusion. The use of multimodal neural monitoring is controversial and may allow for early recognition of neurologic injury (21). Similarly, the use of steroids to prevent spinal cord deterioration is controversial and unproven but is an option in patients with severe spinal stenosis or with neurologic deficits.

Positioning

Patients are typically placed in Mayfield 3-point fixation to provide stable positioning without the risk of ocular pressure. Alternatively, patients may be positioned on a padded horseshoe with Gardner-Wells tongs to provide distraction. Care must be taken to ensure that the weight of the head is not resting on the eyes when utilizing this method.

After placement of pins, the patient is rotated into the prone position onto padded gel rolls, a Wilson frame, or the Jackson table. A Jackson table is preferred for obese patients, as it allows for greater decompression of the abdominal compartment and subsequently less venous hypertension and potential for blood loss (Fig. 10-2). A vertical footboard is used to prevent downward sliding when inclining the bed, and the position of the head is fixed. The bed is placed in a reverse Trendelenburg position to aid venous drainage and reduce intraoperative bleeding. However, maintenance of mean arterial pressure after positioning is essential to prevent cord ischemia. Hyperextension is avoided in stenotic patients, as this reduces canal diameter and may predispose to injury. The head is typically positioned in a slight “military tuck” position, with the head flexed and the neck somewhat extended.

FIGURE 10-2
Patient positioned prone in 3-point Mayfield fixation on a Wilson frame. Note reverse Trendelenburg inclination of the bed, which enables the cervical spine to be positioned level to the floor and above the level of the heart, facilitating anatomic recognition and venous drainage, respectively.
to increase exposure but maintain cervical lordosis. The arms are secured by the patient’s sides, and the shoulders are taped slightly inferiorly to aid in x-ray visualization of lower cervical levels.

Once secured, fluoroscopy can be used to demonstrate adequacy of positioning and maintenance of alignment if alignment is a concern. If neural monitoring is used, signals are rechecked after final positioning.

**Exposure**

The incision is marked utilizing landmarks, with the C2 and C7 spinous processes easily palpable in most patients. Intraoperative radiographs can aid in planning incisions for small operations.

A midline incision is created and dissected to the fascia with electrocautery. The midline avascular raphe is exploited to minimize blood loss. A self-retaining retractor is placed to maintain exposure when the spinous processes are encountered. Electrocautery is used to create a paramedian fascial incision on either side of the bifid processes. The paraspinal muscles are then elevated off the spinous process and lamina in a subperiosteal fashion, using a Cobb elevator to hold retraction and electrocautery to separate tissue adhesions and maintain hemostasis. Care is taken to avoid damaging the interspinous ligaments, particularly at the cephalad and caudal ends of the planned construct (24). Care is also taken to preserve the joint capsules of the facets at the distal ends of the planned construct. After final exposure, levels are confirmed radiographically. Unless absolutely required for adequate decompression, the nuchal ligaments attachments to C2 and C7 should be preserved or repaired to avoid the development of postoperative kyphosis.

**Decompression**

The laminectomy can be performed primarily with rongeurs. The cephalocaudal limits of the decompression are demarcated by using a Leksell rongeur to remove the supraspinous and interspinous ligaments. Likewise, these ligaments are removed at each level to be decompressed to facilitate processing of local autograft. Laminectomy can then be performed using a combination of Leksell and Kerrison rongeurs. In cases of severe stenosis, a “no touch technique” (no canal intrusion with instruments) should be employed. In this case, the lamina-facet junction is identified and marked with the marking pen, and a high-speed burr is used to osteotomize the lamina at the lamina-facet junction bilaterally. The trough is cut through the outer cortical and cancellous layers of bone. The final thin inner cortical bone can be removed with a 1-mm Kerrison rongeur or diamond burr under continuous irrigation. The floating lamina is then carefully elevated off the dura with the aid of an angled curette to separate adhesions between the ligament and dura (Fig. 10-3). Epidural bleeding may be brisk, especially in patients with highly stenotic canals, but this is usually easily controlled with bipolar electrocautery and topical hemostatic agents. Care should be taken to extend the laminectomy to the medial edges of the pedicle to ensure complete decompression. When possible, avoid removing the spinous processes of C2 and C7 as the nuchal ligaments attach at these sites and compromise of the integrity here may contribute to the development of a kyphotic deformity. Partial laminectomy of the cranial aspect of C7 may allow sparing of that level with adequate decompression of the C6–C7 interspace. Another alternative, which is not covered in this chapter, is to combine laminoplasty and posterior fusion (Fig. 10-4).

If foraminal stenosis is causing radiculopathy, foraminotomies may be performed. It is helpful to begin the foraminotomy with palpation of the pedicle and neural foramen with a nerve hook. This not only allows identification of the exact location of the foramen but also gives the surgeon an idea of the degree of stenosis present. A high-speed burr is then used to remove the medial half of the facet articulation overlying the foramen, leaving only a thin shell of bone dorsal to the nerve (Fig. 10-5). A small (1 or 2 mm) Kerrison is then used to access the foramen and remove the remaining bone. The nerve root is visualized, and the decompression of the foramen is confirmed with a nerve hook. Removal of more than 50% of the facet should be avoided at levels not to be fused, as this may lead to instability (31). A good rule of thumb is not to remove the facet past the lateral margin of the pedicle. The utility of a prophylactic C5 foraminotomy to reduce the risks of C5 palsy is controversial and not routinely performed by the authors (17).

**Fusion**

An optimal fusion environment is created by minimizing motion and preparing an optimal fusion bed. The former is supported by instrumentation, and the latter is supported by thorough decortication and facet preparation.

Modular screw and rod-based constructs offer the greatest immediate stability in the cervical spine. Lateral mass screws are most commonly used from C3 to C6 with pedicle screws being commonly implemented at C2 and C7. Although lateral mass screws can be placed at C7, long
The laminectomy can be performed with rongeurs or in an en bloc fashion. An en bloc fashion may be safer in severely stenotic canals and is illustrated here. **A:** Trough is created at the junction of the lamina and lateral mass on either side using a high-speed burr and a “no touch” technique. Completion of the trough may be complete with a 1-mm Kerrison rongeur to minimize canal intrusion. **B:** The laminae are removed en bloc. Adhesions between the ligament and dura are anticipated and taken down with a sharp curette. Additionally, epidural bleeding can be significant but is easily controlled with topical hemostatic agents and gentle bipolar electrocautery.

**FIGURE 10-4**
Posterior cervical fusion can be combined with other techniques, such as laminoplasty. **A:** This patient presented with myelopathy, multilevel cervical stenosis, and spondylolisthesis.
FIGURE 10-4 (Continued)

B: The spondylolisthetic level was treated with a fusion, while the remaining areas of stenosis were decompressed with a laminoplasty.

constructs ending with lateral mass screws may have a higher failure rate, and consideration should be given to pedicle screw fixation at this level. Additionally, long constructs ending at C7 are associated with a significant risk of adjacent level degeneration and may be reasonably extended across the cervicothoracic junction, typically to T1 or T2. Pedicle screws may be placed from C3 to C6, although this technique is technically demanding and involves greater risk of vertebral artery injury than lateral mass screws.

FIGURE 10-5

A: Schematic showing area of bone to be removed to perform a foraminotomy. Care must be taken to remove less than 50% of the facet articulation at levels not to be fused. B: Final foraminotomy with observation of the decompressed nerve root.
We create the pilot holes for lateral mass screws before decompression as landmarks are more easily identified and the risk to inadvertent trauma to the exposed dura and spinal cord is lessened (Fig. 10-6). The decompression however is performed prior to screw insertion, decortication, and bone grafting. Where pedicle screws are placed, the pilot holes can be made after decompression, which allows for direct palpation of the pedicle to assure proper placement.

The placement of lateral mass screws requires identification of the borders of the lateral mass. The cephalad and caudal borders are defined by the articulations, the lateral is the palpable lateral edge of bone, and the medial border is defined by the transition point of the lateral mass and lamina. Usually, there is a valley or depression at this point. With the borders identified, the quadrilateral surface of the lateral mass can be divided into four equal quadrants from which to base screw trajectory. Based on technique, we identify and mark our screw entry point with a match-head burr.

Numerous lateral mass screw trajectories have been described with the Magerl, Roy-Camille, and Anderson methods being most commonly utilized. We use that described by Anderson and mark our screw entry point at the cephalocaudal midpoint approximately 1 mm medial to the center point of the lateral mass. After the starting point is created, a power drill is used to create a prospective tract approximately 30 degrees cranially and 20 degrees laterally (Fig. 10-7). These angles can be closely

FIGURE 10-6
Intraoperative photo showing exposure and placement of screw pilot holes. Lateral mass pilot holes are created prior to decompression to protect the spinal cord and facilitate anatomic recognition of trajectory. All tracts are marked and placed in quick succession to minimize mediolateral variability and thus maximize ease of rod insertion.

FIGURE 10-7
Figure showing lateral mass screw entry point and trajectory. No slightly medial of center entry point and cephalocaudal angulation in line with the facet articulation. Lateral angulation can be approximated by leaning the drill guide against the intact spinous process.
approximated by leaning the drill on the next caudal spinous process. Further clarification of the cranial angle can be obtained by removing the articular cartilage of the joint with a high-speed burr over the dorsal half of the joint and directly observing their angulation. We use a high-speed drill with a K-wire in lieu of a standard fluted drill bit as we feel that smooth edges of the K-wire may lessen the chances of neurovascular injury. We also use an adjustable drill guide set at progressively greater depths to reduce the risk of “plunging” during this portion of the procedure. A 12-mm length is initially used and increased in 2-mm increments until the ventral cortical surface is breached. Abutment of the drill against the ventral cortex can almost always be felt, but a ball-tipped probe can be used to confirm depth if there is any uncertainty. Bicortical screw purchase increases the risk of neurovascular injury and is typically reserved for long fusions and cases in which there is significant osteopenia or deformity. All screw trajectories are created in a similar fashion. It is helpful to place a ball-tip probe down the first tract created to allow that trajectory to be emulated for adjacent and contralateral screws. It is also helpful to create trajectories on a single side in fairly rapid sequence, maintaining positional alignment of the drill as each tract is created. Again, for extended fusions, marking each entry point prior to drilling ensures that each screw is uniformly placed and eases rod insertion.

If a laminectomy is to be performed, we pack the pilot holes with a hemostatic agent (Gelfoam and thrombin). Following decompression, the screws are placed, and a rod is bent to conform to the cervical alignment and secured with set screws. The pullout resistance of cervical instrumentation is relatively weak, and care must be taken when attempting to persuade the rod to the screw tulips. If deformity correction is to be attempted, thought should be given to pedicle screw placement or bicortical lateral mass screw placement. Reduction of kyphosis is obtained by changing head position into extension after decompression, lordotic rod bending, and rod compression. The latter may create foraminal stenosis, and care must be utilized.

**Fusion Bed Preparation**

Preparation of the fusion bed is critical for maximizing the chances of a bony fusion. A high-speed drill is used to remove the facet capsule and decorticate the proximal facet articulation at each level to be fused. The facet capsule and cartilaginous endplates are removed. The dorsal aspect of the facet is also decorticated.

Autograft obtained from the laminectomy site is the preferred grafting material, although allograft and a number of synthetic bone substitutes are available. Graft is placed within the facet joint and dorsally over the lateral mass. Iliac crest autograft may be considered in patients at a high risk of nonunion and when there is insufficient local bone. The bone graft must be stable so that it does not migrate medially toward the neural elements. Prior to closure, a lateral radiograph is obtained to assure proper alignment and placement of instrumentation.

**Closure**

The wound is thoroughly irrigated prior to closure. We place 1 g of vancomycin powder in the paraspinal muscles, which has been shown to significantly reduce the risk of surgical site infection after instrumented posterior fusion (23). The wound is closed in layers, with care taken to tightly reapproximate the nuchal ligaments to the spinous processes of C2 and C7. Staples are used for the skin closure, and a sterile dressing is applied. A closed drainage system is typically used.

**PEARLS AND PITFALLS**

In our opinion, the major neurologic risk occurs during intubation and positioning. Collaboration with an experienced anesthesiologist is essential. Since cord compression results in ischemia, maintenance of mean arterial blood pressure of at least 85 mm Hg during the entire procedure is critical.

When an extended construct is planned, it is helpful to mark all screw entry points with a marking pen prior the creation of trajectories. This ensures that all screws will be aligned in a similar coronal plane and facilitate rod placement.

When performing decompression in highly stenotic canals, no instrument larger than a 1-mm Kerrison rongeur should be placed into the canal. The use of a “no touch” technique with a diamond burr should be considered, but constant irrigation must be employed to reduce the risk of thermal injury.

Lateral mass screws are generally safe as long as proper identification of the starting point and screw direction is considered. Marking the starting point with a burr prevents lateral migration and subsequent poor purchase. Angulation upward and outward avoids root and vertebral artery injury, respectively.
Using a K-wire instead of a traditional fluted drill bit may be used to create pilot holes and may be less prone to neurovascular injury as there are no cutting edges to grab sensitive structures. Decorticating the facets joints prior to screw placement can aid in identifying the facet angle and facilitate placement of lateral mass screws with the correct sagittal angle.

Placement of pedicle screws is demanding. We recommend placement of a pedicle screw at C7 because of its superior biomechanical characteristics and increased safety when compared with other cervical levels. Prior to placement, the pedicle dimension is evaluated on the preoperative imaging studies, and attention is paid to the location of the vertebral artery by looking for the presence of a flow void on T2-weighted MRI sequences. In approximately 10% of cases in which the artery is present in the foramen at C7, placement of a pedicle screw may be reconsidered. Fluoroscopic visualization is often difficult here, but the trajectory can be clarified by creating a small laminotomy and palpating the pedicle with a nerve hook. The tract is then created in parallel to the C7 endplate and angulated approximately 20 degrees medially with a blunt-tipped pedicle finder. The tract is then tapped, and the screw is placed as outlined above.

Avoid removing the spinous processes and lamina of C2 and C7 to avoid postoperative kyphosis. Decompression around this lamina can usually be achieved by undercutting the lamina.

**POSTOPERATIVE MANAGEMENT**

The use of a rigid external orthosis is at the surgeon’s discretion but is typically not employed by the authors for short (one- or two-level) constructs. Alternatively, a soft collar may be used for comfort, although use should be limited to prevent deconditioning. In longer constructs and in those with a higher risk of failure (e.g., osteopenic patients, deformity corrections, fusions extending across the cervicothoracic junction), a cervical orthosis is recommended. Patients are mobilized the day of surgery and instructed to avoid heavy lifting and pulling activities.

Pain control relies on a combination of narcotic pain medications and antispasm medications. NSAIDs are avoided for 6 due weeks to their potentially deleterious effects on bone healing (12). Likewise, smoking cessation is encouraged (5).

**COMPLICATIONS**

Complications related to posterior decompression and fusion may be grouped as operative or delayed.

**Operative Complications**

*Neurologic Injury*: Spinal cord deterioration is a devastating complication and occurs in 3% to 5% of patients with significant preexisting myelopathy as these patients have ischemic spinal cords at baseline. Techniques to reduce this include care in intubation, positioning, and resuscitation. Extending the stenotic spine reduces canal diameter and may predispose to injury. Neural monitoring may provide early warning of this complication although outcomes may not be influenced (21). In rare cases, the laminectomy must be performed with the patient in a flexed position prior to reestablishing cervical lordosis. Mean arterial blood pressures are maintained above 85 mm Hg to aid spinal cord perfusion.

*C5 nerve root palsy* occurs with a frequency of approximately 7% to 10% and has had a number of proposed etiologies and risk factors (18). Increased rates have been correlated with the use of a diamond burr, which may result in thermal injury to the nerve unless properly cooled. Decreased rates of this complication have been reported with prophylactic C5 foraminotomy (17).

*Radicular injury* has been reported to occur at a rate of less than 1% due to screw placement (26). Several anatomic studies have examined the safety of various techniques with differing results (15,29). Regardless of the method used, safer trajectories may lie parallel to the facet joint and with maximal lateral angulation (15).

*Vascular Injury*: Vertebral artery injury with lateral mass screw placement is rare (10) and may be avoided by assessing the location of the transverse foramen and vertebral artery on preoperative studies. With typical anatomy, vertebral artery injury can be avoided with proper lateral trajectory.

*Spinal Fluid Leak*: Dural tears may occur with greater frequency in patients who are elderly, are highly stenotic, have ossification of the ligamentum flavum, or have had prior surgeries. Primary closure of durotomies should be attempted. In rare cases, when this is not feasible, an onlay patch and a dural sealant may be utilized. In these cases, consideration should be given to lumbar drainage for 3 days postoperatively to reduce CSF leakage at the dural injury site.
Delayed Complications

Infection: Surgical site infections occur in 1.5% to 4% of all patients undergoing posterior decompression and fusion (19,25) but may be as high as 20% in high-risk individuals, such as the elderly and those being treated for trauma or malignancy (2,13,20). Risk of surgical site infections may be reduced with the administration of preoperative antibiotics, frequent intraoperative irrigation, and utilization of powdered vancomycin (3,4,23). No benefit has been shown with the utilization of more than one dose of postoperative antibiotics (7).

Pseudoarthrosis: Pseudoarthrosis rates have been reported to range from 3% to 9% (10,11). After laminectomy, the area available for bone grafting is small, and thus, careful attention must be paid to thorough decortication and autograft packing of the facet joints. Risk factors for pseudoarthrosis include smoking, age, use of allograft bone, and greater number of levels fused.

Deformity: Cervical laminectomy, particularly when performed over multiple segments or at C2 or C7, may predispose to the development of late deformity. Kaptain et al. (8) reported a 21% incidence in the development of cervical kyphosis after laminectomy for the treatment of cervical spondylotic myelopathy, with the risk being greater in those patients with reduced preoperative cervical lordosis. Kato et al. (9) reported a 47% risk of progression of kyphotic deformity in patients treated with laminectomy for OPLL. Laminoplasty or fusion may decrease the incidence of deformity (1). The addition of a fusion should mitigate this complication; however, where to end the fusion in relation to the decompression is not fully known. Our approach is to extend the fusion past the levels of decompression to avoid adjacent segment kyphosis although some surgeons will fuse and decompress at the same levels. In general, we also recommend extending the fusion across the cervicothoracic junction.

RESULTS

Neurologic improvement after laminectomy and fusion for myelopathy occurs in 70% to 95% of patients, with a recovery averaging approximately 50% of preoperative JOA deficit (1,6,16). Success of bony fusion has been sporadically reported and is incompletely documented but appears to be higher with modern screw and rod-based constructs. Likewise, prevention of long-term deformity is also incompletely described but is likely reduced with modern instrumentation.

RECOMMENDED READING
