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Cervical Myelopathy: Diagnosis, Contemporary Treatment, and Outcomes

Andrew S. Zhang, MD,[a] Christopher Myers, BS,[b] Christopher L. McDonald, MD,[a] Daniel Alsoof, MBBS,[a,b] George Anderson, BS,[b] Alan H. Daniels, MD[a,b]

[a]Department of Orthopaedic Surgery, Warren Alpert Medical School, Brown University, Providence, RI; [b]Warren Alpert Medical School, Brown University, Providence, RI.

ABSTRACT

Cervical myelopathy is a clinical syndrome caused by compression of the spinal cord between the levels of the C1 and T1 vertebrae. Its clinical presentation can mimic other degenerative and neurological pathologies, making diagnosis challenging. Diagnosis is confirmed with appropriate imaging studies carefully correlated with history and physical examination. Treatment options are focused on decompression of the spinal canal from an anterior, posterior, or combined anterior and posterior surgical approach depending on the location of compression and patient factors. Outcomes are favorable if treatment is performed prior to severe symptom onset.

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CLINICAL FEATURES

Cervical myelopathy is a clinical syndrome describing dysfunction of the cervical spinal cord secondary to extrinsic compressive forces. It is the most common cause of spinal cord impairment in adults and is most often secondary to spondylotic degeneration of the cervical spine. Several clinical syndromes may present in a similar manner including syringomyelia, Chiari malformation, normal pressure hydrocephalus (NPH), spinal cord tumor, epidural abscess, amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), Parkinson disease, tabes dorsalis, hereditary spastic paraplegia and tropical spastic paraparesis, and degenerative joint disease.

Cervical myelopathy is sometimes a difficult condition to diagnose due to its highly variable clinical presentation. Depending on the location of the compression, symptoms can include pain in the neck, shoulders, and arms, sensory deficits, motor weakness, and bladder dysfunction.[1] Involvement of the dorsal column medial lemniscal (DCML) pathway can result in diminished sensation of vibration and proprioception. If the spinothalamic pathway is affected, patients can experience reduced sensation of pain and temperature (Figure 1).

Patients with cervical myelopathy may also experience upper extremity lower motor neuron dysfunction (myeloradiculopathy) due to nerve root compression, presenting as weakness and diminished reflexes with associated atrophy due to compression of the anterior horn. In comparison, upper motor neuron dysfunction often presents with hyperreflexia and increased tone because these nerve fibers travel in the corticospinal tracts at the level of the cervical spine. Most commonly, patients report gait impairment due to a constellation of diminished sensation and inadequate motor function.[2] This impairment is often characterized as a broad-based, ataxic gait. The symptom that most commonly prompts patients to seek medical attention is diminished ability to perform fine-motor tasks such as buttoning their clothes or using their cellular phones for the same reason.[3-5] Some patients experience exacerbation of their symptoms or a lightning-strike-like pain with neck flexion, which is referred to as Lhermitte sign (Table 1). Patients may demonstrate other pathologic reflexes such as the Babinski sign, Hoffman sign, inverted radial reflex,

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Requests for reprints should be addressed to Alan H. Daniels, MD, 1 Kettle Point Ave, East Providence, RI, 02914.

E-mail address: alan_daniels@brown.edu

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finger escape sign and may also demonstrate clonus of the lower extremities.

The onset and severity of these symptoms are invariably progressive in nature, although progression can occur over long periods of time, often misleading patients to attribute their symptoms to normal aging. Symptoms often advance in a stepwise fashion, where patients will experience a decline in baseline function, followed by a plateau period where they maintain their new level of functionality. Patients will then experience another decline in functional status followed by another plateau period. Unless spinal cord decompression is performed, this pattern will continue to occur until severe weakness or paralysis manifests. However, this presentation may still be confused for normal aging, leading to an average of a 6.3-year delay in seeking treatment.[4] According to a cohort study by Clarke and Robinson[6] with 120 patients with cervical myelopathy, 75% had a stepwise decline in function, 20% had gradual decline, and only 5% experienced symptoms with prolonged remission afterward. Early identification of cervical myelopathy is critical so that surgical intervention can halt symptomatic progression.

CLINICAL SIGNIFICANCE

- Surgical management is usually recommended for cervical myelopathy to decompress the spinal canal. Techniques include an anterior, posterior, or combined approach.
- There is no consensus supporting a superior surgical approach, and selection is based on patient factors.
- Most patients improve after surgery, and patients with the most severe symptoms experience the largest improvements.
- Patients should be offered early surgical intervention to prevent symptom progression and improve their baseline symptoms.

GRADING SYSTEMS

Different systems have been developed that attempt to grade the severity of myelopathy, help guide the timing of operative intervention, and study outcomes. One of the most used scoring systems is the modified Japanese Orthopedic Association (mJOA) score, which was adapted from the JOA score to remove the ability to use chopsticks and replaced with the ability to eat with a spoon for more global applicability (Table 2). Classically, patients have been characterized as having mild (score ≥15), moderate (score 12-14), or severe (score <12) cervical myelopathy based on their mJOA score. In contrast, both the Nurick and Ranawat scoring systems provide brief and general scoring systems based on a stepwise progression of overall functional debilitation (Tables 3 and 4).

IMAGING

Although cervical myelopathy is a clinical diagnosis, correlating presenting features with structural abnormalities

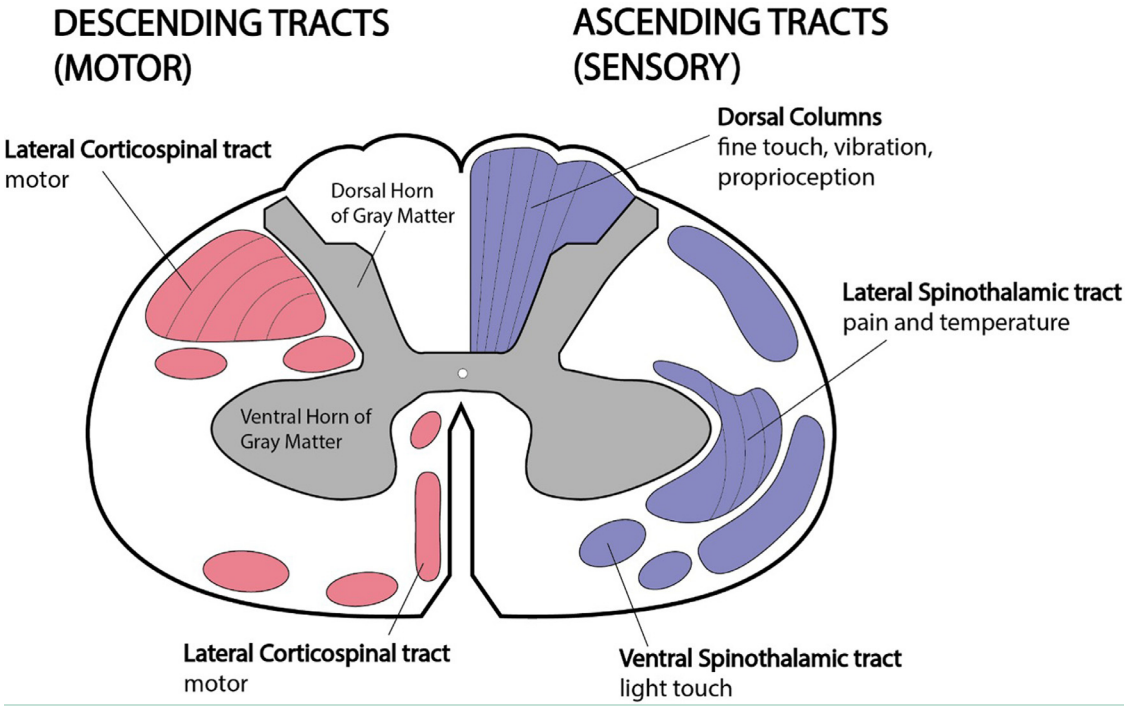

Figure 1 Schematic representation of a cross section of the spinal cord. Relevant ascending (sensory) and descending (motor) tracts are depicted in their appropriate spatial orientation, along with their associated functions.

Table 1 Common Presenting Symptoms for Cervical Myelopathy

Cervical Myelopathy Presenting Symptoms
Nondermatomal numbness of arms > legs
Gait disturbance (spastic, broad-based gait)
Hand clumsiness (difficulty holding objects or performing fine-motor activities)
Upper extremity radicular symptoms (including Lhermitte phenomenon)
Neck pain and stiffness
Leg stiffness Urinary difficulties (retention and incontinence)

found on imaging is crucial for operative planning. Plain anteroposterior (AP) and lateral radiographs of the cervical spine can assess osseous changes including sclerosis, osteophytes, and instability. They can provide insight into overall alignment of the cervical spine and can elucidate the presence of congenital stenosis. Dynamic radiographs (flexion and extension lateral images) can provide additional information regarding cervical motion and stability. Computed tomography (CT) of the cervical spine can provide additional information about ossification of the posterior longitudinal ligament (OPLL), ossification of the ligamentum flavum (OLF), or other sites of compression that may be responsible for the patient's symptoms.

Magnetic resonance imaging (MRI) is the imaging study of choice to visualize spinal cord changes (Figure 2A). With T2-weighted imaging, cerebrospinal fluid (CSF) appears hyperintense anteriorly and posteriorly to the spinal cord (Figure 2B). In areas of spinal cord compression, there will be loss of this surrounding fluid (Figure 2C). In some cases, there can be hyperintensity of the spinal cord itself on T2-weighted imaging, indicative of myelomalacia. These changes can represent localized disease but have not consistently been found to correlate with prognosis.[7,8] However, T1 hypo-intensity may correlate with irreversible disease and worse outcomes.[9] Diffusion tensor imaging (DTI) has preliminarily been used to capture severity of myelopathy as well.[10]

In situations in which obtaining an MRI is not feasible, most commonly due to implanted metallic hardware (such as pacemakers) that is not MRI-compatible or metallic debris such as retained needles or bullets, computed tomography myelography with intrathecal administration of contrast dye can help evaluate sites of compression within the spinal cord (Figure 3). The dye will appear more radiodense in contrast to the spinal cord and may serve as an equivalent to the high signal of the cerebrospinal fluid surrounding the low-signal spinal cord typically seen on MRI.

It is important to interpret imaging within the context of clinical presentation. There is a surprisingly high incidence of cervical imaging abnormalities in older patients.[11] In a study of asymptomatic patients older

Table 2 The Modified Japanese Orthopedic Association (mJOA) Score for Cervical Myelopathy

Category	Score	Description
Upper Extremity Motor Subscore (/5)	0	Unable to move hands
	1	Unable to eat with a spoon but able to move hands
	2	Unable to button a shirt but able to eat with a spoon
	3	Able to button a shirt with great difficulty
	4	Able to button a shirt with mild difficulty or other mild fine-motor dysfunction (marked handwriting change, frequent dropping of objects, difficulty clasping jewelry, etc.)
	5	Normal hand coordination
Lower Extremity Subscore (/5)	0	Complete loss of movement and sensation
	1	Complete loss of movement; some sensation present
	2	Inability to walk but some movement
	3	Able to walk on flat ground with walking aid
	4	Able to walk without walking aid but must hold a handrail on stairs
	5	Moderate to severe walking imbalance but able to perform stairs without handrail
	6	Mild imbalance when standing or walking
	7	Normal walking
Upper Extremity Sensory Subscore (/3)	0	Complete loss of hand sensation
	1	Severe loss of hand sensation or pain
	2	Mild loss of hand sensation
	3	Normal hand sensation
Urinary Function Subscore (/3)	0	Inability to urinate voluntarily (requiring catheterization)
	1	Frequent urinary incontinence (more than once a month)
	2	Urinary urgency or occasional stress incontinence (less than once a month)
	3	Normal urinary function

Table 3 The Nurick Scoring System for Cervical Myelopathy

Grade	Findings
0	Signs or symptoms of root involvement but without evidence of spinal cord disease
1	Signs of spinal cord disease but no difficulty in walking
2	Slight difficulty in walking that does not prevent full-time employment
3	Difficulty in walking that prevents full-time employment or the ability to do all housework
4	Able to walk only with someone else's help or with the aid of a frame
5	Chairbound or bedridden

than 64 years of age, MRI revealed disc herniation or bulge in 57%, spinal cord impingement in 26%, and cord compression in 4%.[12] Imaging alone is not sufficient to diagnose cervical myelopathy because it must be paired with a patient's clinical presentation and functional status to appropriately guide treatment.

Table 4 The Ranawat Scoring System for Cervical Myelopathy

Class	Deficit
Class I	No neural deficit
Class II	Subjective weakness, dysesthesias, and hyperreflexia
Class IIIA	Objective weakness and long-track signs; patient remains ambulatory
Class IIIB	Subjective weakness and long-tract signs; patient no longer ambulatory

TREATMENT

Conservative Management

Given the progressive nature of cervical myelopathy, surgical management is usually recommended over nonsurgical measures due to the risk of continued clinical decline as well as the increased risk of catastrophic neurologic injury with minor trauma in cases of spinal cord compression. Cervical immobilization in the form of a collar or brace, limiting high-risk activities, and strengthening exercises have

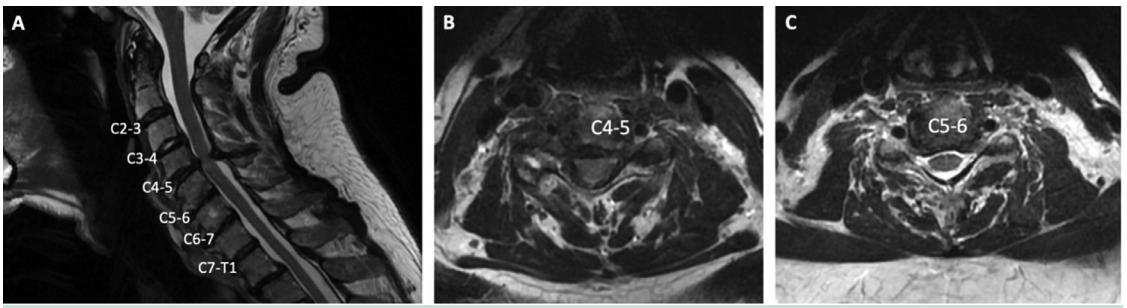

Figure 2 T2-weighted MRI of the cervical spine. **(A)** Sagittal cross section representation of cervical spine, with pathology at the C4-5 level, causing stenosis and impingement of the spinal cord. There is evidence of subtle edema at this level of the spinal cord. **(B)** Axial cross section at the C4-5 level, demonstrating loss of surrounding CSF, and with stenosis both anteriorly and posteriorly about the spinal cord. **(C)** Axial crosssection representation of the cervical spine at C5-6 level of the same patient, with hyperintense CSF circumferentially around the spinal cord, without significant stenosis. CSF = cerebrospinal fluid; MRI = magnetic resonance imaging.

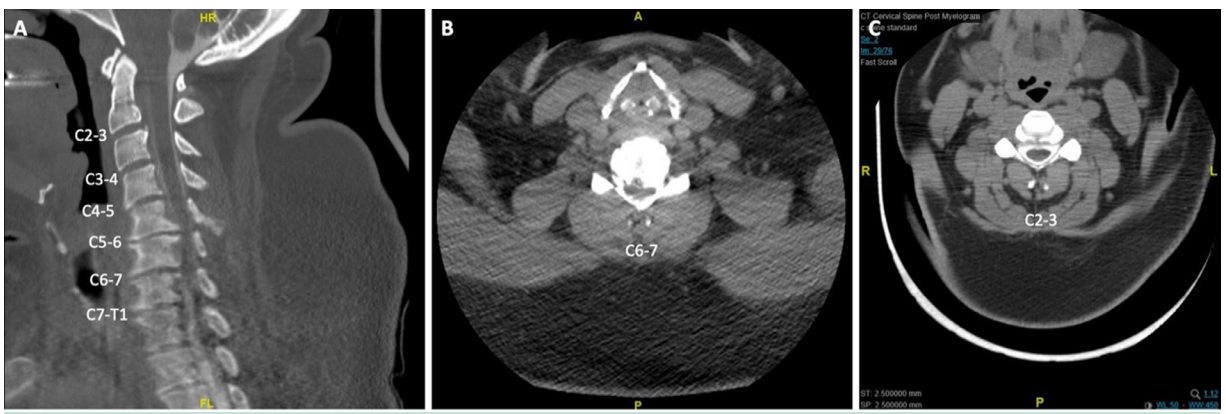

Figure 3 CT myelogram of the cervical spine with contrast dye injected into the thecal sac prior to CT imaging. Sagittal cuts **(A)** demonstrate loss of cervical lordosis with multiple level degenerative changes as well as severe canal stenosis with posterior osteophyte formation at C6-7. Axial cut at the level of C6-7 **(B)** demonstrating critical canal stenosis with complete effacement of contrast dye, which can be compared to an axial cut at C2-3 **(C)** demonstrating minimal stenosis with dye apparent circumferentially around the spinal cord. CT = computed tomography.

been attempted, but there is little evidence to support their use. These options would be advised only in patients who defer surgery or have mild symptoms with risk factors that make them poor surgical candidates. In these patients, guidelines from the spine surgery community recommend counseling patients on the possibility of progression of their disease, as well as regular neurologic examinations to detect these changes.[13,14]

Surgical Management

For most symptomatic patients, referral to a spine surgeon for consideration of surgical decompression is indicated to address the offending agents that are responsible for mechanical compression of the spinal cord. Although one of the main goals of surgery is preventing symptom progression, recent data has shown that patients will usually experience at least some degree of functional improvement after decompression for cervical myelopathy, and patients with more severe symptoms will often experience the greatest improvement in function.[15-17]

There are several operative approaches to alleviate spinal compression based on the specific individual's pathology (Table 5). Anterior surgeries include anterior cervical discectomy and fusion and cervical disc arthroplasty. Posterior approaches include laminoplasty, laminectomy with fusion, and skip laminectomy. A combined anterior and posterior approach may be used when there is marked kyphosis (especially postlaminectomy kyphosis) and when there is extensive pathology requiring multilevel anterior cervical decompression and fusion requiring posterior supplemental fusion.

The main consideration in surgical planning is the determination of the location of the pathology to obtain an adequate decompression of the spinal cord. Additionally, certain patient factors may also dictate the surgical approach. Some select patients may be ideal candidates for motion-preserving procedures such as a cervical disc arthroplasty or laminoplasty. Elderly patients are often more susceptible to postoperative issues with dysphagia, and therefore, anterior approaches may be avoided to circumvent these potential complications. Prior injuries to the vocal cords or esophagus, or cervical radiation treatment may also preclude an anterior approach. A patient's specific anatomy may also make access to the upper or lower cervical vertebra difficult through an anterior approach. Conversely, a muscle-splitting posterior approach may invoke more postoperative pain and prolong recovery. However, the main principle of cord decompression must be accomplished to alleviate or halt the progression of the patient's symptoms.

Table 5 Surgical Options for the Treatment of Cervical Myelopathy Based on Surgical Approach.

Surgical Options for Treatment of Cervical Myelopathy
Anterior Approach
Anterior cervical discectomy and fusion (with or without corpectomy)
Cervical disc arthroplasty
Posterior Approach
Laminoplasty
Laminectomy with fusion
Skip laminectomies
Combined Approaches
Anterior cervical discectomy and fusion with posterior laminectomy and fusion

Cervical Disc Arthroplasty. Although cervical disc arthroplasty (CDA) has been available since the 1960s, the modern CDA is a relatively new anterior approach for cervical myelopathy that was first introduced in 2007. It has become popularized for younger patients because it has been touted as a motion-sparing technology, which may decrease the rate of adjacent level degeneration and an alternative to fusion. A full decompression is performed, and the prosthesis is inserted (Figure 4).

CDA is most commonly performed at 1 level; however, certain devices have been approved for 2-level spondylosis as well. Contraindications to CDA include 3 or more levels of spondylosis, significant facet degeneration, allergy to implant materials, prior surgery at the surgical level, and osteoporosis. CDA has been shown to improve functional outcomes using the Neck Disability index and Short Form (SF)-36 as far as 10 years postoperatively.[18,19] Complications unique to CDA include heterotopic ossification and vertebral body osteolysis from prosthetic wear. Complications associated with the anterior approach include hoarseness, dysphagia, and hematoma. The most common complication of CDA is heterotopic ossification, but the incidence has not been well studied. Estimates range between 7% and 69% of cases, and 1 systematic review has asserted it is not clinically significant.[20]

Anterior Cervical Discectomy and Fusion. Anterior cervical discectomy and fusion (ACDF) has long been the workhorse to address ventral pathologies. After discectomy, a static implant or graft is inserted into the disc space to achieve a solid fusion. Along with an ACDF, a corpectomy can also be performed, which is where the entire vertebral body is removed along with the disc spaces (Figure 5).

Corpectomy can allow access to pathology behind the vertebral body, which would not otherwise be accessible through a normal ACDF approach, allow for a larger anterior column reconstruction, and decrease the number of bony surfaces that need to fuse in certain patient populations. Compared with laminectomy and fusion, 1 meta-analysis found that ACDF with or without corpectomy had approximately half the complication rates.[21] Another study that examined laminoplasty compared to ACDF found that ACDF had fewer postoperative complications with similar long-term benefits.[22]

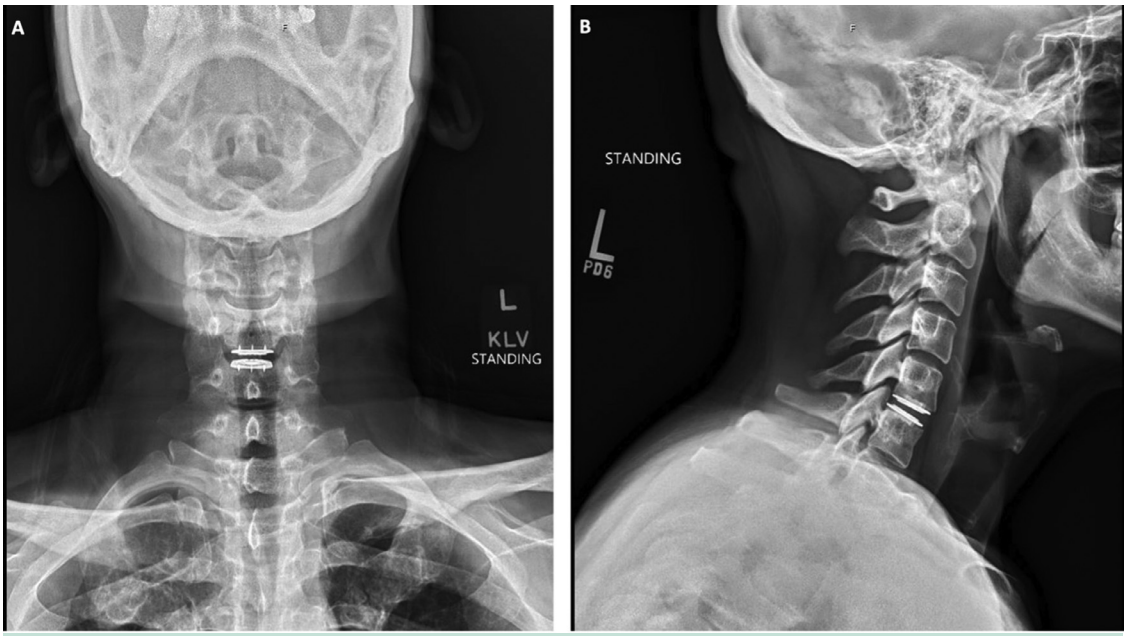

Figure 4 Anteroposterior **(A)** and lateral **(B)** radiographs showing example of cervical disc arthroplasty for cervical myelopathy.

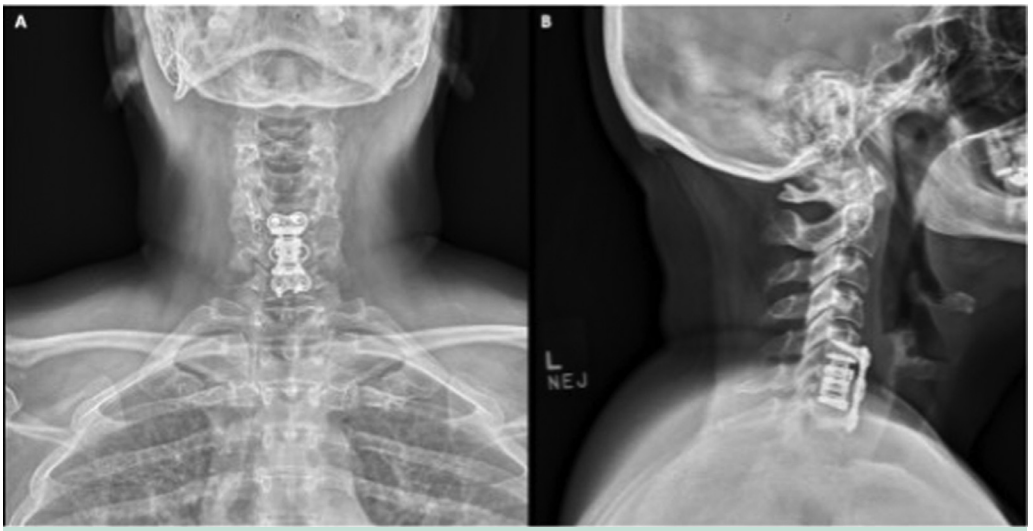

Figure 5 Anteroposterior **(A)** and lateral **(B)** radiographs of an example of an anterior cervical discectomy and fusion with corpectomy and cage reconstruction.

Laminoplasty. Cervical laminoplasty is a posterior-based surgical procedure that spares the lamina and decompresses the spinal cord by enlarging the spinal canal at the compressed levels. There are multiple techniques for laminoplasty. The open-door laminoplasty involves expanding the spinal canal by making a complete osteotomy through the lamina on 1 side, while hinging the posterior arch at the lamina-facet junction on the other side. The gap between the lamina and facet may then be kept ajar with a variety of implants based on surgeon preference (Figure 6).

Outcomes of laminoplasty at 10 years show preservation of neurologic improvement.[23,24] Patients younger than 60 years old seem to benefit most from the procedure. When compared to ACDF, JOA recovery rates were statistically equivalent, with comparatively preserved range of motion, and lower rates of dysphagia and dysphonia.[25,26] Complications unique to the posterior approach include C5 nerve palsy and axial neck pain. C5 nerve palsy occurs in approximately 5%-10% of posterior cases and consists of deltoid and biceps brachii weakness, as well as sensory deficits in the C5 dermatome. Symptoms tend to resolve within 1 year of operation, with most patients experiencing resolution within 4.1 months.[27] Similarly, axial neck pain is a common concern following surgery.[28] One study demonstrated that at 2-year follow-up, 32% of patients reported significant postoperative neck pain.[29] Hosono et al[30]

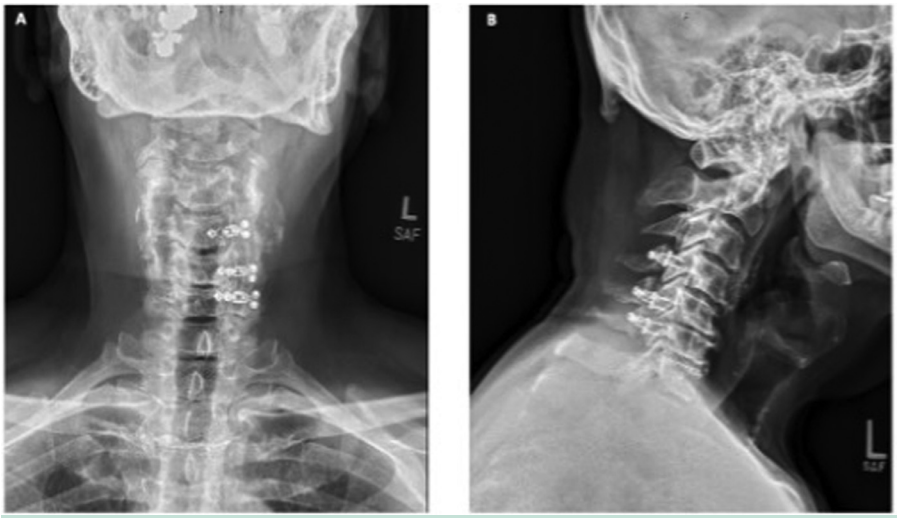

Figure 6 Anteroposterior **(A)** and lateral **(B)** radiographs of an open-door laminoplasty with use of plate and screw constructs to maintain the hinged lamina.

showed that 26% of patients experienced axial neck pain as their chief complaint 3 months postoperatively but continued to improve up to 1.5 years postoperatively. Other complications include loss of range of motion, loss of lordosis, and inadequate decompression.

Laminectomy with Fusion. A laminectomy with fusion is another posterior-based surgical procedure. However, in this approach, the lamina is completely removed to fully decompress the spinal cord. Laminectomies can be performed at any level deemed necessary by the surgeon based on symptoms and preoperative MRI. Screws with rods are then placed in the segments where the lamina have been removed to prevent instability (Figure 7).

The surgeon may also decide to instrument above or below the area of decompression as needed if there is any evidence of instability. Due to the increased rigidity of the fused segment, adjacent segment disease either above or below the levels fused may also occur. One retrospective review found that laminectomy with fusion had higher rates of postoperative morbidity, mortality, and readmission compared to ACDF or laminoplasty.[31] Another study noted that compared to laminoplasty, laminectomy with fusion had a higher rate of C5 nerve palsy as well as cervicalgia.[32]

Skip Laminectomy. A skip laminectomy is a posterior cervical surgery that attempts to minimize soft tissue damage and provide a more controlled decompression

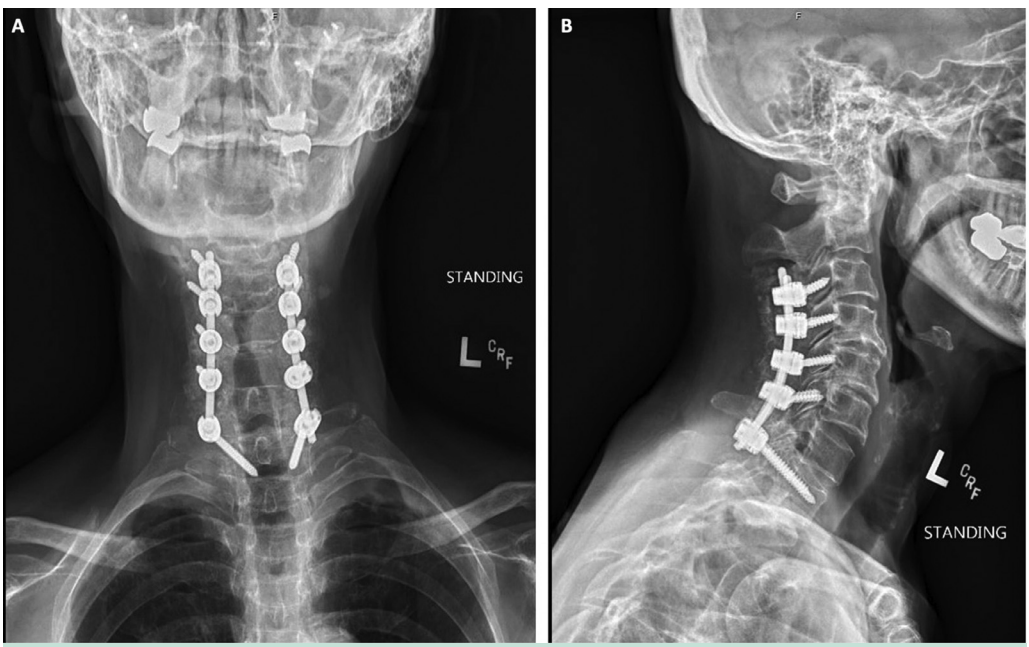

Figure 7 Anteroposterior **(A)** and lateral **(B)** radiographs of posterior cervical decompression and fusion procedure for treatment of cervical spondylotic myelopathy.

compared to other posterior-based surgical decompressions. This procedure was described in 2002 where full laminectomies were performed at some levels, whereas at other levels with less stenosis, only partial laminectomies of the cephalad part of the inferior lamina was undertaken and the ligamentum flavum was also removed to decompress the spinal cord while still leaving muscular attachments to the spinous processes intact.[33] Although concerns about adequacy of decompression remain, there are mixed reports regarding rates of axial neck pain, range of motion, and impact on muscle mass compared to laminoplasty.[33,34]

OUTCOMES

In certain circumstances, nonoperative management of cervical myelopathy can be recommended. However, this is generally deferred due to the likely clinical deterioration. A review of the literature by Karadimas et al[35] found that 20%-60% of patients with myelopathic experience progression of symptoms if left untreated, and a systematic review by Rhee et al[13] in 2013 found little evidence to support nonoperative management of symptomatic moderate to severe cervical myelopathy. However, nonoperative treatment may be appropriate for mild myelopathy in poor operative candidates. Updated guidelines by Fehlings et al[14] in 2017 corroborate these recommendations. In a recent prospective study by Martin et al[36] in which 117 patients were followed conservatively for a mean of 2.5 years, they found that 57% and 93% of newly diagnosed and recurrent myelopathic patients, respectively, experienced progression of symptoms during this time.

With the various approaches to address multilevel spondylotic cervical myelopathy, Lawrence et al[37] found comparable outcomes and safety profiles between anterior versus posterior approaches. In a multicenter study Fehlings et al[38] found that anterior and posterior surgeries for cervical myelopathy had equal efficacy in several patient-reported outcome measures following surgery, but those that underwent anterior surgery tended to be younger with less severe and more focal disease. Asher et al[39] compared patients who underwent anterior versus posterior surgeries through the Quality Outcomes Database and found that those patients who had anterior surgery had shorter length of stays, but otherwise did not demonstrate significant differences in patient reported outcomes, 90-day readmission, or return-to-work rates. In a recent randomized clinical trial, Ghogawala et al[40] studied 163 patients who underwent multilevel ACDF or a posterior surgery, consisting of laminectomy and fusion or laminoplasty. They found that Short Form-36 physical component summary scores did not differ between the 2 groups at 1-year follow-up.

Without level 1 evidence supporting a superior surgical approach for the treatment of cervical myelopathy, surgeons should continue to choose their operative strategies based on patient factors and anatomy. Surgery for moderate to severe myelopathy is generally recommended because of the improved functional outcomes following surgical intervention.

Traditionally, patients had been counseled that they may not get any functional improvement from operative intervention. However, more recent literature has challenged that traditional school of thought. One study examining 1963 patients with 12-month follow-up after surgery for cervical myelopathy found that most patients experienced improvement in symptoms, and 37% of patients improved enough to move down in myelopathy severity based on the mJOA scoring system (eg, from severe myelopathy preoperatively to mild or moderate myelopathy postoperatively).[39] Other studies have supported these findings and demonstrated that an overwhelming majority of patients will improve after surgery for myelopathy, and patients with the most severe symptoms will experience the largest improvements and continue to improve over long-term follow-up.[16,17] Even select patients with mild cervical myelopathy will experience meaningful improvements, prompting a paradigm shift to offer earlier operative intervention to patients with myelopathy not only to prevent further symptom progression but also to improve their baseline symptoms, which can be quite debilitating.[15]

CONCLUSION

Cervical myelopathy is the most common cause of spinal cord dysfunction in adults. Appropriate diagnosis is crucial to prevent further clinical decline. Surgical treatment options are available based on specific patient factors, with substantial evidence to suggest improved outcomes with surgical intervention, especially for moderate to severe disease.

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