Invited Review

Cervical spondylotic myelopathy: A two decade experience

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Context: Cervical myelopathy occurs as a result of compression of the cervical spinal cord. Symptomatology includes, but is not limited to, pain, weakness, paresthesias, or gait/balance difficulties.

Objective: To present a two-decade experience with the management of cervical myelopathy.

Methods: Literature was reviewed to provide current guidelines for management as well as accompanying clinical presentations.

Results: Surgical decompression, if necessary, may be achieved from either an anterior, a posterior, or a combined anterior-posterior (AP) approach. The indications for each approach, as well as the surgical techniques, are described.

Conclusion: Several etiologies may lead to cord compression and cervical myelopathy. The best vector of approach with regard to anterior versus posterior surgical intervention is still under investigation. Regardless, management via surgical decompression has been demonstrated repeatedly to improve the CSM patients' quality of life.

Keywords: Cervical myelopathy, Anterior cervical decompression and fusion, Posterior cervical decompression and fusion, Laminoplasty, Sagittal alignment

Introduction

Cervical spondylotic myelopathy (CSM) occurs secondary to compression of the cervical spinal cord. Symptomatology includes, but is not limited to, pain, neck stiffness, weakness, paresthesia, bowel and/or bladder disturbances, and/or gait/balance difficulties. Common objective clinical signs include atrophy of hand musculature, sensory loss, and Lhermitte's sign (*i.e.* electric shocks down the back following flexion of the neck). However, the hallmark of CSM is the presence of long tract signs on physical examination. These signs include the presence of upgoing toes on Babinski testing, hyperreflexia on assessment of deep tendon reflexes, the presence of ankle clonus, and increased lower extremity tone, or spasticity, on passive motion. In the upper extremities, the presence of a Hoffman's sign is another long tract sign frequently seen in the presence of CSM. CSM was first described

by Stookey, in 1928,¹ and later established as a clinical phenomenon, in 1952, by Brian.² Neurovascular damage may develop as a result of progressive cord compression. Numerous studies have cited the onset of CSM as most commonly beginning between the ages of 40 and 60 years.³⁻⁷ Collectively, all degenerative cervical spine changes leading to cord compression have been grouped under the collective term degenerative cervical myelopathy (DCM).⁸ Within North America, myelopathy due to degeneration of the spine has an estimated incidence and prevalence of 41 and 605 per million, respectively. Overall, non-traumatic DCM represents one of the most common causes of spinal cord impairment in adults.^{8,9}

Clinical presentations

Case 1

A 53-year-old woman with progressive cervical myelopathy presented with difficulties with balance, dropping objects, handwriting, numbness, paresthesias, and weakness in all 4 extremities. Her neurological examination demonstrated bilateral hyperreflexia. Preoperative imaging demonstrated spondylotic changes from C4-

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Figure 1A Lateral plain film with degenerative changes and mild kyphosis.

C7 with kyphotic angulation (Figures 1A and B). The patient underwent a 3-level anterior cervical discectomy and fusion (ACDF) surgery. Postoperative imaging

Figure 1B Sagittal MR with spondylotic changes which are most severe at C4-C5, C5-C6, and C6-C7 with kyphotic angulation.

Figure 1C Immediate postoperative CT scan shows good decompression/alignment.

Figure 1D Lateral plain film demonstrating good alignment and fusion after 3 level ACDF using autologous iliac crest grafts (no motion seen on flexion/extension views).

Figure 1E AP plain film shows well-aligned construct at one year.

demonstrated good decompression and alignment (Figures 1C and D). At one year postoperatively, follow-up imaging revealed a well-aligned construct without instrumentation complications. At her two-year follow-up, her myelopathy symptoms had greatly improved and she now only had symptoms related to a separate low back condition. Some mild swallowing issues and iliac donor site issues were completely resolved.

Case 2

A 70-year-old man presented with progressive loss of ability to ambulate and to care for himself. His complaints included upper extremity tingling and numbness, dropping objects, complete inability to handwrite, no hand dexterity, and an unsteady gait with poor balance and multiple falls in the months prior to the initial evaluation. He was confined to a wheelchair. Physical examination showed lower extremity spasticity, diffuse hyperreflexia, upgoing toes, bilateral ankle clonus, a wide based gait with instability, and a positive Hoffman's sign on the right side. Preoperative imaging

Figure 2A Lateral plain film with degenerative changes and reasonable lordosis.

demonstrated diffuse spondylosis and abnormal signal in the spinal cord at the C4-C5 level (Figures 2A and B). The patient underwent C2-C7 decompression and fusion with the use of crossed laminar screws at the C2 level and pedicle screws at the C7 level (Figures 2C and D). Of note, termination of a spinal construct at C7 can result in effective outcome with an appropriate sagittal alignment and without delayed kyphotic deformity. What is essential to preserve sagittal alignment is to only expose the upper third of the C7

Figure 2B Sagittal MR with diffuse spondylosis and abnormal signal in spinal cord at C4-C5 level.

Figure 2C Lateral plain film with good alignment after C2-C7 decompression, stabilization, and fusion.

Figure 2D AP plain film shows well aligned construct with crossed laminar C2 screws which were placed due to anatomical issues at the C2 transverse foramina.

vertebra, and thereby preserve the muscular attachments to the C7 spinous process as well as avoiding use of any cautery on the C7-T1 facet joints.¹⁰ At two-year follow-up, he had a dramatic improvement clinically while regaining the ability to function independently. Myelopathic signs and symptoms improved and he was working out at the gym again.

Preoperative planning

Pre-surgical management

In patients presenting with progressive cervical myelopathy with moderate or significant deficits, one would be hard pressed to not recommend intervening surgically. Aside from severe medical comorbidities preventing a safe operation, the most appropriate therapy would be surgical intervention. Myelopathy tends to progress, and as such, non-surgical management tends to be futile for this condition. Sadasvian *et al.* followed 22 patients to delineate the natural history of CSM. All 22 patients deteriorated over time using the Nurick classification.¹¹ Moreover, alternative non-surgical approaches such as physical therapy, diagnostic or therapeutic injections, weight control, acupuncture, bio-feedback, or chiropractic manipulation may not provide any proven, sustained benefits. As such, the passage of time without surgical intervention predisposes the patient to further problems rather than a therapeutic solution. Of note, mixed results have been reported in prior studies. In 2000, Kadanka *et al.* compared surgical versus non-operative treatment for CSM in a randomized control trial of 48 patients. Using the modified Japanese Orthopedic Association (mJOA) classification of disability, this study reported no difference between patients treated with surgery versus no surgery on long-term follow-up of 2 years.¹² Still, more recent prospective studies indicate a benefit to surgical intervention. For example, Fehlings *et al.* demonstrated improved health-related outcome measures in a prospective study of 278 patients undergoing surgical intervention for CSM.^{13,14}

Differential diagnoses

Overall, a combination of subjective symptoms, objective clinical signs, and radiographic imaging are utilized to diagnosis CSM. However, the etiology of cervical myelopathy may be secondary to a myriad of pathological processes including: neoplasm, infection, trauma, inflammatory condition, or degenerative disease. Several pathologies below can have clinical manifestations that may overlap and should be considered in the differential diagnosis when evaluating a patient for CSM. Disease processes to consider include:

amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), syringomyelia, spinal tumors, transverse myelitis, neuromyelitis optica (NMO), cobalamin deficiency, paraneoplastic syndromes, and vascular etiologies.^{15,16}

Imaging

Preoperatively, in 2017, a magnetic resonance (MR) imaging study is the most valued imaging modality. An MR study is obtained to evaluate for cervical stenosis resulting in myelopathy. Preoperative anteroposterior (AP) and lateral plain films are routinely obtained and include dynamic flexion-extension views to assess for spinal stability. A computed tomography (CT) scan, particularly if prior cervical surgery has been performed, may be obtained as well. CT scans may also be of value in cases of suspected ossification of the posterior longitudinal ligament (OPLL), metabolic bone disease, and for the assessment of bony structure and size. In addition, a CT angiogram may be obtained to evaluate for any aberrant vascular anatomy. For the relatively small number of patients who are unable to have an MR imaging study, a CT-myelogram is another option to assess for any compressive lesions involving the cervical spinal cord.

Neurophysiological monitoring

With regard to neurophysiological monitoring, some surgeons routinely employ intraoperative somatosensory-evoked potentials (SSEPs) and/or motor-evoked potentials (MEPs), especially during operative positioning, placement of instrumentation, and deformity correction maneuvers. However, it has not been our practice to routinely utilize neuromonitoring intraoperatively in a 20+ year experience of operating on myelopathic patients. Neuromonitoring adds time as well as expense for each surgical intervention. Similarly, in a recent retrospective review of 720 consecutively treated patients, Traynelis *et al.* demonstrated that decompression and reconstruction for symptomatic cervical spine disease, without intraoperative monitoring, did not adversely impact patient safety and could reduce associated surgical costs.¹⁷

Approach considerations

The vector of approach to address cervical myelopathy is a controversial topic. In general, a significant preoperative kyphotic deformity precludes a posterior approach alone. In addition, we are more likely to favor anterior approaches in patients with fewer levels of involvement, and younger patients. A posterior approach may be favored for more levels with a predominantly dorsal vector of compression. Additionally, more elderly patients and patients with neutral or

preserved cervical lordosis are more likely to have posterior approaches recommended in our practices. Nevertheless, in cases with clinical equipoise, an ongoing randomized, controlled, clinical trial, funded by the Patient-Centered Outcomes Research Institute (PCORI), is underway which strives to determine whether ventral or dorsal surgery is associated with superior clinical outcomes for the treatment of CSM.^{18,19} Dorsal interventions commonly utilized include laminectomy, with or without an associated fusion, or laminoplasty (where motion is preserved).

Surgical technique

Anterior approach

The patient is positioned supine on the operating room table with the head supported by a Mayfield horseshoe head holder. With significant spinal cord compression or myelopathy, techniques which limit neck motion during intubation are employed. These can be either an awake, fiberoptic intubation or use of a Glide scope. Hyperextension should be avoided as even transient neck extension may lead to further spinal cord compression with the potential for a worsening neurological condition. Preoperative radiographic evaluations are reviewed to confirm proper intraoperative cervical sagittal alignment. If an autologous bone graft is to be utilized, then a bolster is placed under the iliac crest. As a general rule, we routinely employ Gardner Wells skeletal traction prior to making the initial skin incision. The use of traction is particularly helpful for cases of diminished bone mineral density where distraction pins at the level of the vertebral body proper may not be feasible to assist with distracting the intervertebral interspace.

Controversy exists regarding the laterality for the skin incision; however, as a general rule, a right-handed surgeon often prefers an approach from the right side. Still, the more variable anatomic course of the right recurrent laryngeal nerve may yield a greater risk of injury.²⁰ Despite this, some studies have demonstrated no association between the side of approach and the incidence of recurrent laryngeal nerve injuries.^{21,22} After confirmation of the appropriate level, a skin incision is made. Attempting to optimize the cosmetic result, we prefer a transverse incision for surgeries that are to be performed at one or two levels. When three or more levels are treated, our preference is an oblique incision that parallels the medial border of the sternocleidomastoid muscle. On these larger surgeries, this oblique approach seems to lessen the likelihood of complaints of postoperative dysphagia. Sharp dissection is performed through the subcutaneous tissue and

platysma with a subsequent subplatysmal dissection. Deep dissection is performed bluntly whereby the sternocleidomastoid muscle and carotid sheath serve as lateral border with the trachea, esophagus, and the strap muscles of the neck as the medial border. The carotid artery is identified in the lateral border by direct palpation.

Once the prevertebral space has been exposed, a radiographic marker is utilized to confirm the correct level. One method is with the use of a radiopaque bayonetted spinal needle inserted into the disc space. Studies have demonstrated that exposure of a non-operative intervertebral disc can lead to accelerated degeneration of that disc.^{23,24} As such, localization can also be performed with placement of a radiographic marker into the ventral vertebral body cortex. The longus colli muscles are dissected and elevated from the vertebral bodies on each side of the identified disc space with a maximum lateral extent of dissection of 3 mm to avoid causing a Horner's syndrome if the sympathetic chain is disrupted. A self-retaining retractor system is then utilized.

Following retractor placement, in patients with adequate bone mineral density, we place a cortical screw into the vertebrae above and below. These screws provide for attachment of distraction devices during the procedure. At this point, the operating microscope is draped and brought into the field and the remainder of the anterior procedure is performed under direct microscopic guidance. A discectomy is achieved with removal of the annulus fibrosis and the nucleus pulposus as well as the underlying posterior longitudinal ligament (PLL). For the great majority of cases where neurological issues are present, we routinely resect the PLL and directly visualize the underlying dura mater. A blunt nerve hook is passed through the epidural space to confirm that an adequate decompression has occurred. In the event of a dural tear, an attempt can be made to repair the leak; however, this is challenging when a simple discectomy is being performed. As such, cerebrospinal fluid (CSF) diversion using a lumbar subarachnoid drain should be considered in these situations. In our experience, autologous iliac crest bone graft, which is osteoinductive, osteogenic, and osteoconductive, results in excellent fusion rates. Alternative options for interbody fusion include structural allograft and cages. Nonetheless, it is our preference to avoid bony substitutes. Notably, the Food and Drug Administration (FDA) put forth an advisory, in 2008, alerting against the use of recombinant human Bone Morphogenetic Protein-2 (rhBMP-2) in the cervical spine.²⁵ Although rhBMP-

2 may increase the ultimate fusion rates, the excessive complication (*e.g.* seroma, hematoma, inflammation, swelling) rates preclude its safe utilization in the cervical spine.²⁶

Cervical plating is performed after identification of the anatomic midline. Screw selection should enable maximal bony purchase based on the preoperative imaging. It is essential to ensure that the plate system lies flush with the ventral vertebral bodies after the screw-plate locking mechanism is engaged. This is especially important at the rostral portion of the plate where prominence of the construct can lead to problematic and persistent dysphagia. Prior to a layered wound closure, lateral radiographic confirmation of proper placement of the graft(s) and instrumentation is obtained.

Posterior approach

Patients are placed under general anesthesia in the prone position with the head secured using a three-pronged Mayfield skull clamp. Fluoroscopic guidance is utilized throughout the procedure with the head maintained in a neutral position relative to the cervical spine at the onset of the surgery.

A midline incision is made over the appropriate cervical levels based on a preoperative review of the surgical pathology. Dissection and reflection of soft tissues is carried out with subsequent identification of osseous landmarks. Typically workflow is as follows: spinal instrumentation, bony decompression, sagittal alignment corrective maneuvers, and spinal fixation. If posterior cervical fixation is chosen instead of laminoplasty, preoperative imaging is essential to ensure appropriate screw lengths are selected. Of note, CSM is rarely the result from compression of the spinal cord at the C1-C2 levels as the capacious spinal canal in this location makes the presence of myelopathy less frequent in the upper cervical region than in the subaxial cervical spine. Despite this, particularly with tumors and inflammatory conditions, spinal cord compression may occur at the upper cervical levels (C1-C2). For stabilization at the C2 level, we tend to utilize C2 pars screws of 20 mm length. If the patient's anatomy precludes the use of a pars screw, then either a C2 pedicle screw or crossed C2 laminar screws (as demonstrated in [Figure 2](#)) may be considered. In the subaxial spine, we generally place lateral mass screws of 14 mm length from C3 to C6. Though others have cited success with subaxial cervical pedicle screws, we have avoided these out of concern for the potential for neurovascular injury.²⁷ At C7 and T1, we favor pedicle

screws of 24 mm to 30 mm length depending on the size of the involved vertebrae.

Preservation of the bony landmarks, prior to decompression, adds safety to the procedure and assists the surgeon in orienting the screws properly. Following placement of the spinal instrumentation and a subsequently sufficient bony and ligamentous decompression, corrective maneuvers can be employed to ensure the screw-rod constructs improve, or at a minimum preserve, sagittal balance. Of note, Glassman *et al.* have demonstrated symptomatology increased linearly with progressive sagittal imbalance.²⁸ Akin to studies focused on the thoracolumbar spine, Tang *et al.* documented an increase in disability with positive cervical sagittal malalignment.^{29,30} In order to achieve better sagittal alignment, after the dorsal decompression is completed, the Mayfield head holder is unlocked and the head is dorsally translated and extended, relative to the cervical spine. This maneuver is performed by one member of the surgical team who breaks sterility while the other team member directly observes the neural elements in the surgical field to ensure that excessive kinking does not occur during extension. A lateral fluoroscopic view is obtained before and after the corrective maneuver. Upon achieving the desired degree of correction, the Mayfield head holder is securely locked into place in the new orientation and the adjusted neck position is confirmed on fluoroscopy. Adjustments to the head position allow for improvement in the sagittal alignment and an optimized horizontal gaze.³¹ At this stage, rods are bent into a normal lordotic curvature and these are secured to the implanted screw heads to achieve fixation. For the posterior approach, local morselized autologous bone graft is utilized to promote fusion. In our practice, allograft, cement, or bone graft substitutes are not employed posteriorly.

Postoperative care

Regardless of an anterior versus a posterior approach, instrumentation is evaluated postoperatively with AP and lateral plain films and a CT scan on the day of surgery. The postoperative clinical follow-up consists of a wound check and staple removal, if necessary, 10-14 days after surgery. Subsequent follow-up visits are scheduled 6 weeks, 12 weeks, 6 months, 1 year, and 2 years postoperatively. At these evaluations, plain films are routinely obtained to assess the fusion status and the positioning of the instrumentation. More advanced imaging is obtained and more frequent visits are scheduled when indicated. Of note, judging fusion success on posterior cases is more difficult than with anterior surgeries and may require more

advanced imaging such as with a CT scan. However, anterior cases typically only require plain films and flexion/extension views to accurately discern whether a fusion has occurred.

Adjunctive orthoses

Postoperatively, a variety of orthoses are available as adjuncts to maintain spinal stability, and hopefully, promote bony arthrodesis. Typically, we utilize a hard cervical collar for 6-12 weeks for both anterior and posterior cases. With posterior approaches, in instances where wound healing is an issue, the collar may be removed sooner. Controversy does exist regarding the necessity of postoperative orthoses following cervical fusion.^{32,33} We recognize that the majority of European spine surgeons no longer utilize external orthoses in the postoperative period. We rarely utilize a halo vest due to poor patient tolerance. Moreover, the lower cervical spine has issues with “snaking” in the halo vest which allows for too much motion.^{34,35} As such, halo vests are typically reserved for use in the C1-C2 regions or surgeries that extend to the occiput which are rarely areas where cervical myelopathy occurs.

Complications

Each approach has its own associated set of potential complications. Anterior surgeries have the uniform issues with dysphagia. The frequency of dysphagia after anterior surgery varies greatly based on the classification of what is determined to be an actual swallowing problem. Overall, each anterior approach begets a few days of swallowing difficulties with some persisting for approximately 2-3 weeks. In our opinion, the elderly, more rostral cervical levels (as opposed to C5 or below) and women appear to suffer postoperatively dysphagia more frequently. Additional complications associated with an anterior approach include: voice hoarseness as a result of recurrent laryngeal nerve injury, especially with lower cervical cases, and voice weakness due the superior laryngeal nerve injury with upper cervical cases. Lastly, Horner’s syndrome can occur from excessively wide lateral elevation of the longus colli muscles.³⁶

Issues associated with posterior approaches mainly include axial neck pain. Wound infection represents another large category as postoperative deep wound infection are virtually non-existent in anterior cases but can occur in up to 18% of posterior cases.³⁷ Of note, with either an anterior or posterior approach, C5 palsies can occur in 4%-5%, albeit the reported incidence varies from 0-30% with most occurring 2 to 3 days after surgery.³⁸⁻⁴²

Conclusions

Several etiologies may lead to cord compression and cervical myelopathy. The best vector of approach with regard to anterior versus posterior surgical intervention is still under investigation. Regardless, management via surgical decompression has been demonstrated repeatedly to improve the CSM patients' quality of life. While conservative, non-operative care plays a role in the care of most spinal disorders, there is essentially no realistic role for delaying surgery in patients with CSM unless medical comorbidities preclude the safe performance of surgery.

Disclaimer statements

Contributors None.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Ethics approval None.

Competing interests statement The authors have no personal or institutional interest with regards to the authorship and/or publication of this manuscript.

Contributorship statement RFH and NA performed the literature search, composed the manuscript, and compiled the figures. AM critically revised the manuscript. All authors have approved the manuscript as it is written.

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