Cervical Spondylotic Myelopathy and Sagittal Deformity

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ABSTRACT
The etiology of cervical spondylotic myelopathy (CSM) is a manifestation of repetitive trauma to the spinal cord, resulting in pathological motor and sensory findings. As neurological dysfunction resulting from CSM can be debilitating, and as delay in management can cause permanent injury, the proper management of cervical deformity to address CSM deserves particular attention. Operative treatment options revolve around minimizing the repetitive trauma to the cervical spinal cord. Such entails a combination of deformity correction, decompression, and spinal fixation and fusion. Although CSM is predominantly a clinical diagnosis, magnetic resonance imaging (MRI) and/or myelography with CT is necessary to determine the extent and location of spinal cord compression. Surgical decompression of the spinal cord, with or without fusion achieves stability and optimizes the opportunity to recover neurological function. Both ventral and dorsal surgical approaches, as well as a combination of both approaches, are used as common operative management options, but uncertainty regarding the determination of the optimal approach remains. This uncertainty is in large part related to the heterogeneity of the pathological process and clinical and imaging presentations. The importance of the individualization of the strategic decision-making process is emphasized.

KEY WORDS: Cervical sagittal alignment, cervical spondylotic myelopathy, cervical spondylosis, cervical stenosis, CSM, operative treatment, sagittal balance, spinal deformity

INTRODUCTION
Cervical spondylosis is a common but frequently undiagnosed manifestation of progressive degeneration of the cervical spine. It is one of the most common causes of acquired spinal cord dysfunction (32). The degenerative process can result in spinal deformity, as well as myelopathy and/or radiculopathy. Cervical spondylotic myelopathy (CSM) is the direct result of repetitive trauma to the spinal cord, thus resulting in abnormal motor and sensory findings. Such trauma can take the form of stretching (distraction), compression, and angular distortion (15,18). As neurological dysfunction resulting from CSM can be debilitating and adversely affect quality of life, and delay in management can cause permanent injury, the proper management of cervical deformity to address CSM deserves particular attention. Conservative (non-operative) management is appropriate for mild CSM, however, the management of cervical deformity is complex, and operative treatment often remains the standard of care for moderate to severe CSM (18). Operative treatment options typically involve eliminating repetitive trauma, and entails deformity correction, decompression, and spinal fixation and fusion (6). As a variety of operative options and techniques are available to address CSM, and none are universally appropriate for all cases, it is clear that a firm understanding of diagnostic strategies, operative techniques and underlying principles are critical. An understanding cervical spine anatomy, its related neurovascular structures, and the cervical spinal canal

and disc space is crucial to understand the pathophysiology of CSM; thus, facilitating the determining of the most appropriate management strategy.

**NORMAL ANATOMY**

An understanding of cervical spine anatomy, its related neurovascular structures, and the cervical spinal canal and disc space is crucial to the understanding of the pathophysiology of CSM – thus, allowing the accurate diagnosis and appropriate management. The cervical spine has seven vertebral bodies that connect the occiput to the thoracic spine. It is commonly divided into two zones: the occipitocervical (OC) junction and the subaxial cervical spine (2).

**Osseous structures**

The first cervical segment (C1) and second cervical segment (C2) have attachments to the occiput to form the OC junction (2). C1, also known as the atlas, has an anterior and posterior arch, connected laterally by the lateral mass on each side. Its lateral mass has bilateral superior and inferior articulating processes (SAP and IAP) that articulate with the occipital condyles concavely (2). The lateral masses have short transverse processes (TP) laterally that contain transverse foramen through which vertebral arteries (VA) traverse. C2, also known as the axis, has odontoid process, also known as the dens, which articulates with the anterior arch of C1. C2 has long pars interarticularis that SAP and IAP, and is bound laterally by TP, where VA travels through the transverse foramen. Unlike in other cervical levels C2 transverse foramen is angulated 45 degrees laterally, which causes partial roofing of the VA by the SAP (2). The third through seven cervical segments (C3-C7) have uniform morphologies. Each vertebral segment has the body and the arch. The body has lateral edges, which curve superiorly and form uncinate processes bilaterally that articulate with the inferior end plate of the segment above and form uncovertebral joint. The lateral mass on each side contains SAP and IAP. TP contains transverse foramen through which VA travels, except in C7.

**Ligamentous structures**

Several ligaments connect the occiput to atlas, occiput to atlas and dens, and atlas to axis. The atlanto-occipital membrane is the continuation of anterior longitudinal ligament (ALL), and posterior portion, which spans the posterior arch to the opisthion. The posterior longitudinal ligament (PLL) continues as the tectorial membrane. The ALL and PLL span the entire cervical spine. Three ligaments connect the occiput to the dens: the apical ligament, the alar ligament, and the cruciate ligament. The apical ligament connects the tip of the dens to the basion. The alar ligament connects the lateral aspect of the dens tip to the medial occipital condyle bilaterally, and functions to restrict excessive rotational movement and lateral bending to the contralateral side (30). The cruciate ligament has superior and inferior limbs, and a transverse limb on each side, also known as the transverse ligament, which inserts into the C1 lateral mass.

**Spinal cord and neural elements**

The cervical spinal cord is a continuation of the medulla that connects the brainstem to the thoracic spinal cord, and has nerve roots exiting through neural foramina bilaterally. Cervical nerve roots exit above their numbered pedicle by convention (i.e. C2 nerve roots exit out of C1-2 foramen above C2 pedicle). There are total 8 paired cervical nerve roots. The C8 nerve roots exit from C7-T1 foramen. Each nerve root bifurcates into ventral and dorsal roots, and ventral roots carry motor fibers, and dorsal roots, sensory. C1 lacks a dorsal root ganglion and, therefore, does not have a sensory dermatome (2).

**EPIDEMIOLOGY AND DISEASE PROGRESSION**

As CSM is a disease (pathological process) of the cervical spine, predominantly manifested by progressive degeneration cervical spine - leading to spinal canal stenosis and spinal cord compression. It most frequently occurs in the elderly population. In addition to degenerative cervical spondylosis, cervical stenosis and spinal cord compression can be caused by developmental defects, especially in the younger population. From cadaveric studies, cervical stenosis is present in 4.9% of the adult population, 6.8% in the age group older than 50’s, and 9% in the age group older than 70’s (19). CSM is the most common etiologic diagnosis in patients with non-traumatic spastic paraparesis and tetraparesis (23). The average age of CSM diagnosis is 64 years. It is present more in men than women at a ratio of 2.7:1. C5 and C6 are known to be the most commonly affected levels (25). CSM is the sequelae of cervical spondylosis, ultimately leading to spinal cord compression - resulting in myelopathic signs and symptoms. Such a degenerative cervical spondylotic process does not always result in clinically symptomatic CSM (16). It was observed...
that 95% males and 70% females in asymptomatic population in the age group of 70's had radiographic findings of cervical spondylosis (11), and nearly 60% had disc degeneration and 20% had cervical foraminal stenosis in asymptomatic population in the age group older than 40 years (4).

**CLINICAL PRESENTATION AND DIAGNOSIS**

Multiple imaging modalities, such as MRI, plain radiography and computer tomography (CT) can be used to confirm clinical impression (16). Patients often present with symptoms that include neck stiffness or pain, arm weakness, paresthesia, gait instability, autonomic symptoms, such as urinary incontinence, frequency, and urgency, and/or Lhermitte's sign (14,28). It has been shown that gait disturbance is the most common clinical symptom/finding associated with CSM, and that such gait instability occurs prior to the onset of motor and sensory deficits of upper extremities (12). Neurological examination findings, such as long tract signs, hyperreflexia, and spasticity, can be utilized to aid the diagnosis as well as to determine the extent of the cervical disease (21). MRI findings of CSM include increased intramedullary signal intensities (SI) on T2-weighted imaging (T2-WI) and decreased signal intensity on T1-weighted imaging (T1-WI) (13). Studies have shown that the more intense and well-defined borders of signal intensity changes on T2-WI are, the more pathophysiological changes have been made to the cord, and the more diffuse changes are, the less intense changes made (1,5). Necrosis can also be visualized on T2-WI. Necrosis of gray matter can have the appearance of “snake-eye”, and is found to be associated with poorer surgical outcomes (22).

**TREATMENT OPTIONS**

Surgical decompression of the cervical spinal cord and fusion to achieve stability has been shown to enhance recovery from spondylotic myelopathy. Approximately 20% of cervical spine operations are performed for CSM, with high complicate rates that range from 10.3 to 16.4 % (3,9,17,29,33). Both ventral and dorsal surgical approaches, as well as a combination of ventral and dorsal approaches, are employed (Figure 1) (20). Significant uncertainty remains as to the optimal option for decompression (7). A non-randomized, prospective, clinical trial composed of 50 patients was performed showing improvement of

![Figure 1: Pre-operative MRI image, Post-operative CT image, Standing plain film 1 year post-operatively (cervical sagittal balance) shown for Ventral Fusion (A-C) and Dorsal Fusion (D-F). PCS = Physical Component Summary. For PCS, higher scores are better (20).](image-url)
symptoms and HR-QOL scores in patients treated surgically (9). Greater HR-QOL improvement was observed following ventral surgery (P=0.05), and dorsal surgery also had longer average length of hospital stay (4.0 vs 2.6 days; P<0.01), along with greater mean hospital costs ($29465 vs $19245; P<0.01). Baseline demographics and HR-QOL scores were comparable between ventral and dorsal surgery patients, but dorsal surgery patients had significantly more severe myelopathy (P<0.01) (9). Further studies are warranted, as the study cannot be used definitively to compare ventral and dorsal approaches due to the existence of confounding factors, especially in setting of patients with more severe myelopathy having received dorsal surgery. Another factor that determines the clinical outcomes in such cervical deformities is global sagittal balance. Sagittal balance is present when a plumb line drawn from C2 or C7 on a sagittal angle falls within 2.5 to 4 cm of the postero-superior aspect of S1 in the sagittal vertical axis (SVA). It is said to have positive sagittal balance if SVA falls anterior to the baseline plumb line, and negative if posterior (31). Sagittal imbalance or misalignment is a spinal deformity that causes pain and disability, and there is a clinical correlation between SVA and health-related quality of life (HR-QOL) (10). Cervical sagittal alignment (CSA) or balance, in particular, refers to normal cervical alignment, which is typically determined by the degree of the occipito-cervical angle and C2-C7 lordosis (24). CSA can be measured using a tangent line drawn from C2 to C7 at posterior vertebral body margins, which is known as the posterior tangent method (11). The occiput to C2 lordosis angle is known to be 14 +/- 7 degrees in asymptomatic healthy individuals, and the mean C2-C7 lordosis is measured to be 16 +/- 16 degrees for men and 15 +/- 10 degrees for women in ages 20-25, and this degree is expected to increase with age to approximately 22 +/- 13 for men and 25 +/- 16 for women in ages 60-65 (11). CSM typically results from cervical spine deformities that cause cervical sagittal imbalance, and therefore, surgical intervention to correct such deformity is warranted. The role of sagittal balance and imbalance in cervical spine have been focused on recently to predict clinical outcomes of CSM,(8) as cervical sagittal imbalance has been correlated with severity of CSM (27). This is illustrated in figure 1. There, however, is paucity of data that demonstrates the absolute correlation between pre-operative and post-operative cervical sagittal balance, and the surgical outcomes and overall prognosis (26). There are current ongoing studies to show such correlation and prognostic significance of cervical sagittal balance on the overall prognosis of CSM deformity correction, and the difference in HR-QOL outcomes following different approaches for CSM deformity corrections with cervical sagittal balance measurement as an independent risk factor.

REFERENCES


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