Cervical spondylotic myelopathy: surgical outcomes in the elderly

Cervical spondylotic myelopathy is a progressive degenerative condition of the cervical spine that results in neurological deficit in either an acute or a delayed fashion. It is the most common disease process that affects the spinal cord in those aged 55 years or above. In this article we discuss the pathophysiology of the condition and highlight symptoms, timing of presentation and clinical indications. With a particular emphasis on the elderly patient, defined most often as those above 60–70 years of age, we discuss prognostic indicators, surgical treatment options and patient outcomes. This article concludes with a discussion of certain medical conditions that particularly affect the elderly patient and a discussion of future perspectives in cervical spondylotic myelopathy research.

KEYWORDS: cervical myelopathy ▪ cervical spine ▪ cervical spondylosis ▪ elderly ▪ prognosis ▪ surgery ▪ treatment outcome

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Learning objectives

Upon completion of this activity, participants should be able to:

- Describe common presentations of cervical spondylotic myelopathy (CSM)
- Describe the differential diagnosis of CSM
- Identify treatment approaches for CSM
- List critical issues associated with the surgical treatment of CSM
- Identify prognostic factors for CSM outcomes

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Cervical spondylotic myelopathy (CSM) can be broadly defined as symptomatic dysfunction of the cervical spinal cord caused by degenerative changes of the bony and ligamentous spine. Although the prevalence of CSM is still unknown, it is the most common form of spinal cord dysfunction in patients over 55 years of age [1]. In this article we will highlight our current understanding of CSM with a particular emphasis on elderly patients. We will discuss the pathophysiology, diagnosis and treatment options available and highlight some of the current research that is being used to identify surgical candidates who may benefit the most. We conclude with an overview of trends in the field and speculate where the next decade of research will focus.

Pathophysiology

The process of spondylosis begins in the intervertebral disc as a result of water content reduction. This may lead to disc shrinkage, partial collapse of the vertebral bodies and in some cases, herniation of the interveterbral disc. In an attempt to compensate for these early degenerative changes, the bony spine may undergo changes that include formation of ostephytes in the posterior arch, facets joint or vertebral body, and thickening or ossification of the ligamentum flavum. Figure 1 illustrates a 72-year-old male with CSM; Figure 1A illustrates a midsagittal CT scan showing osteophyte formation around the vertebral bodies. Figure 1B shows a preoperative midsagittal T2-weighted MRI, illustrating spinal cord compression, which is most prominent at the C5/6 level where there is T2 signal changes within the spinal cord. Figure 1C illustrates the postoperative midsagittal T2 image where the cord compression at the C5/6 level has been addressed with an anterior decompression and instrumented fusion. In Figure 1C, cerebrospinal fluid (CSF) can be seen around the cord where previously (Figure 1B) the CSF was obliterated at this level; the T2 signal change in the cord remains so in the immediate postoperative period. Figure 1D is a lateral x-ray of the cervical spine that shows the instrumented fusion hardware used in this patient. In addition to these degenerative changes, a host of other pathologies exist that may cause compression of the cervical spinal cord and the consequent symptoms. Ossification of the posterior longitudinal ligaments is a compressive cord disorder that most commonly occurs in the cervical spine and leads to severe myelopathy [2]. By contrast, ossification of the ligamentum flavum is reported to be less common in the cervical spine and is most

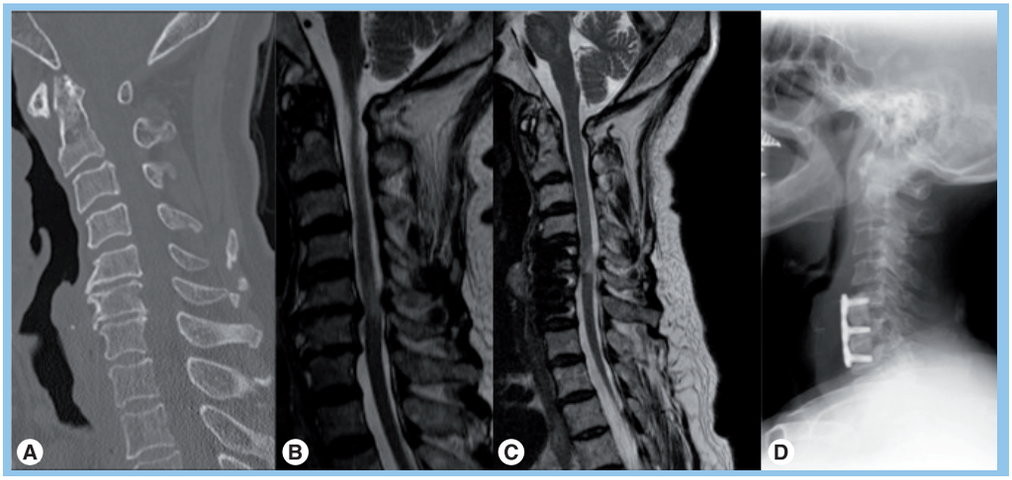

Figure 1. A 72-year-old male with cervical spondylotic myelopathy. This individual presented with a 2-year history of progressive hand numbness, weakness and gait impairment. Clinical examination revealed atrophy of the hand intrinsic muscles, a positive Hoffman sign and a broad-based unstable gait. **(A)** A midsagittal CT scan showing osteophyte formation around the vertebral bodies. **(B)** A preoperative midsagittal T2-weighted MRI, illustrating spinal cord compression most prominent at the C5/6 level where there is T2 signal changes within the spinal cord. Given the clinical presentation and imaging findings, this individual was offered surgical treatment in the form of an anterior decompression and instrumented fusion at the C5–7 level. **(C)** The postoperative midsagittal T2 image where the cord compression at the 5/6 level has been addressed with an anterior decompression and instrumented fusion. One can visualize cerebrospinal fluid around the cord where previously **(B)** the cerebrospinal fluid was obliterated at this level; the T2 signal change in the cord remains so in the immediate postoperative period. **(D)** A lateral x-ray of the cervical spine that shows the instrumented fusion hardware used in this patient.

commonly associated with neck pain and arm weakness [3]. Similarly, calcification of the ligamentum flavum is another rare compressive cord disorder that presents with sensory deficits in the upper limbs, hand clumsiness, difficulty walking and urinary dysfunction [4]. The clinical presentations of these rare conditions are very similar, if not identical to, CSM. The treating physician should therefore obtain the necessary CT and MRI images to delineate the exact pathology and seek the advice of a spine surgeon skilled at differentiating these conditions.

The effect of advanced spondylotic changes can involve either an acute or chronic presentation. Acute presentation is usually the result of the compression of a spinal nerve and/or the vertebral artery, which can cause pain, motor weakness or sensory changes. Patients can also present with gradual and long-standing symptoms that are usually the result of chronic compression and subsequent demyelination (the evidence for this demyelination comes from postmortem pathophysiological studies in humans and electrophysiological studies in long-standing nerve root compression). Several factors have been identified that contribute to this chronic deterioration of the neural elements. These have recently been reviewed in great detail and will be highlighted in this article [5]. Stretch-associated force, ischemia and subsequent apoptosis have each been implicated with neurological decline. Of particular importance to this discussion is the ongoing ischemia that occurs with chronic and progressive bony compression. Anterior compression compromises perfusion at the level of the transverse arterioles (branches of the anterior sulcal arteries) and posterior compression compromises perfusion of the intramedullary branches of the central gray matter. The pathology is somewhat different across age groups. Although spondylotic changes often begin in the lower segments (C4–C7) of the cervical spine in all age groups, the number of patients presenting with diffuse involvement is more common with increasing age [6]. Similarly, hypermobility at the C3–C4 level and the formation of canal stenosis occur more commonly in the elderly population. Given the rarity of C3–C4 compression in CSM patients, Mihara *et al.* attempted to quantify this presentation and reported an incidence five-times higher in those aged above 65 years [7].

As briefly outlined above, CSM represents a spectrum of degenerative changes that occur over time and affect people in different ways. In the paragraphs that follow we will outline in greater detail the clinical presentation, along with surgical treatment options and outcomes.

Clinical features of CSM

Cervical spondylotic myelopathy is a common cause of serious morbidity in the elderly population [8]. Patients most commonly present with symptoms of gait and hand dysfunction that can profoundly undermine the performance of activities in daily living, particularly in the elderly [9]. Pain in arm, forearm, and/or hand is frequent and can occur unilaterally or bilaterally [10]. Loss of sphincter control and urinary incontinence infrequently appears in CSM but can manifest in a number of ways ranging from urgency and frequency to hesitancy. Epstein *et al.* found that 20% of their patients with CSM over 65 years of age had bladder dysfunction, mostly associated with urinary retention [11]. In fact, patients with CSM may show both storage and voiding dysfunction; therefore the combination of urinary frequency and large postvoid residual volume is not uncommon in this patient population.

Symptoms generally develop in a slow and insidious fashion, reflecting the chronic pathology of this disorder. Delayed diagnosis is common, with the time from symptom onset to diagnosis ranging from weeks to years. Conflicting results of the relationship of duration of symptoms and severity of CSM in elderly groups have been reported. Some investigators report no difference in duration of symptoms and severity at admission between younger and elderly CSM patients [12–14]. The majority of studies, on the other hand, have found an association between the duration of symptoms and neurological deficits at admission and surgical outcomes [15–21]. A common cut-off point to study the effect of symptom duration on surgical outcomes is 12 months. Based on this arbitrary time point, some authors have reported that patients with symptoms longer than 12 months present with a worse prognosis [22]. This delayed diagnosis can, in part, result from the insidious onset of symptoms and subsequent delay in seeking medical attention and proper investigation. The widespread use of MRI over the last decade offers a means for earlier diagnosis of CSM. It is reasonable to predict that future series will demonstrate a trend toward shorter symptom duration and potentially better outcomes.

In the early stages of CSM, the most common clinical sign at presentation is gait abnormality due to weakness, stiffness (representing rigidity or spasticity – the difference should be clinically determined), and proprioceptive loss in the legs [23]. To facilitate monitoring outcomes in CSM, standardized, disease-specific assessment tools including the walking test [24], Nurick [25]

and Japanese Orthopaedic Association (JOA)/a modified version of the Japanese Orthopedics Association (mJOA) [26] have been developed. Typical findings upon physical examination are suggestive of upper motor neuron dysfunction including Babinski's and Hoffman's signs. Houten *et al.* have reported that Hoffman's sign is a more sensitive marker of spinal cord compression and is found to be more prevalent in individuals with less severe neurological deficits than Babinski's sign [27]. Signs of walking difficulty are often followed by upper extremity numbness and loss of fine motor control of the hands. Wasting of the intrinsic hand muscles is a classic physical finding in CSM [28].

Thus, the clinical features of CSM are represented by a spectrum of symptoms depending on the duration since onset. The treating physician can expect to encounter a number of physical signs, depending on the severity of spinal cord or nerve root compression. Finally, CSM specialists make use of a number of standardized assessments to classify and follow patients. One cautionary note must be emphasized: there are a number of rare conditions that can mimic CSM in various ways. The prudent clinician must utilize a differential diagnosis consisting of autoimmune disease (systemic lupus erythematousus and Sjogren's syndrome, granulomatous disease [sarcoidosis] and other demyelinating disease such as multiple sclerosis). The prevalence of these conditions is rare; however, the treatment strategy is very different prompting the need for an appropriate work-up in suspicious cases.

The natural history of CSM

Our current understanding of the natural history of CSM is based on a number of studies that investigate CSM relative to factors associated with either clinical deterioration or improved outcomes. The ultimate goal of such an understanding is to optimize the timing of intervention in order to maximize neurological function. A systematic review of this subject was recently carried out that identified 32 publications directly addressing the natural history [29]. The results of this systematic review echoes those of other published reports – the natural history of CSM is variable and individual patient characteristics may affect treatment decisions. We will examine this evidence with regard to characteristics of CSM that may affect patient outcomes.

Five recent studies have been carried out that attempt to delineate the natural history of CSM with homogenous groups that utilize objective outcome measures over a reasonable amount of time [30–34]. Several other studies with less scientific rigor have also been carried out but will not be reviewed here. Each of these studies define their population in terms of age (all less than 75 years) and baseline deficit, making use of mJOA scores [30–34], timed 10 min walk [30–33], video recorded activities of daily living [30–33] and electromyography (EMG)/somatosensory evoked potential (SEP) testing [34]. The same scales and measurements are repeated over time and inferences are made about the natural progression of disease. The results of such longitudinal studies are mixed. The conclusions of two studies are that patients with mild CSM (mJOA <12) and less than 75 years of age tend not to worsen over time and intermittently improve over 36 months [30,31]. In patients with mild-to-moderate CSM, symptoms seem to stabilize over a period of 24 months and plateau slightly worse than at baseline [32,33]. Last, Bednarik *et al.* demonstrated that the development of CSM occurs in significantly more patients who first demonstrate either clinical radiculopathy or abnormalities on EMG and SEP testing [34]. The key findings on EMG are those consistent with anterior horn cell dysfunction, whereas the SEP changes reflect altered axonal conduction with a prolongation in latency and possibly reduction in amplitude.

Two clinical themes emerge from the abovementioned studies. The first focuses on the management of patients less than 75 years of age with mild CSM. In this patient group, nonoperative management coincides with a stable clinical course over a 36-month time course. The second concentrates on predictive factors. The presence of EMG abnormalities in the anterior horn cells or the presence of clinical radiculopathy is associated with the development of CSM in patients with asymptomatic cervical stenosis. The significance of this finding with regard to possible treatment options (surgical or nonoperative) has yet to be demonstrated.

Based on the best available evidence, one can conclude that the natural history of CSM is mixed and cannot be individualized to a given patient. This should be emphasized during discussions with patients regarding the natural history and potential treatment options. Some experience a slow, stepwise decline, others experience long periods of quiescence with no progression of symptoms. Some patients may even improve from their baseline presentation without treatment. Pathological studies indicate that a progressive demyelination of white matter occurs over years and that acquired stenosis may lead

to necrosis in both gray and white matter. Ogino *et al.* reported on nine patients, with an average age of 76.4 years, from diagnosis to death [35]. The average symptom duration in this cohort of patients was 18.2 years. The authors correlate the degree of anterior–posterior compression with the severity of changes in gray and white matter: from mild demyelination to extensive gray matter necrosis with white matter gliosis.

Given the complexity of the disease in terms of variability within the population and progression, such patients should be managed by a spinal surgeon who has taken an interest in the disease process. As surgical techniques improve and adjunct biological therapies become available, there will certainly be a change in the surgical outcome groups. This can only be followed with strict study protocols and close patient observation.

Surgical treatment of CSM: options & controversy

A variety of surgical techniques exist to treat CSM. The essence of the surgical option rests in a few critical decisions: to approach the degenerating spine from anterior or posterior, the degree of surgical decompression and the method in which to fuse the remaining segments. Whereas Figure 1 illustrated a case of CSM treated from an anterior surgical approach, Figure 2 illustrates a posterior surgical approach. Figure 2 demonstrates the case of a 54-year-old female who presented with a 10-month history of progressively worsening symptoms of numbness and loss of fine motor skills in both hands. In addition, she was demonstrating early signs of impaired gait and upper extremity weakness. Physical examination revealed hyper-reflexia, a positive Hofmann sign and atrophy of the hand intrinsic muscles. Figure 2A is a midsagittal CT scan that demonstrates bony degeneration of the cervical spine with osteophyte formation and loss of the normal lordotic curve. Figure 2B is a midsagittal T2-weighted MRI that shows compression of the spinal cord at multiple levels ranging from C3 to C6. Given her clinical presentation and imaging findings, this patient was offered a posterior decompression and fusion. Figure 2C illustrates a postoperative T2-weighted midsagittal MRI that demonstrates reconstitution of the normal spinal curve and ample CSF around the entire cervical cord. Figure 2D is a lateral x-ray of the cervical spine that shows the instrumented fusion hardware used in this patient. The goal of treatment in any patient is to halt the progression of neurological symptoms and to offer the spinal cord an optimal environment for potential recovery. No less than five surgical techniques exist to manage these three issues and with evolving technology, new options are becoming available. The surgical community evaluates each technique by comparing them relative to each other and various outcome measures. We will review some of this evidence while highlighting the most common surgical procedures.

The methods employed to compare surgical techniques in CSM have largely been based on case series or poorly designed cohort studies. There is a lack of randomized, prospective design. Despite the methodological shortcomings, a number of comparisons can be made that provide an overview of the advantages and disadvantages of the available techniques. These have recently been the subject of a comprehensive systematic review [36]. When considering an anterior approach, a decision must be made to remove a cervical disc (anterior cervical discectomy with fusion [ACDF]) or the disc and adjacent vertebral body (anterior cervical corpectomy with fusion [ACCF]). A total of eight clinical studies addressing this issue have been published since 1966 [37–44]. Three conclusions can be derived from these studies: the use of anterior plate fixation allows for similar fusion rates between the two techniques; in the absence of anterior plate fixation, ACCF may provide a higher fusion rate than ACDF; in the absence of anterior plate fixation, ACCF has a higher graft failure rate than ACDF. One study specifically addressed the concern of smoking [39]. They found that smokers had higher rates of fusion with ACCF as compared with ACDF. These observations can be used to guide clinical decisions and to inform patients.

When attempting to compare anterior with posterior surgery, a surgeon encounters several options. One of these is the use of anterior cervical discectomy (with or without fusion) relative to laminectomy. Eight studies have been published to this effect since 1966 [26,45–51]. As above, these studies were recently subject to systematic review [36]. The results of this analysis suggest that comparable results can be obtained with anterior or posterior surgical decompression with the caveat that patients receiving a laminectomy (posterior surgery) alone may deteriorate in a delayed fashion due to kyphosis. The authors of the systematic review therefore recommended an anterior approach for short segment disease.

From the aforementioned studies, one theme arises; a variety of surgical techniques can be applied with similar rates of success. The focus

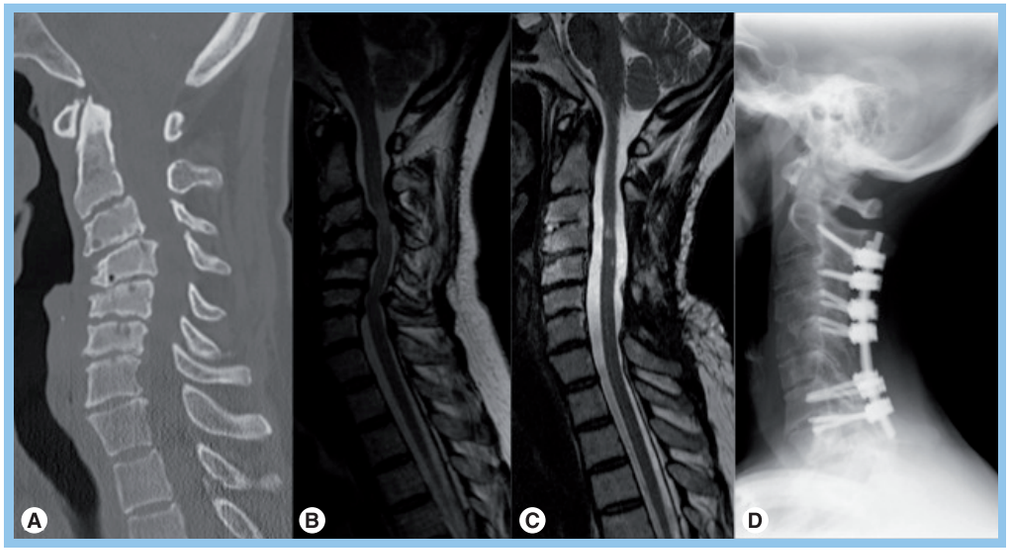

Figure 2. A 54-year-old female presenting with a 10-month history of progressively worsening symptoms of numbness and loss of fine motor skills in both hands. Clinical examination revealed early signs of impaired gait and upper extremity weakness in addition to hyperreflexia, a positive Hofmann's sign and atrophy of the hand intrinsic muscles. **(A)** A midsagittal CT scan that demonstrates bony degeneration of the cervical spine with osteophyte formation and loss of the normal lordotic curve. **(B)** A midsagittal T2-weighted MRI that shows compression of the spinal cord at multiple levels ranging from C3 to C6. Given her clinical presentation and imaging findings, this patient was offered a posterior decompression and fusion. **(C)** A postoperative T2-weighted midsagittal MRI that demonstrates reconstitution of the normal spinal curve and ample cerebrospinal fluid around the entire cervical cord. **(D)** A lateral x-ray of the cervical spine that shows the instrumented fusion hardware used in this patient.

on the surgical technique should be based on the maximal focus of cord compression and the results of the above comparative studies should be used to inform patients of advantages and disadvantages.

Surgical outcomes

As one can gather from the above discussion, CSM is not only a diverse condition in terms of its presentation and natural history, but also in terms of surgical management. Therefore, outcomes are difficult to summarize and apply to any one particular patient. Nonetheless, certain factors have been established that may provide an indication of prognosis after surgical treatment. These can be summarized as clinical and imaging features.

The topic of clinical prognostic indicators of surgical outcome has been the subject of a recent systematic review [52,53]. Based on the available evidence, the authors made recommendations as to which clinical factors may aid in predicting outcomes following surgical decompression. Three themes surfaced from the literature: age, duration of symptoms and preoperative neurological function. Each of these has a prognostic value. This observation is based on eight studies and a cumulative total of 573 patients. In each case, authors compared outcomes based on different patient groups undergoing surgery. In terms of age, the definition of 'older' ranged from greater than 60 years to greater than 70 years. Six studies found that older age resulted in a worse surgical outcome in comparison with younger age [14,18,54–57]. Duration of symptoms was defined in each study as longer or shorter than an upper limit (ranging from 1 to 3.25 years). In five studies a longer duration of symptoms predicted worse clinical outcome [18,48,54,57,58]. In one study, the effect was only present in the elderly patients (>65 years) [56]. In two studies, the duration of symptoms did not affect outcome. Regarding preoperative neurological function, two studies identified a better neurological outcome with better preoperative neurological function [14,58].

MRI is standard of care for both diagnosis and preoperative planning of patients suspected of CSM. As a result of this, several research groups have analyzed the preoperative MRI of patients and attempted to identify features that may predict outcome following surgery. This topic has been subjected to a recent systematic review, which examined over 42 articles; the interested reader is directed here [36] for a comprehensive understanding. Three themes emerge from this work: multilevel hyperintesity on T2-weighted MR images, T1-weighted

hypointensity and T2-weighted hyperintensity together, and a transverse cord area of less than 45 mm^2 (representing cord atrophy) each predict a poor surgical outcome in comparison with the absence of these findings. These imaging findings are likely to represent the long-standing and ongoing damage to the neural elements of the spinal cord and the corresponding white matter tracts.

Special considerations in the elderly population

Surgical treatment of CSM in older patients presents many unique challenges. Long-standing changes to the bony cervical spine and the presence of medical comorbidities add a dimension of complexity onto already difficult procedures. Age, duration of symptoms, imaging findings and medical comorbidities all contribute to the surgical outcomes. While the literature contains mixed results with regard to each of these factors on patient outcomes there are a host of medical diseases encountered in older age groups that should be optimized before proceeding to surgical treatment of CSM. Hypertension, diabetes mellitus, coronary insufficiency, cardiomyopathy, pulmonary problems, previous cerebral infarction and gastrointestinal ulcers are commonly found comorbidities that influence surgical outcomes in elderly patients with CSM. In general, the recovery rate is slower in elderly CSM patients. Matsuda *et al.* specifically addressed this topic and reported that CSM patients over the age of 75 years with cerebral infarction or aggravation of diabetes mellitus, osteoarthritis and peripheral neuropathy were functionally worse at baseline prior to surgery; however, patients both with and without medical comorbidities became independent in daily activities over time [59].

Future perspective

Cervical spondylotic myelopathy represents a constellation of degenerative changes in the bony cervical spine that result in compression of the spinal cord or nerve roots resulting in a variety of clinical presentations. By its very nature, CSM is a challenging condition to both understand and treat. A series of well-conducted studies has provided answers to a few very important clinical questions. The first is that the duration of symptoms has a negative impact on patient outcomes following surgery; the second is that the mode of surgical decompression does not appear affect patient outcome as long as the maximal point of compression and concomitant kyphosis are considered in the surgical plan. The next decade of research into the natural history and treatment options for CSM will focus on the paucity of class I and II data. The timing of surgical intervention is currently being addressed in a rigorously controlled study carried out by the AOSpine North America group (PA, USA) – the results are expected within the next year. In addition to these, a host of novel treatments are becoming available, including both artificial cervical discs and biological agents that may augment current treatment strategies. These too must undergo the scrutiny of well-controlled studies.

Executive summary

- Cervical spondylotic myelopathy (CSM) is the most common spinal disorder in persons over the age of 50 years.
- CSM is a process that begins with degeneration of the intervertebral disc and bony spine. Compression of the spinal cord or exciting nerve roots can occur in an acute or chronic fashion.
- The most common clinical presentation in the elderly is gait and hand dysfunction. These two ailments are the cause of significant morbidity in the aging population.
- A variety of surgical techniques exist to treat CSM. The essence of surgical treatment rests in decompressing the spinal cord or nerve roots that are causing symptoms and stabilizing these segments with implants.
- Age, duration of symptoms and preoperative neurological function are used to prognosticate. Younger patients with shorter duration of symptoms and better preoperative neurological function fare better with surgical treatment.

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▪▪ **Very well written overview of the pathophysiology of cervical spondylotic myelopathy (CSM). This would be of interest to those clinicans who aim to have a deeper understanding of the basic science research that has improved our knowledge of this degenerative condition and its effect on the spinal cord.**

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■■ **This article was published as part of a series in the *Journal of Neurosurgery*, whereby many aspects of CSM are systematically reviewed. The interested reader is refered to the above volume of the journal for an extensive review of the clinical aspects of CSM.**

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Activity evaluation: where 1 is strongly disagree and 5 is strongly agree.					
	1	**2**	**3**	**4**	**5**
The activity supported the learning objectives.					
The material was organized clearly for learning to occur.					
The content learned from this activity will impact my practice.					
The activity was presented objectively and free of commercial bias.					

1. A 55-year-old woman presents with increasing unsteadiness while walking and more recent concerns that her "hands just don't work as well," accompanied by pain in the forearm and hand. She is unable to pinpoint the exact onset of these symptoms but reports slow development over several months. A medical history is essentially negative, although she reports a history of hypertension that has been well controlled with medication. She is also moderately obese with a body mass index of 30 kg/m^2. The clinician suspects cervical spondylotic myelopathy (CSM).

   However, which of the following should be considered in the differential diagnosis?

   - ☐ **A** Multiple sclerosis
   - ☐ **B** Parkinson's disease
   - ☐ **C** Cerebrovascular accident
   - ☐ **D** Migraine variant

2. An electromyogram is obtained and the results are within normal limits. Which of the following is considered the most appropriate management strategy in this situation?

- ☐ **A** Aggressive physical therapy
- ☐ **B** Myelography and spinal decompression
- ☐ **C** Neck brace and reduced mobility
- ☐ **D** Observation and symptomatic treatment

3. Which of the following factors in this patient would increase the likelihood of treatment failure?

- ☐ **A** Female sex
- ☐ **B** Presence of cardiovascular comorbidities
- ☐ **C** Symptoms persisting longer than 1 year
- ☐ **D** Obesity

4. Despite initial therapy, the patient continues to experience symptoms over the course of the next year, although her neurologic exam remains essentially unchanged. She returns to your office and asks what else can be done. In educating her about treatment options, which of the following points should be emphasized?

- ☐ **A** The type of surgical approach is critical
- ☐ **B** Surgery should be delayed as long as possible because outcomes are less favorable in patients under the age of 60 years
- ☐ **C** Patients should be treated with nonsurgical options for as long as possible
- ☐ **D** Surgery is a reasonable option for her, particularly given her essentially good neurologic function