

A review of the current management of cervical spondylotic myelopathy

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Abstract

Cervical spondylotic myelopathy (CSM) is the commonest cause of non-traumatic paresis or paralysis in the middle age-group and above. It is an insidious slowly progressive disease with variable presentations. The commonest mode of presentation are neck pain, loss of fine movement of the hands and unsteady gait. Cervical spine magnetic resonance imaging (MRI) is the investigative tool of choice and this demonstrate the state of the disc, cord and neural tissue compression and help in decision making as regards management plan. The mainstay of treatment is surgery. The choice and approach of surgery depends on clinical presentation and findings from imaging. Though there is a role for conservative treatment in well selected group of patients but surgical treatment takes into account, the aim of decompressing neural tissue (cord and or nerve root) with or without stabilizing the spine.

Key words; Spondylotic, myelopathy, MRI, cord decompression

Introduction

Cervical spondylotic myelopathy (CSM) is the most common non-traumatic cause of spastic paraparesis or quadriparesis in adult from age 55 years and above^{1,2}. Although the vast majority of individuals >50 years old have radiologic evidence of significant degenerative disease of the cervical spine, only a small percentage will experience neurologic symptoms³. CSM is rare in patients <40 years of age. It is a pathology that evolve over time with huge challenges in the management of these groups of patients in neurosurgical practices. World-wide as the mean age and life expectancy increase, a vast majority of the population would present with this pathology^{1,2}.

There is a wide variability among patients with this pathology in terms of clinical presentation, image findings and this influence management approach². The mainstay stay of diagnosis is based on clinical findings (history and physical examination) which is assessed

with the findings on images such as cord compression and signal changes at late stages of evolution. Nevertheless, the diagnosis of CSM can be difficult because the signs and symptoms can vary widely among the population^{1,3}. Besides, onset of symptoms is usually insidious, with long periods of fixed disability and episodic worsening events. Some findings that can commonly appear are gait spasticity, followed by upper extremity numbness and loss of fine motor control in the hands⁴. Surgical management of this pathology has evolved with advances in technology and technical know-how, and this has led to a significant improvement in outcome. There is strong evidence showing that surgery within one year from onset of symptoms strongly improves outcome in patients with CSM⁴.

Generally, it is a common consensus that surgical intervention positively impacts on the prognosis of CSM, There must be a clear-cut selection criteria for the most appropriate surgical technique. Factors such as the site of neural tissue compression (cord or nerve root), cervical spine alignment (lordosis, kyphosis) and patient-specific

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spinal biomechanics⁵ determines the choice of approaches (anterior or posterior).

Surgical Anatomy

The cervical spine is one of the 5 regions of the spine and it is made up of seven vertebrae. It consists of a body, pedicle and posterior elements with adjoining ligaments and joints. The vertebral body is the largest and most anterior part of the cervical spine. Posteriorly, two pedicles and laminae form the vertebral arch. The pedicle holds the posterior element to the vertebral body. The junction where the pedicle and lamina join each other is the transverse process, on each side of the vertebral body, the transverse process has a foramen which vertebral artery exit from C6 - C1. Other processes of the vertebrae include spinous process in the midline and four articular processes. Two adjacent vertebrae are connected to each other by a ligamentous structure called intervertebral disc which consists of inner nucleus pulposus and a multilayer annulus fibrosus which is weaker posteriorly. The main component of the nucleus pulposus is glycosaminoglycan which consists of over 90% water and its water content decreases as one ages and this starts the cascade of CSM. The cervical spine has some unique features as shown in Fig.1. Firstly, the first two vertebrae have distinct names, atlas for C1 and axis for C2, reflecting their specialized structure and function. C1 (atlas), which lacks the body and spinous process, forms the atlanto-occipital joint as it articulates with the condyles of occipital bone and this is responsible for neck flexion and extension. C2 (axis) has a vertebral body but it uniquely has a bony protuberance stabilized by the transverse ligament called odontoid process. C2 vertebra plays an important role of supporting rotational movement of the neck. The other vertebrae - C3 to C7 are similarly shaped and thus grouped together as the lower cervical spine. These five vertebrae house a vertebral body that is concave superiorly and convex inferiorly and this is taken into account when placing cage during anterior cervical discectomy and fusion (ACDF). They also have uncovertebral joints, Joints of Luschka, located between the uncinus process and uncus projecting from vertebral bodies of two adjacent levels. There is a cylindrical apophyseal mass called the lateral mass, the popular site for lateral mass screw instrumentation. Its close relations include: existing spinal nerve and vertebral artery anteriorly, the lamina posteriorly, the pedicle anteriomedially, the transverse process anteriolaterally

and in its superior and inferior ends are the corresponding articular facets. Overall, the flexibility of the cervical spine accommodates a wide range of motion and thus increases its vulnerability to injury⁶.

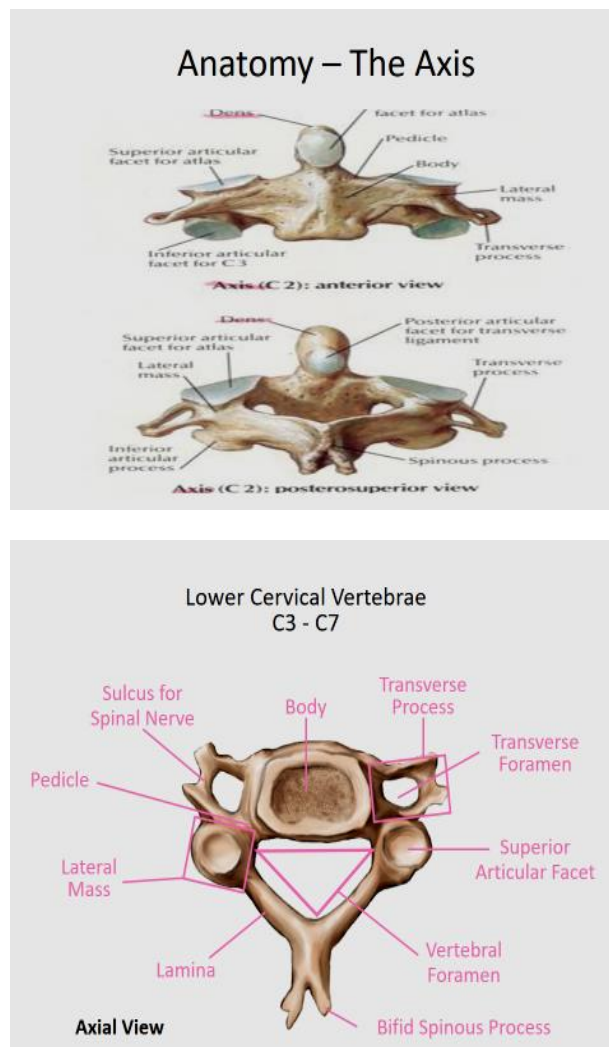


Fig. 1: A pictorial diagram of the cervical spine from Harold Ellis Textbook of Anatomy

Pathophysiology

CSM was first described by Brain et al. in 1952⁷. The pathophysiology arises from a multi-factorial cascade. It develops in almost all patients with $\geq 30\%$ narrowing of the cross-sectional area of the cervical spinal canal⁸ (although some patients with more severe cord compression do not have myelopathy^{9,10}).

This cascade of events starts with a process which usually begins with the degenerative changes involving the nucleus pulposus and subsequently the annulus fibrosus which made up the intervertebral disc and thereafter

leads to the collapse of the cervical discal space^{1,2,3}. As result of the continuous motility and weight bearing involving the reduced disc space, the endplates of the adjacent vertebral bodies progressively super mechanical stress and this leads to the formation of bony osteophytes. These osteophytes are a natural adaptation to increase the load-bearing surface of these endplates in order to compensate for cervical spine hypermobility secondary to disc degeneration. Uncinate process hypertrophy occurs, encroaching on the intervertebral foramina. Layers of annulus fibrosis are thinner dorsally, leading to tears and disc material herniating posteriorly into the cervical canal. Annulus fibrosus dissects away from the PLL and endplates, the dorsal vertebral bodies form reactive bone(sub-periosteal reaction) leaving exposed bone encroach on nervous tissue^{1,2,3}. However, it has been found that the posterior longitudinal ligament (OPLL) ossification, most commonly seen in the Asian race, can also lead to contribute to CSM¹¹.

Several process have been described to explain how the pathophysiological process comes about. These include:

Mechanical Factors. The repeated micro-trauma and or macro-trauma to the spinal cord, induced by both static and dynamic mechanical factors could lead to the development of CSM. These factors combine to aspects the spinal cord through two mechanisms: direct trauma and ischemia¹².

Dynamic Mechanical Factors. Dynamic stressors refer to the abnormal movement of the cervical spine during flexion or extension, and this can contribute to spinal cord injury in conjunction with static factors. Flexion of the cervical spine may lead to compression of the spinal cord against osteophytic bars while extension may lead to compression against the hypertrophied ligamentum flavum^{12, 13, 14}.

Static Mechanical Factors. Narrowing the cervical spinal canal have been attributed to the following factors such as (a) the osteophyte formed decreases the diameter of the spinal canal and it may lead to direct compression of the spinal cord and subsequently result clinically in varying pattern of neurological deficit. (b) The hypertrophy of the ligamentum flavum, OPLL and spondylolisthesis, and or kyphosis of the cervical spine may result in narrowing of the spinal canal diameter with resultant compression of the neural tissue. These static

factors identified above have severe consequence on patients with congenital cervical canal stenosis¹².

Ischemia. Degenerative changes involving the spine could lead to compression of blood vessels that supply the cervical spinal cord and proximal nerve roots resulting in ischemia of the spinal cord. This may arise from direct compression of larger vessels such as the anterior spinal artery which supply anterior 2/3 of the cord and results in reduction in the flow of the pial plexuses as well as in small penetrating arteries which supply the cord^{1, 15, 16}. In addition, impairment of cord venous outflow resulting in significant venous congestion which build up intra-neural pressure venous flow, thus contributing to spinal cord ischemia. Studies has pointed to vascular mechanism as the main factor responsible for CSM. Some postmortem studies in patients with CSM demonstrating abnormal histological findings, such as spinal cord necrosis and gray matter cavitations¹. Furthermore, attributing to this fact, is the region of CSM main involvement. The C5-C7 spinal cord level is the most affected region correlating with the area with the most vulnerable vascular supply^{12, 13, 15, 16}.

The dentate traction theory had also been used to explain this pathophysiological process, this states that the spinal cord is pulled laterally by the dentate ligament, which are tensed by an anterior spondylotic bar. This show the effect of tensile strength in a degenerative spinal elements¹⁷.

These pathophysiological cascade can happen in isolation or synergistically as it could encompasses the whole processes causing CSM. Histologically, there is degeneration of the central grey matter at the level of compression, degeneration of the posterior columns above the lesion (particularly in the anteromedial portion), and demyelination in the lateral columns (especially the corticospinal tracts) below the lesion. Anterior spinal tracts are relatively spared. There may be atrophic changes in the ventral and dorsal roots and neurophagia of anterior horn cells¹⁸.

Clinical features

CSM can cause a variety of symptoms and signs. Nevertheless none of them has been proven to be pathognomonic. The onset of the disease is invariably insidious. In the initial series reported by Brain et al., the duration of symptoms ranged from 7 days to 26 years,

and almost half of the patients presented symptoms for more than one year at the time of diagnosis⁷.

In a study involving 1,076 patients with CSM, gait disturbance was the most common symptom¹⁹ and spastic gait was one of the first symptoms, followed by upper extremity numbness and loss of fine motor control of the hands. Other common symptoms of CSM are neck pain, as well as referred pain in the shoulder or subscapular area. Furthermore, it has already been shown that one-third of patients with neck pain due to CSM present with headache and greater than two thirds may present with unilateral or bilateral shoulder pain. A significant number of these patients also present with pain radiating to the arm, forearm and hand with long periods of remission²⁰. Upper motor neuron findings such as spasticity, hyperreflexia, clonus, Babinski, and even bowel and bladder dysfunction may also be present. These findings often occur together with lower motor neuron findings, such as hyporeflexia and atrophy in the upper extremities. Numbness or paraesthesias in the upper extremities is usually nonspecific, although dermatomal sensory complaints can occur from a coexisting radiculopathy. Sensory changes in the lower extremities is also common and typically involve the dorsal columns. Furthermore, motor weakness as well as gait impairment, are also commonly present^{13, 19, 21}.

Clustering of CSM into these 5 clinical syndromes has been described²²:

1. Transverse lesion syndrome: involvement of corticospinal, spinothalamic tracts and posterior columns. The anterior horn cells are segmentally involved. It is the most frequent of all syndromes, possibly an "end-stage" of the disease process.
2. Motor system syndrome: This usually involves the corticospinal tract and the anterior horn cells with minimal or no sensory deficit. The pattern of presentation is that of a mixture of lower motor neuron findings in the upper extremities and upper motor neuron findings (myelopathy) in the lower extremities which can mimic amyotrophic lateral sclerosis (ALS) which is a differential of CSM. Reflexes may be hyperactive below the area of maximal stenosis (including the upper extremities), seldomly it begins several levels below the canal stenosis
3. Central cord syndrome: motor and sensory deficit affecting the upper limbs more than the lower limbs. This is characterized by dysfunction of the

watershed areas located centrally within the cord, which may be responsible for prominence of hand symptoms (results in "numb-clumsy hands" presentation). Lhermitte's sign may be more common in this group.

4. Brown-Séquard syndrome: this is associated with asymmetrical narrowing of the canal with the side of greater narrowing producing ipsilateral corticospinal tract (upper motor neuron weakness) and posterior column dysfunction with contralateral loss of pain and temperature sensation
5. Brachialgia and cord syndrome: radicular upper limb pain with lower motor neuron weakness, and some associated long tract involvement (motor and/or sensory)

Imaging Diagnosis

The diagnosis of CSM often includes cervical radiographs or CT-Scan which may demonstrate osteophyte formation, a normal alignment and reduced disc space (Fig 2). Nevertheless, Magnetic resonance imaging (MRI) of the cervical spine (Fig. 3) still remains the most useful diagnostic tool²³. MRI provides information about the state of the spinal cord, the ligaments, and the intervertebral discs, MRI may also help to rule out other differential diagnoses, such as spinal cord tumors or syrinx. Furthermore, T2-weighted hyperintensity at the level of spinal compression has also been shown to correlate with CSM severity and has been supposed to be an important prognostic factor. Such findings are thought to represent edema and inflammation^{12,23,24}. However, T1-hypointensity has been shown to be a more severe sign and this connotes ischemia, gliosis, or myelomalacia and it correlates with worst outcome after surgical intervention^{25, 26, 27}.



Fig. 2: This is a lateral view C-Spine X-ray of a 54 year old man who presented to our clinic with myeloradiculopathic

symptoms and signs and the radiograph showing straightening of the spine, degenerative changes, bony osteophyte and reduced disc spaces



Fig. 3: This is a T2-Weighted sagittal MRI of the above described patient in Fig. 2 showing kyphotic deformity, C3/4, C4/5 disc herniation, with cord compression and signal changes

Surgical Management

Except for the mild case of CSM in few clear-cut cases, surgery is the mainstay of treatment of moderate and severe CSM. Most treatment guideline recommend operative over conservative therapy for moderate to severe cases of CSM unlike the mild case in which the conservative approach may suffice. The surgical management of CSM has evolved beginning with the classical anterior cervical discectomy and fusion (ACDF) procedure popularized by Cloward²⁸ and Smith and Robinson [29]. Other techniques, such as posterior laminectomy and fusion procedures, as well as a vast number of laminotomy surgical techniques have been mentioned in literature^{23, 24, 28, 29}. The aim of the surgery is to decompress neural tissue, stabilize spine and correct deformity whenever necessary. This can be broadly divided into anterior, posterior or combined surgical approaches otherwise called 360 degree approach. Other critical factors that need to be considered include to maintain or restore the alignment of the cervical spine, maintain permanent stability and fusion. Advantages, disadvantages, and limitations of each approach must be known by the surgeons and clearly explained to the patient pre-operatively^{12, 23, 24, 29}.

The selection of the appropriate surgical approach requires that every patient be evaluated individually and surgical approach based on its own merit. However, factors such as the sagittal balance and number of levels

to be addressed may have strong influence on choice of surgery. For instance, patients with loss of cervical lordosis (kyphotic deformity) should not be considered for laminectomy without fusion or laminoplasty^{12, 23}.

Anterior Surgical Techniques for CSM. This is indicated in anterior compression of the spinal cord probably caused by disc protrusions and or marked bony osteophyte. Advantage of this approach is the ease in restoring the cervical lordosis in instances where the kyphosis exacerbates the spinal cord compression or when loss of cervical lordosis is a contra indicated for laminoplasty^{30, 31}. This approach aid the resection of the osteophyte, disc and help in placement of an interspace graft thereby removing ventral pathology and restoring normal lordosis^{32, 33, 34}. However, corpectomy may be indicated when large osteophytes extend behind the vertebral bodies and also for patients with calcification of the posterior longitudinal ligament^{31, 33, 34}. Vaccaro et al in their study highlighted the effect of the number of vertebral bodies resection on the rate of nonunion. Early instrumentation failure was seen in 9% of patients with 2-level corpectomies with bone graft and ventral instrumentation. Nevertheless this failure rates increased up to 50% in patients who underwent 3- or more level corpectomies^{35, 36, 37}. Anterior cervical discectomy and fusion (ACDF) of 1–3 levels has been reported in several literature to be safe and effective in decompressing ventral pathology. However, when done for more than three levels or in case of more than 2 corpectomies, the rate of further complications (fracture, graft extrusion and pseudoarthrosis) increases significantly and posterior instrumentation is an essential step to avert these complications^{20, 38, 39}.

Surgeries done through the anterior approach include the anterior cervical discectomy (ACD) and with fusion (ACDF). ACDF can be done with or without instrumentation.

ACDF involves the use of a spacer which is inserted to aid fusion of the cervical spine after discectomy. Studies have shown no difference in fusion rate by comparing ACDF with ACD based on Level I evidence⁵. A retrospective and prospective series involving multiple non-randomized studies showed that discectomies without fusion are inferior to ACDF due to the increased likelihood of postoperative kyphosis and prolonged cervical pain⁹. Kyphosis should not be the sole criteria to determine the superiority of one anterior technique over

the other, especially since we still do not know the long-term consequences of kyphotic deformity⁹. Apart from the risk of deformity, many different a recent a multicenter meta-analysis studies point to ACDF as superior to ACD in terms of fusion rate, functional outcome, and disc space collapse^{4, 13}. On the other hand, other randomized controlled trials did not agree that there is a significant difference in clinical outcome between patient populations treated with these two methods –ACDF or ACD^{8, 12}.

ACDF With or Without Instrumentation

ACDF can be performed with or without instrumentation. The advantages of instruments such as plates and screws include graft extrusion, accelerate fusion and stability without the use of external support most especially in multi-level discectomies. At least in single-level cases, instrumentation is rarely done and often reserved for those with anticipated low fusion rate such as those with advancing age, prolong smoking history and osteoporosis as seen in postmenopausal women¹⁵. ACDF alone already boasts a high success rate of about 90% irrespective of instrumentation. But among these patients without plating, it has been shown they may likely require re-operation due to pseudoarthrosis and worsening symptoms thus emphasizing the importance of instrumentation as adjunct to ACDF¹⁷⁻¹⁸.

Some authors have raised concern that patients who had plating stands a risk of injury to the soft tissues like the esophagus, postoperative dysphagia, or develop adjacent level disease requiring a higher cost of treatment and lengthening operative time¹⁹⁻²⁰. Acute trauma, reoperations, and history of adjacent segment fusion are strong indications for instrumentation. Smoking, nonsteroidal anti-inflammatory drug use, and menopause may also warrant the use of cervical plates due to increased rates of pseudoarthrosis. Smoking remains to be one of the main predictors of pseudoarthrosis following spinal surgery²².

Hardware failure is another contentious issue in making a decision in the use of instrumentation instead of ACDF alone. But this risk have shown to reduced due to use of load sharing dynamic plate instead of static plate as shown by Li et al. Dynamic plates take advantage of the Wolff's theory which postulates that increased axial load-sharing promotes fusion.²⁴

In addition to dynamic plates, low-profile angle-stable plates and plates with smaller locking screws are among

the recent developments in fixation technique. Biodegradable plates and screws that can be resorbed are also a promising alternative with no significant long-term consequences to date. Although many have taken a conservative approach regarding plating, these newly developed plates have the potential to make fixation a more appealing option for a broader spectrum of patients²⁵.

Disc Replacement- Autograft or Allograft or Synthetic Materials??.

Disc replacement involves the use of graft to promote fusion of the operated discectomy region in the cervical spine. The grafts can be obtained from the patient's own body (autograft) such as the tricorticate iliac crest bone or ribs or vascularized fibular graft. It can be cadaveric from bone bank (allograft) which is presently not done. Though the two types of graft are both effective for fusion, neither of them are entirely free from complications. Though they have long been considered the gold standard, autografts are commonly associated with donor site pain, infection and as well as fracture of the donor site. Allografts could present with recipient immunological reactions, necrotic graft and delayed fusion when compared to autograft thus requiring the use of plates. Alternatives to both include the use of ceramics, hydroxyapatite, and tricalcium phosphate which have gained a widespread use for their high biocompatibility and satisfactory ability to stimulate fusion¹.

Intervertebral cage have found a place as a synthetic means of disc replacement. Various types of intervertebral cages have been developed and subsequently used as cervical implants to avoid complications associated with either autograft or allograft associated with traditional grafts in addition to ensuring high fusion rate. Studies have shown these cages to preserve disc height, facilitate the fusion process and promote additional stability. The synthetic interbody cages currently available include cages made of poly-ether-ether-ketone (PEEK), porous tantalum, and zero-profile anchored spacers which could be expandable with advantage of been adjusted to fit to the disc space. Studies have shown that low-profile PEEK cages may reduce esophageal damage because its placement is limited to the confinement of the intervertebral disc space.²⁷

Posterior Surgical Techniques for CSM. There are two major posterior approaches namely laminectomy (with or without fusion) and laminoplasty.

Posterior approaches most often are indicated in the pathology that is located at the posterior portion of the spinal canal such as in cases of hypertrophied redundant ligamentum flavum. Posterior decompression is also useful in cases of anterior compression as it indirectly decompresses the spinal cord by enlarging the cervical canal. Posterior procedures offer several advantages for the treatment of CSM when compared to anterior approaches. These advantages include that they may not require fusion of the spine, it allow direct visualization of the spinal canal and aid wide decompression of spinal cord and nerve roots. These procedure has its drawback as procedures such as laminectomy without fusion and laminoplasty which can result in the development of spinal instability or post-laminectomy kyphosis and does not allow primary resection of ventral pathology.

Laminectomy (with and without Fusion). This technique for posterior decompression of CSM is laminectomy without fusion is historical and oldest. The major postoperative complication of such approach is post-laminectomy instability with kyphotic deformity. Patients at risk of this complication are those who present with signs of pre-existing instability and those in which aggressive facet resection was performed with this group of patients requiring instrumentation for stabilization at the time of the laminectomy is done^{23,52}. Instrumentation using lateral mass screw and rod aimed to stabilize the cervical spine and maintain normal lordotic configuration. As regard posterior spine instrumentation previous techniques such as interfacet wiring have been replaced by lateral mass and pedicle screw fixation^{53, 54}. Instrumented fusions are associated with risk of neural injury, adjacent segment degeneration and vertebral artery injury^{12, 55, 56}.

Laminoplasty. Laminoplasty has been popularized in several Japanese literature in view of the high prevalence of CSM related to OPLL. Several types have evolved and these include The “open-door” technique was popularized in 1970s by Hirabayashi and this have undergo technical modifications over the years^{55, 57, 58}. Advantage of laminoplasty is in the preservation of the bony posterior elements and thus decreases the risk of post-laminectomy kyphotic deformity in comparison with laminectomy without fusion. In comparison with

laminectomy with fusion, laminoplasty has a decreased incidence of adjacent-level degeneration by preserving normal cervical range of motion^{55, 57}. Some literatures have suggested that fusion significantly reduces neck pain in patients with stenotic myelopathy⁵⁹. However, other literature have shown no clear evidence that laminectomy with fusion is better than laminoplasty in reducing neck pain in patients with CSM⁶⁰.

A careful evaluation of the CSM patient and judicious use of outcome scales such as the Modified Japanese Orthopaedic Association Score for cervical Myelopathy⁶¹ or Nurick grade of disability from cervical Spondylosis⁶² are available for initial assessment as well as for outcome measurement to determine effectiveness of treatment⁶³.

Conclusion

Cervical spondylotic myelopathy is a common degenerative disease of the spine which may result in disabling deforming and neurological compromise with huge burden to the patient and caregivers. The clinical findings are variable and mainly insidious. Clinical evaluation, dynamic and static X-rays, as well as MRI are important tools in the preoperative evaluation as well as making decision for surgery. The choice and approach of management is based on patient’s clinical condition, imaging findings as well as the technical knowhow of the surgeon. Early surgical intervention irrespective of mild myelopathy with clear-cut indication improves long-term functional recovery.

Reference

1. Cooper PR. Cervical spondylotic myelopathy. *Contemp Neurosurg* 1997;19:1-7.
2. Baron EM and Young WF, “Cervical spondylotic myelopathy: a brief review of its pathophysiology, clinical course, and diagnosis,” *Neurosurgery*, vol. 60, supplement 1, pp. S35–S41, 2007
3. Cusick JF. Pathophysiology and Treatment of Cervical Spondylotic Myelopathy. *Clin Neurosurg*. 1989; 37:661–681
4. Furlan JC, Kalsi-Ryan S, Kailaya-Vasan A, Massicotte EM, and Fehlings MG, “Functional and clinical outcomes following surgical treatment in patients with cervical spondylotic myelopathy: a prospective study of 81 cases,” *Journal of Neurosurgery*, vol. 14, no. 3, pp. 348–355, 2011.
5. Sadasivan KK, Reddy RP, and Albright JA, “The natural history of cervical spondylotic myelopathy,” *Yale Journal of Biology and Medicine*, vol. 66, no. 3, pp. 235–242, 1993.
6. Ho AL, Desai AM: *Intervertebral Disc Degeneration: Prevalence, Risk factors and Treatments*. Nova Science Publishers, New York; 2016.
7. Brain WR, Northfield D, and Wilkinson M, “The neurological manifestations of cervical spondylosis,” *Brain*, vol. 75, no. 2, pp. 187–225, 1952.

8. Yu YL, du Boulay GH, Stevens JM, Kendall BE. Computed Tomography in Cervical Spondylotic Myelopathy and Radiculopathy: Visualization of Structures, Myelographic Comparison, Cord Measurements and Clinical Utility. *Neuroradiology*. 1986; 28:221–236
9. Epstein JA, Marc JA, Hyman RA, Khan A, et al. Total Myelography in the Evaluation of Lumbar Disks. *Spine*. 1979; 4:121–128
10. Houser OW, Onofrio BM, Miller GM, et al. Cervical Spondylotic Stenosis and Myelopathy: Evaluation with Computed Tomographic Myelography. *Mayo Clin Proc*. 1994; 69:557–563
11. Hoff JT and Wilson CB, “The pathophysiology of cervical spondylotic radiculopathy and myelopathy,” *Clinical Neurosurgery*, vol. 24, pp. 474–487, 1977.
12. McCormick WE, Steinmetz MP, and Benzel EC, “Cervical spondylotic myelopathy: make the difficult diagnosis, then refer for surgery,” *Cleveland Clinic Journal of Medicine*, vol. 70, no. 10, pp. 899–904, 2003.
13. Baron EM and Young WF, “Cervical spondylotic myelopathy: a brief review of its pathophysiology, clinical course, and diagnosis,” *Neurosurgery*, vol. 60, supplement 1, pp. S35–S41, 2007.
14. Yue WM, Tan SB, Tan MH et al., “The Torg-Pavlov ratio in cervical spondylotic myelopathy: a comparative study between patients with cervical spondylotic myelopathy and a nonspondylotic, nonmyelopathic population,” *Spine*, vol. 26, no. 16, pp. 1760–1764, 2001.
15. Ferguson RJL and Caplan RL, “Cervical spondylitic myelopathy,” *Neurologic Clinics*, vol. 3, no. 2, pp. 373–382, 1985.
16. Firooznia H, Ahn JH, Rafii M, and Ragnarsson KT, “Sudden quadriplegia after a minor trauma. The role of preexisting spinal stenosis,” *Surgical Neurology*, vol. 23, no. 2, pp. 165–168, 1985.
17. Levine DN J Neurosurg Psychiatry pathogenesis of cervical spondylotic myelopathy. 1997 Apr; 62(4):334-40
18. Ogino H, Tada K, Okada K, et al. Canal Diameter, Anteroposterior Compression Ratio, and Spondylotic Myelopathy of the Cervical Spine. *Spine*. 1983; 8:1–15
19. Gorter K, “Influence of laminectomy on the course of cervical myelopathy,” *Acta Neurochirurgica*, vol. 33, no. 3-4, pp. 265–281, 1976.
20. Vedantam A, Revanappa KK, and Rajshekhar V, “Changes in the range of motion of the cervical spine and adjacent segments at \geq 24 months after uninstrumented corpectomy for cervical spondylotic myelopathy,” *Acta Neurochirurgica*, vol. 153, no. 5, pp. 995–1001, 2011.
21. Young WF, Weaver M, and Mishra B, “Surgical outcome in patients with coexisting multiple sclerosis and spondylosis,” *Acta Neurologica Scandinavica*, vol. 100, no. 2, pp. 84–87, 1999.
22. Crandall PH, Batzdorf U. Cervical Spondylotic Myelopathy. *J Neurosurg*. 1966; 25:57–66
23. Hsu W, Dorsi MJ, and Witham TF, “Surgical management of cervical spondylotic myelopathy,” *Neurosurgery Quarterly*, vol. 19, no. 4, pp. 302–307, 2009.
24. Cao JM, Zhang YZ, Shen Y, Su YL, Ding WY, and Yang DL, “Selection of operative approaches for multilevel cervical spondylotic myelopathy by imageological score,” *Journal of Spinal Disorders & Techniques*. In Press.
25. Mehalic TF, Pezzuti RT, and Applebaum BI, “Magnetic resonance imaging and cervical spondylotic myelopathy,” *Neurosurgery*, vol. 26, no. 2, pp. 217–227, 1990.
26. Matsuda Y, Miyazaki K, Tada K et al., “Increased MRI signal intensity due to cervical myelopathy: analysis of 29 surgical patients,” *Journal of Neurosurgery*, vol. 74, pp. 887–892, 1991.
27. Okada Y, Ikata T, Yamada H, “Magnetic resonance imaging study on the results of surgery for cervical compression myelopathy,” *Spine*, vol. 18, no. 14, pp. 2024–2029, 1993.
28. Cloward RB, “The anterior approach for removal of ruptured cervical disks,” *Journal of Neurosurgery*, vol. 15, no. 6, pp. 602–617, 1958.
29. Smith GW and Robinson RA, “The treatment of certain cervical-spine disorders by anterior removal of intervertebral disc and fusion,” *Journal of Bone and Joint Surgery*. American, vol. 40, pp. 607–624, 1958.
30. Matz PG, Pritchard PR, and Hadley MN, “Anterior cervical approach for the treatment of cervical myelopathy,” *Neurosurgery*, vol. 60, no. 1, pp. 64–70, 2007.
31. Cabraja M, Abbushi A, Koeppen D, Kroppenstedt S, and Woiciechowsky C, “Comparison between anterior and posterior decompression with instrumentation for cervical spondylotic myelopathy: sagittal alignment and clinical outcome,” *Neurosurgical Focus*, vol. 28, no. 3, p. E15, 2010.
32. Papadopoulos EC, Huang RC, Girardi FP et al., “Threelevel anterior cervical discectomy and fusion with plate fixation: radiographic and clinical results,” *Spine*, vol. 31, no. 8, pp. 897–902, 2006.
33. Stewart TJ, Schlenk RP, and Benzel EC, “Multiple level discectomy and fusion,” *Neurosurgery*, vol. 60, no. 1, pp. S143–S148, 2007.
34. Gok B, Sciubba DM, McLoughlin GS et al., “Surgical treatment of cervical spondylotic myelopathy with anterior compression: a review of 67 cases,” *Journal of Neurosurgery*, vol. 9, no. 2, pp. 152–157, 2008.
35. Vaccaro AR, Falatyn SP, Scuderi et al., “Early failure of long segment anterior cervical plate fixation,” *Journal of Spinal Disorders*, vol. 11, no. 5, pp. 410–415, 1998.
36. Wang JC, Hart RA, Emery SE et al., “Graft migration or displacement after multilevel cervical corpectomy and strut grafting,” *Spine*, vol. 28, no. 10, pp. 1016–1022, 2003.
37. Singh K, Vaccaro AR, Kim J et al., “Biomechanical comparison of cervical spine reconstructive techniques after a multilevel corpectomy of the cervical spine,” *Spine*, vol. 28, no. 20, pp. 2352–2358, 2003.
38. Sasso RC, Ruggiero Jr RA, Reilly TM et al., “Early reconstruction failures after multilevel cervical corpectomy,” *Spine*, vol. 28, no. 2, pp. 140–142, 2003.
39. Kale S, Cahill DW: Current anterior techniques for single-level cervical disc disease. *Contemp Neurosurg*. 2002, 24:1-6. 10.1097/00029679-200203300-00001
40. Bono CM, Ghiselle G, Gilbert TJ, et al.: An evidence-based clinical guideline for the diagnosis and treatment of cervical radiculopathy from degenerative disorders. *Spine J*. 2011, 11:64-72. 10.1016/j.spinee.2010.10.023
41. Fraser JF, Hartl R: Anterior approaches to fusion of the cervical spine: a metaanalysis of fusion rates. *J Neurosurg Spine*. 2007, 6:298-303. 10.3171/spi.2007.6.4.2
42. Barlocher CB, Barth A, Krauss JK, Bingeli R, Seiler RW: Comparative evaluation of microdiscectomy only, autograft fusion, polymethylmethacrylate interposition, and threaded titanium cage fusion for treatment of single-level cervical disc disease: a prospective randomized study in 125 patients. *Neurosurg Focus*. 2002, 12:4. 10.3171/foc.2002.12.1.5
43. Wirth FP, Dowd GC, Sanders HF, Wirth C: Cervical discectomy. A prospective analysis of three operative techniques. *Surg Neurol*. 2000, 53:340-348. 10.1016/S0090-3019(00)00201-9
44. Hauerberg J, Kosteljanetz M, Boge-Rasmussen T, Dons K, Gideon P, Springborg JB, Wagner A: Anterior cervical discectomy with or without fusion with ray titanium cage: a prospective randomized clinical study. *Spine (Phila Pa 1976)*. 2008, 33:458-464. 10.1097/BRS.0b013e3181657dac
45. Bose B: Anterior cervical instrumentation enhances fusion rates in multilevel reconstruction in smokers. *J Spinal Disord*. 2001, 14:3-9. 10.1097/00002517-200102000-00002
46. Grob D, Peyer JV, Dvorak J: The use of plate fixation in anterior surgery of the degenerative cervical spine: a comparative prospective clinical study. *Eur Spine J*. 2001, 10:408-413. 10.1007/s005860000210
47. Kaiser MG, Haid RW Jr, Subach BR, Barnes B, Rodts GE Jr: Anterior cervical plating enhances arthrodesis after discectomy and fusion with cortical allograft. *Neurosurgery*. 2002, 50:229236

48. Carlson BB, Burton DC, Jackson RS, Robinson S: Recidivism rates after smoking cessation before spinal fusion. *Orthopedics*. 2016, 39:318-322. 10.3928/01477447-20160301-03
49. Li H, Min J, Zhang Q, Yuan Y, Wang D: Dynamic cervical plate versus static cervical plate in the anterior cervical discectomy and fusion: a systematic review. *Eur J Orthop Surg Traumatol*. 2013, 23:41-46. 10.1007/s00590-013-1244-8
50. Rodrigo V, Maza A, Calatayud JB, Bances L, Diaz FJ, Gimeno MJ, Carro B: Long-term follow-up of anterior cervical discectomy and fusion with bioabsorbable plates and screws. *Clin Neurol Neurosurg*. 2015, 136:116-121. 10.1016/j.clineuro.2015.04.002
51. Vanichkachorn J, Peppers T, Bullard D, Stanley SK, Linovitz RJ, Ryaby JT: A prospective clinical and radiographic 12-month outcome study of patients undergoing single-level anterior cervical discectomy and fusion for symptomatic cervical degenerative disc disease utilizing a novel viable allogeneic, cancellous, bone matrix (trinity evolution) with a comparison to historical controls. *Eur Spine J*. 2016, 25:2233-2238. 10.1007/s00586-016-44147
52. Bohlman HH, Emery SE, Goodfellow DB, and Jones PK, "Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy: long-term follow-up of one hundred and twenty-two patients," *Journal of Bone and Joint Surgery*, vol. 75, no. 9, pp. 1298-1307, 1993.
53. Herkowitz HN, "A comparison of anterior cervical fusion, cervical laminectomy, and cervical laminoplasty for the surgical management of multiple level spondylotic radiculopathy," *Spine*, vol. 13, no. 7, pp. 774-780, 1988.
54. Ishida Y, Suzuki K, Ohmori K et al., "Critical analysis of extensive cervical laminectomy," *Neurosurgery*, vol. 24, no. 2, pp. 215-222, 1989.
55. Guigui P, Benoist M, and Deburge A, "Spinal deformity and instability after multilevel cervical laminectomy for spondylotic myelopathy," *Spine*, vol. 23, no. 4, pp. 440-447, 1998
56. Ratliff JK and Cooper PR, "Cervical laminoplasty: a critical review," *Journal of Neurosurgery*, vol. 98, no. 3, pp. 230-238, 2003.
57. Heller JG, Silcox DH, and Sutterlin III CE, "Complications of posterior cervical plating," *Spine*, vol. 20, no. 22, pp. 2442-2448, 1995.
58. Kamioka Y, Yamamoto H, Tani T et al., "Postoperative instability of cervical OPLL and cervical radiculomyelopathy," *Spine*, vol. 14, no. 11, pp. 1177-1183, 1989.
59. Kaminsky SB, Clark CR, and Traynelis VC, "Operative treatment of cervical spondylotic myelopathy and radiculopathy: a comparison of laminectomy and laminoplasty at five year average follow-up," *The Iowa Orthopaedic Journal*, vol. 24, pp. 95-105, 2004.
60. Highsmith JM, Dhall SS, Haid RW, Rodts GE, and Mummaneni PV, "Treatment of cervical stenotic myelopathy: a cost and outcome comparison of laminoplasty versus laminectomy and lateral mass fusion," *Journal of Neurosurgery*, vol. 14, no. 5, pp. 598-604, 2011.
61. Chile's BW, Leonard MA, Choudhri HF, et al Cervical Spondylotic Myelopathy: Patterns of neurological deficit and recovery after anterior cervical decompression. *Neurosurgery*. 1999; 44: 762-769
62. Nurick S. The Pathogenesis of the spinal cord disorder associated with cervical Spondylosis. *Brain* 1972; 95: 87-100
63. Onuminya J.E., Salisu Kabiru, Abubakar Kabir, Shobode M.A., Mamman M.I., Waheed T.A. Management of cervical spondylosis and spondylotic myelopathy in National Orthopaedic Hospital Dala Kano: a 6 year review. *Nigerian Journal of Orthopaedics and Trauma*, 2016; 15(2): 58-63