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USE OF DIFFUSION TENSOR TRACTOGRAPHY AS AN ADJUNCT IN THE DIAGNOSIS AND SUPPORT IN THE TIMELY TREATMENT OF DEGENERATIVE CERVICAL MYELOPATHY

USO DE LA TRACTOGRAFÍA CON TENSOR DE DIFUSIÓN COMO COMPLEMENTO EN EL DIAGNÓSTICO Y APOYO EN EL TRATAMIENTO OPORTUNO DE LA MIELOPATÍA CERVICAL DEGENERATIVA

Carlos Morales Valencia
Centro Médico Licenciado Adolfo Lopez Mateos, México

Antonio Sosa Najera
Hospital Angeles Morelia, México

Leonardo Alvarez Vazquez
Centro Médico Licenciado Adolfo López Mateos, México

Arturo De Jesús Gómez Cano
Hospital General De León, México

Milton Inocencio Ruiz flores
Centro Médico Licenciado Adolfo Lopez Mateos, México

Kevin Biblain Rodriguez Vega
Centro Médico Licenciado Adolfo Lopez Mateos, México

José Roberto Solis Perez
Centro Médico Licenciado Adolfo Lopez Mateos, México

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Use Of Diffusion Tensor Tractography as an Adjunct In The Diagnosis and Support in the Timely Treatment of Degenerative Cervical Myelopathy

Carlos Morales Valencia[1]
carlosmorales175@hotmail.com
https://orcid.org/0000-0001-5538-9947
Neurosurgery, Centro Médico
Licenciado Adolfo Lopez Mateos
Toluca, Edo., México

Antonio Sosa Najera
antoniososa0109@gmail.com
https://orcid.org/0000-0002-9456-0118
Neurosurgery and Spine surgery
Hospital Angeles Morelia
Morelia, Michoacán, México

Leonardo Alvarez Vazquez
leonardoneurocirugia@gmail.com
https://orcid.org/0000-0002-4298-033X
Neurosurgery and Spine surgery
Centro Médico
Licenciado Adolfo López Mateos
Toluca, Edo. México

Arturo De Jesús Gómez Cano
goca_22@hotmail.es
https://orcid.org/0009-0004-3224-5683
Neurosurgery and Spine surgery
Hospital General De León
Guanajuato, México

Milton Inocencio Ruiz flores
mdruizmilton79@yahoo.com.mx
https://orcid.org/0009-0001-4358-7118
Neurosurgery, Centro Médico
Licenciado Adolfo Lopez Mateos
Toluca, México

Kevin Biblain Rodriguez Vega
biblain389@ciencias.unam.mx
https://orcid.org/0009-0006-7214-3985
Neurosurgery, Centro Médico
Licenciado Adolfo Lopez Mateos
Toluca, México

José Roberto Solis Perez
robertosolis_10@hotmail.com
https://orcid.org/0009-0001-9145-9946
Neurosurgery, Centro Médico
Licenciado Adolfo Lopez Mateos
Toluca, México

[1] Autor principal
Correspondencia: carlosmorales175@hotmail.com

ABSTRACT
Cervical degenerative myelopathy is a chronic, progressive disease. It is a dysfunction of the spinal. Cord that can commonly be caused by a number of conditions, including deterioration of the osteocartilaginous components of the cervical spine, which is often related to aging. Diagnosis is clinical and by cabinet imaging. Diffusion tensor tractography, being a non-invasive technique, is considered an adjunct to the T2 sequence, which reveals spinal cord deterioration in people with early stage cervical spondylosis before those changes were visible on conventional magnetic resonance imaging, thus improving clinical outcome and patient management. The therapeutic options that currently exist appear to produce an improvement in neurological function in those with progressive disease or intolerable symptoms.

Keywords**:** spinal cord compression, spine tractography, nurick scale, degenerative cervical myelopathy

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Uso de la Tractografía con Tensor de Difusión como Complemento en el Diagnóstico y Apoyo en el Tratamiento Oportuno de la Mielopatía Cervical Degenerative

RESUMEN

La mielopatía degenerativa cervical es una enfermedad crónica y progresiva. Es una disfunción de la columna. Cordón que comúnmente puede ser causado por una serie de afecciones, incluido el deterioro de los componentes osteocartilaginosos de la columna cervical, que a menudo está relacionado con el envejecimiento. El diagnóstico es clínico y por imágenes de gabinete. La tractografía con tensor de difusión, al ser una técnica no invasiva, se considera un complemento de la secuencia T2, que revela el deterioro de la médula espinal en personas con espondilosis cervical en etapa temprana antes de que esos cambios fueran visibles en la resonancia magnética convencional, mejorando así el resultado clínico y el manejo del paciente. . Las opciones terapéuticas que existen actualmente parecen producir una mejora en la función neurológica en aquellos con enfermedad progresiva o síntomas intolerables.

***Palabras clave*:** compresión medular, tractografía de columna, escala de Nurick, mielopatía cervical degenerativa

INTRODUCTION

The number of patients undergoing surgery in treatment for cervical degenerative myelopathy each year has increased sevenfold from 1993 to 2002. Approximately 10% of all patients aged 55 years or older have clinically represented degenerative cervical myelopathy. 85% of adults over 60 years of age have radiological lesions of cervical spondylosis with risk of progression. The median age of patients with cervical degenerative myelopathy is 56 years, and the population of people over 60 years of age in the United States is expected to double by 2050 to nearly 100 million Americans [1,2].

Pathogenesis and pathophysiology

Tissue degeneration in any part of the body occurs primarily as a function of intensity of use over time. However, musculoskeletal structures that support significant structural loads may experience accelerated deterioration. In the cervical spine, these degenerative changes can be divided into spondylotic (or osteoarthritic) and non-osteoarthritic changes, with a further categorization of subtypes. A conceptual breakdown of the pathoetiologic components of cervical degenerative myelopathy is presented below in Figure 1[3].

Figure 1

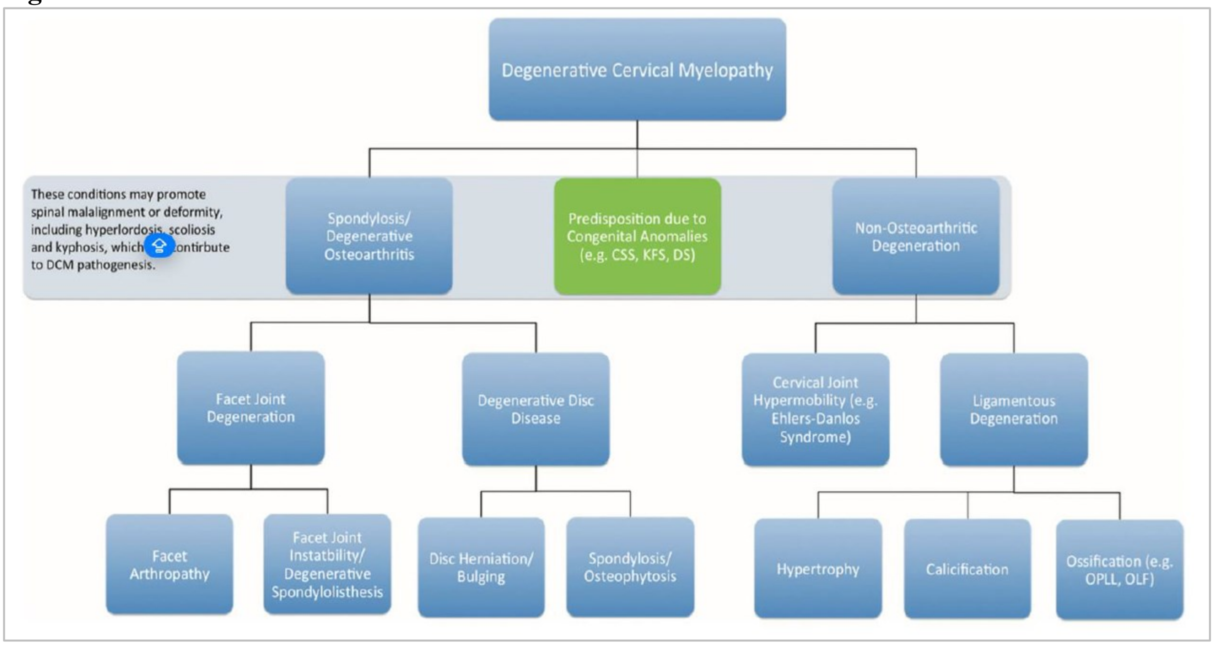


Figure 1: A conceptual breakdown of the pathoetiologic components of cervical degenerative myelopathy . The predominant features form the basis of the diagnosis, but often more than one of these pathologies present concomitantly. In addition, congenital anomalies may predispose to an accelerated

manifestation of cervical degenerative myelopathy. CSS Congenital spinal stenosis; KFS, Klippel-Feil syndrome; DS, Down syndrome; OPLL, Ossification of the posterior longitudinal ligament; OLF,Ossification of the yellow ligament. [3]

Although degenerative cervical spondylosis can affect any component of the cervical spine, such as bone quality and joint structures, the most clinically significant changes occur in the intervertebral discs and facet joints [4]. Cervical myelopathy is induced by static factors (Space available for the spinal cord), dynamic factors (Intervertebral range of motion) or a combination of both. Within the static factors cited are the content and the continent, and their direct implications towards the cervical spinal cord due to the degenerative process (Figure 2), documented by a simple T2-weighted MRI study in sagittal and axial section [4].

Figure 2

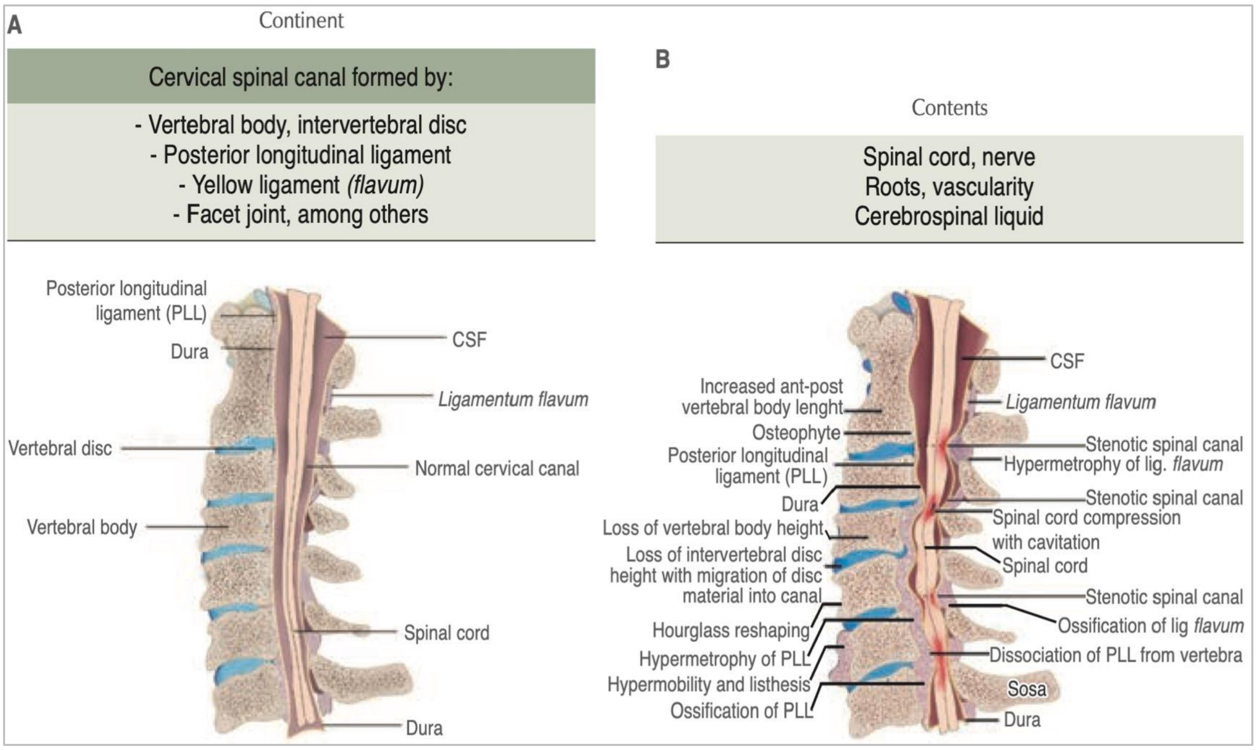


Figure 2 .- A) Structures that form the normal cervical content-continent. B) Degenerative pathological processes that result in reduction of the continent, affecting the content. CSF = cerebrospinal fluid. PLL = posterior longitudinal ligament. [5]

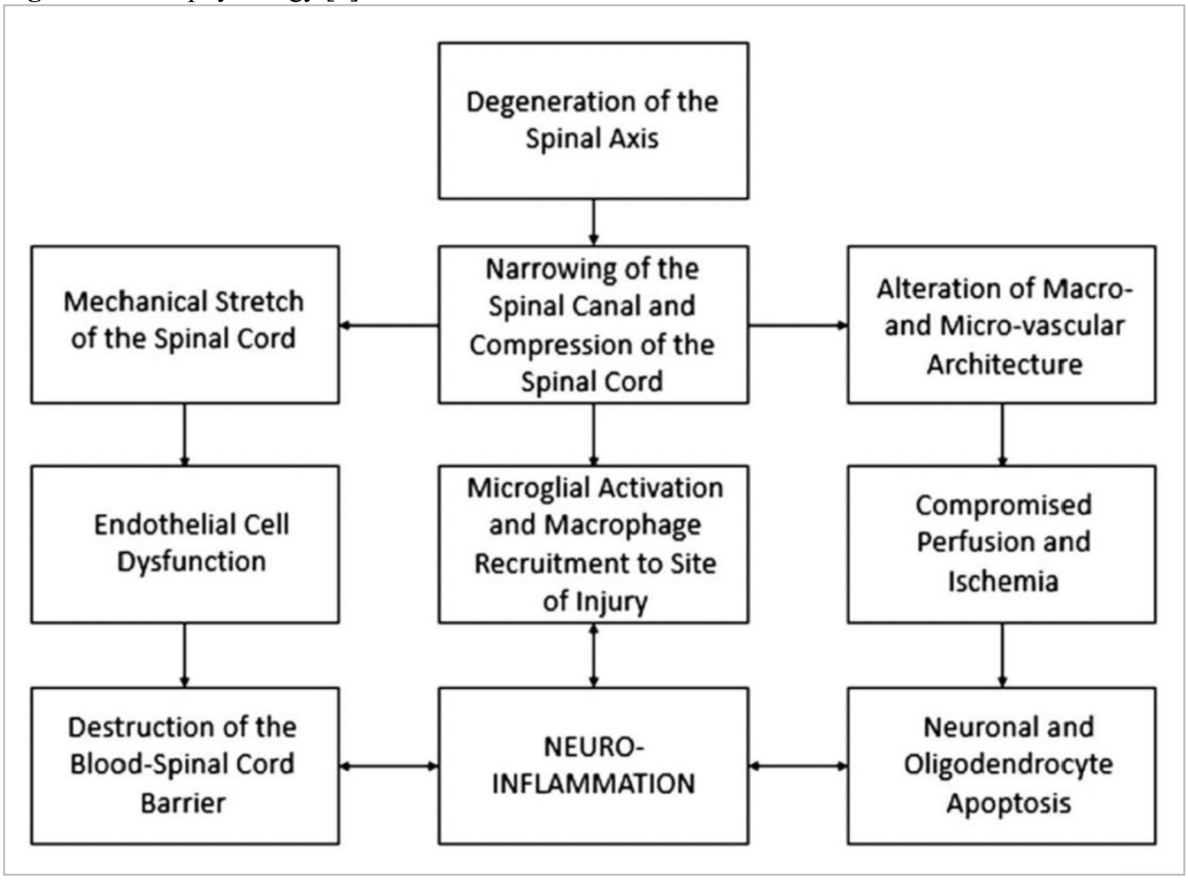
Among static factors, such as congenital spinal canal stenosis and cervical spondylosis, and dynamic factors, such as repetitive microscopic damage to the spinal cord caused by cervical instability, that is, chronic compression of the spinal cord induces direct damage to neurons and glial cells and a secondary ischemic cascade, excitotoxicity and apoptosis [5]. Additionally, hypertrophy in the facet joints that accompanies intervertebral disc herniation leads to progressive spinal stenosis, eventually resulting in cervical myelopathy. Other static factors, such as facet cyst,ossification of the posterior longitudinal ligament, and ossification or calcification of the ligamentum flavum, can further decrease the cross-sectional area of the spinal canal, which may aggravate cervical myelopathy [5].

The Research Committee for Ossification of Spinal Ligaments (Part of the Japanese Ministry of Health, Labor and Welfare) established a common agreement, a classification system used for the ossification of posterior longitudinal ligament . This system classifies the posterior longitudinal ligament into 4 types: 1. Continuous, a long lesion, extending over several vertebral bodies; 2. Segmental, one or more separate lesions behind the vertebral bodies; 3. Mixed, a combination of the continuous and segmental types; and 4. Circumscribed, located mainly in the posterior part of a disc space [4].

Dynamic factors of the cervical spine, such as hypertrophy of the yellow ligament, can also cause myelopathy. Cervical myelopathy can occur when the dynamic sagittal diameter is <11 mm during extreme flexion or extension. Cervical spine instability is defined as >3.5 mm translation and >11° angulation on flexion-extension projections of a dynamic radiograph [5].

The anatomic basis of cervical degenerative myelopathy is ischemia resulting from compression, compromise of venous drainage by the ventral spondylotic rods, compression of the anterior spinal artery and its ventral branches, and compression of the pial plexus. Early studies on cervical degenerative myelopathy reported ischemic changes secondary to compression [5]. Long-term mechanical forces applied to the cervical spinal cord as a result of the processes described above cause direct damage to neuronal and glial cells (Figure 3) [1,6].

Figure 3. Pathophysiology [1]



Clinical evaluation

The patient reports early manifestations of balance problems such as the recent need to use a handrail when climbing stairs. Paresthesias and weakness in the upper extremities are present and patients may have concomitant radicular signs and symptoms. In severe cases of cervical degenerative myelopathy, changes in bowel or bladder dysfunction may be present. The physical examination should include an assessment of balance, such as tandem walking, heel-toe walking [7].

Cervical degenerative myelopathy presents with bilateral upper and lower extremity motor and/or sensory deficits without facial involvement. In addition, patients with cervical degenerative myelopathy have a combination of upper and lower motor neuron signs [8,9]. Currently, imaging plays several key roles in the management of patients with cervical degenerative myelopathy including diagnosis, surgical treatment planning, prognosis, and postoperative evaluation. The outcome of patients with compressive myelopathy can be measured using various severity scales, such as the Nurick , or the Japanese Orthopaedic Association score . However, these are of low sensitivity, with few categories and generally arbitrary, any one of which may cover a wide range of severity. These popular scales provide the clinician with a metric to quantify the extent and progression of disease [8].

A new staging system is proposed, the "SOSA" classification (Table 1)[5], which is obtained by measuring the cervical spinal canal in a sagittal T2-weighted MRI. According to the diameter of the cervical canal measured in millimeters and its correlation with the patient's nurick scale, this allows guiding towards conservative and/or surgical treatment of the cervical spinal canal with or without myelopathy (Table 2)[5].

Table 1: SOSA classification [5]

0	NCC 18-16 mm without myelopathy
1	NCC 15-13 mm without myelopathy
2a	NCC 12-11 mm without myelopathy
2b	NCC 12-11 mm with myelopathy
3a	NCC 10-7 mm without myelopathy
3b	NCC 10-7 mm with myelopathy
4	NCC 6 mm or less with myelopathy
NCC= Narrow Cervical Canal.	

Table 2

1 + N (0)	NCC Mild. Clinical and radiological surveillance
2a+N (0)	NCC Moderate. Moderate risk of myelopathy. Clinical and radiological surveillance.
2b+N (I-V)	NCC Moderate. Surgical treatment.
3a+ N (0)	NCC Severe. High risk of mielopathy. Surgical treatment.
3b + N (I-V)	NCC Severe. Urgent surgical treatment.
4 + N (I-V)	NCC Critical. Urgent surgical treatment.
NCC = Narrow Cervical Canal. N = Nurick.	

Table 2: SOSA + Escala de Nurick. **[5]**

Diagnosis

A proper evaluation of a patient with suspected cervical degenerative myelopathy includes obtaining a detailed patient history, performing a complete neurological examination, and ordering appropriate tests to rule out other diagnoses [1].

Radiograph

Anteroposterior and lateral neutral radiographs are routinely obtained in the evaluation of the cervical spine. Other views, such as open-mouth odontoid, oblique, and dynamic lateral flexion-extension radiographs, may also be considered for further evaluation [10]. Plain radiographs are usually the initial imaging modality for the evaluation of cervical degenerative myelopathy.

Lateral views are often used in conjunction with other forms of cross-sectional imaging. In addition, lateral imaging can identify subluxation, disc degeneration and kyphosis. Dynamic lateral radiographs in flexion and extension can also be used to detect cervical instability.

Specific measurements of spinal alignment, including cervical lordosis, sagittal plane translation and horizontal plane translation, should be evaluated. Cervical lordosis from C1-C7 or C2-C7 is commonly assessed by calculating the Cobb angle. Sagittal plane translation is assessed via the cervical sagittal vertical axis: The cervical sagittal vertical axes C2 and C7 are good measures of global sagittal alignment and are determined by the distance between C2 or C7 and the posterior superior corner of the sacrum (Figure 4)[1].

The spine functions as an overall unit and, as a result, the parameters of the lower spine can influence the alignment of the cervical region. Finally, horizontal gaze can be assessed by the vertical chin-brow angle, which is the angle between a vertical line drawn from the forehead and a line drawn between the chin and the brow. Plain radiographs may also show evidence of degenerative disc and joint disease, scoliosis, loss of normal cervical lordosis, kyphosis, fusion, and subluxation. Anteroposterior motion of more than 3.5 mm of one vertebra relative to an adjacent vertebra on flexion-extension projections of the cervical spine indicates instability [11].

The lateral view is essential to confirm the degree of disc space narrowing, osteophyte formation in the vertebral endplates of the affected levels, and the presence of spondylolisthesis or retrolisthesis. Radiologic findings observed by radiography, CT, and MRI are listed in Table 3. [1,12].

Figure 4

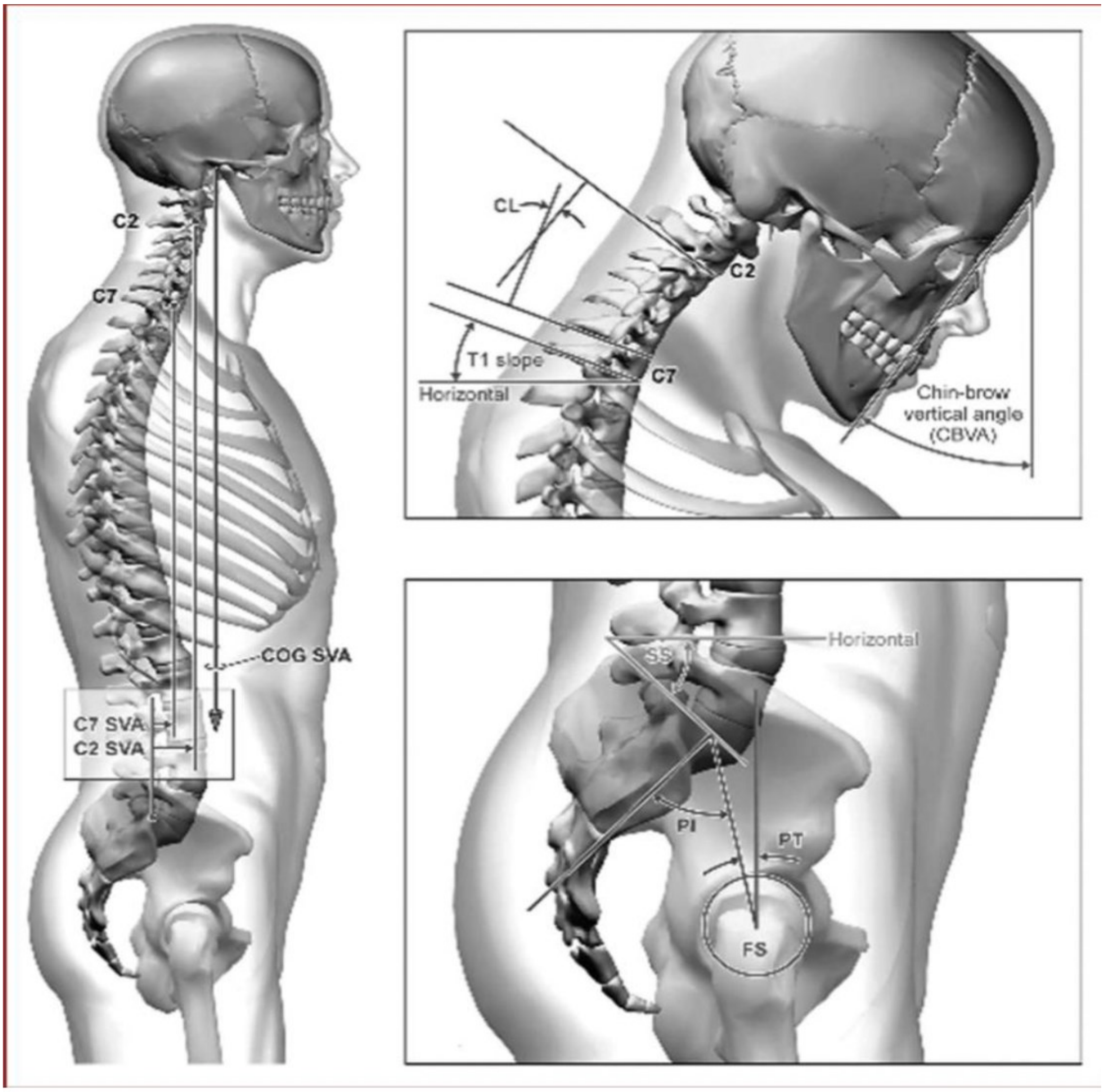


Figure 4: Assessment of cervical alignment. Left,measurement of sagittal plane translation through the cervical sagittal vertical axis (SVA; distance between the C2 or C7 plumb line and the posterior superior corner of the sacrum). Top right, assessment of regional cervical SVA angle by measurement of the Cobb angle (drawing 2 lines parallel to the inferior plate of C2 and C7 and measuring the angle between them), T1 slope (angle between the horizontal plane and T1 endplate), and horizontal gaze evaluated by chin-brow angle. Bottom right, parameters in lower regions of the spine that may affect cervical alignment. CL, cervical lordosis; COG, center of gravity; FS, femoral shaft; PI, pelvic incidence, PT, pelvic tilt; SS, sacral slope.[1]

Table 3 Radiological findings (X-ray, MRI, CT) in degenerative cervical myelopathy [1]

Radiologic findings o degenerative cervical myelopathy
Degenerative arthritic change
Facet hypertrophy
Facet joint instability
Degenerative spondylolisthesis
Subluxation
Disk herniation/bulging
Spondylosis/ostephytosis
Ligamentous aberrations
Hypertrophy of the ligamentum flavum
Ossification of the posterior longitudinal ligament
Ossification of the ligamentum flavum
Calcification of spinal ligaments

Computed Axial Tomography

In 1974 tomography became commercially available and offered the first method of obtaining cross-sectional images of the spine; almost 50 years later, tomography is still useful for the treatment of patients with degenerative cervical myelopathy. Tomography provides high-resolution cross-sectional images, detailed bony lesions, ossified yellow ligament, screw planning and bone quality. CT scans are useful to look for ossifications and to plan surgery. The choice of approach (anterior, posterior or combined) cannot be discussed without CT analysis. If the compression is mainly due to posterior elements such as facet joint osteophytes or ossification of the yellow ligament, a posterior approach may appear as an option. Conversely, disc herniation or in certain cases of posterior longitudinal ligament ossification, may be more accessible through an anterior approach. However, in most cases, compression has multiple causes; computed tomography remains mandatory for surgical planning [13].

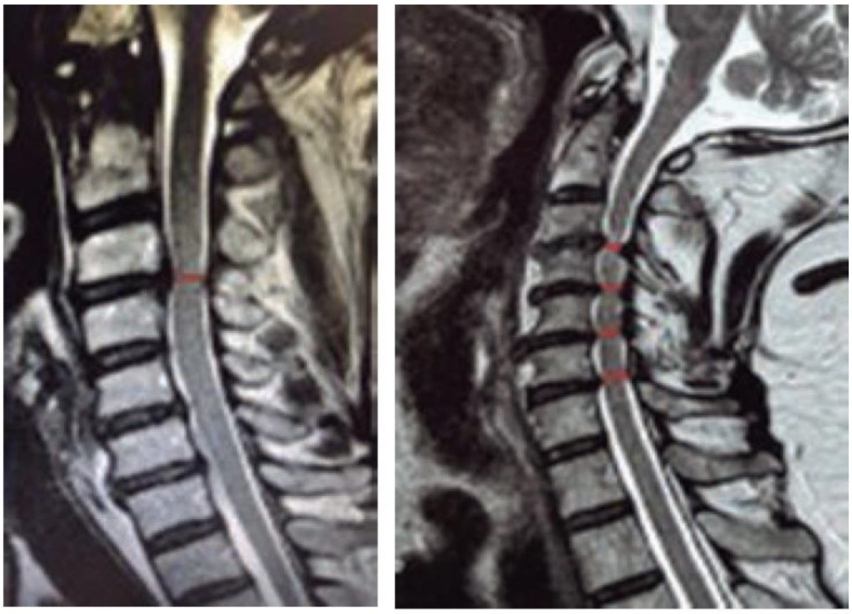
Magnetic Resonance Imaging

Magnetic resonance imaging can visualize neural, bone and soft tissue structures with high resolution and is commonly used to confirm the diagnosis of cervical degenerative myelopathy. Magnetic resonance imaging can clearly delineate the degree of canal degeneration and stenosis, identify spinal cord compression, and detect intramedullary lesions with signal changes. It is also one of the most valuable tools for differentiating between cervical degenerative myelopathy and other causes of neurologic dysfunction because it can detect anatomic changes of the spinal axis and parenchymal abnormalities, including neoplasms, demyelinating plaques and syringomyelia. Unfortunately, magnetic resonance imaging is contraindicated in the case of metallic foreign bodies, aneurysm clips, embedded wires, stimulators or batteries, nitroglycerin patches, pacemakers, or severe claustrophobia[1].

Relevant magnetic resonance imaging findings include anteroposterior diameter, compression ratio and cross-sectional area of the spinal cord, T1 signal hypointensity, T2 signal hyperintensity, T2 signal change segmentation, cerebrospinal fluid (CSF) column effacement, and spinal cord deformity (Figure 5). Magnetic resonance imaging also plays a role in surgical decision making and may be useful in predicting postoperative outcomes [1].

As a tool for surgical planning, anatomic magnetic resonance imaging allows visualization of the origin (anterior versus posterior) and degree of spinal cord compression, and the number of levels at which the spinal cord and/or exiting nerve roots require decompression. The modified K-line, based on mid-sagittal sagittal magnetic resonance imaging, predicts whether a posterior approach will achieve sufficient decompression or whether anterior decompression is necessary. In addition when planning spinal fusion procedures, the degree of degeneration of adjacent levels should be taken into account [14].

Figure 5 Examples of measurement of the cervical spinal canal: simple magnetic resonance imaging of the cervical spine weighted in T2 in sagittal section. [5]



Diffusion Tension Tractography

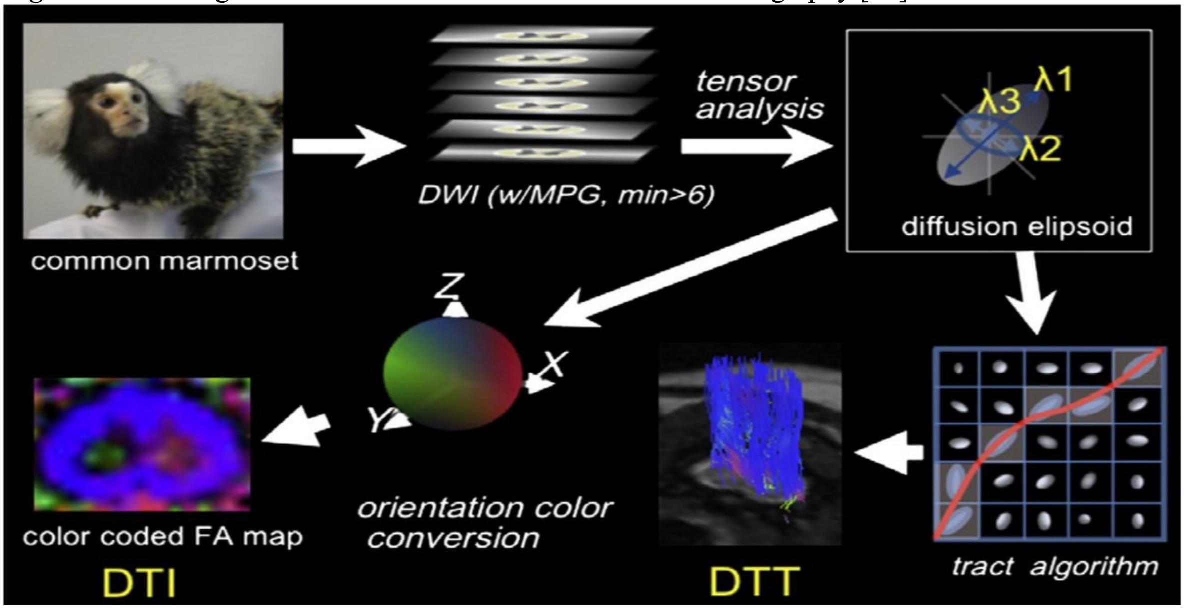
Magnetic resonance imaging has become widely accepted as an excellent method for examining the spinal cord. Diffusion magnetic resonance imaging, which takes advantage of the diffusion of water molecules, is also a widely recognized technique in medicine. Reports on diffusion magnetic resonance imaging of the brain were first published in the 1980s. In these techniques,"diffusion" refers to the Brownian motion of water molecules [15].

Diffusion tensor imaging is an emerging neuroimaging technique that may be useful for detecting early stages of myelopathy, predicting disease progression, and assessing surgical prognosis. Two important parameters measured by diffusion tensor imaging are the apparent diffusion coefficient and fractional anisotropy. Both measurements can provide information about the structural integrity of the spinal cord: lower fractional anisotropy values and higher apparent diffusion coefficients are generally present in patients with myelopathy. Several studies have also shown that diffusion tensor imaging is more sensitive and specific than conventional magnetic resonance imaging and, as a result, may have superior diagnostic capability and better correlation with initial severity scores. In particular, diffusion tensor imaging can detect damage to white matter tracts before a signal change is identified on a T2-weighted MRI [1].

Tractography is a magnetic resonance imaging technique that allows the mapping and, consequently, the evaluation of different white matter tracts in the central nervous system. Several methods are used to reconstruct the fibers, one of them called "fiber mapping using continuous locations" which is based on a linear propagation algorithm that uses the local tensor information for each propagation measurement; the refinement of linear propagation techniques using continuous field ranges has provided the connection that follows the white matter fiber tract. The final step in this process is the co-registration of the white matter tracts in three dimensions on T2 images using software called "automated image registration" [16,17]. Cervical spondylotic myelopathy is a clinical diagnosis based on the description of chronic spinal cord compression in a stenotic canal as a result of spondylosis and/or disc degeneration with subsequent neurological deficit. However, the wide range of clinical signs and symptoms and nonspecific information from anatomic magnetic resonance imaging have made it difficult to make an accurate diagnosis of cervical degenerative myelopathy.[18,19] In addition, the wide range of clinical signs and symptoms and the nonspecific information from anatomic magnetic resonance imaging have made it difficult to make an accurate diagnosis of cervical degenerative myelopathy.[18,19]

The most common parameters evaluated in a study are fractional anisotropy and mean diffusivity. Fractional anisotropy is a parameter that measures the tendency of water to spread in a preferred direction within a group of axons. It is a function of the axonal density and integrity of the white matter fibers, as well as their degree of myelination. Mean diffusivity differs in that it measures the diffusion of water molecules in three dimensions. A higher value of mean diffusivity would indicate a lower amount of cell membranes that hinder the movement of water molecules, as would be the case when there is loss of axonal fibers or edema or vasogenic necrosis. In this regard, it has been shown that it may provide new insights into the diagnosis of cervical spondylotic myelopathy and cervical spinal cord injury (Figure 6)[15].

Figure 6: For image construction with diffusion tensor and tractography [15]



Diffusion tensor tractography, being a noninvasive technique, shows better sensitivity compared to conventional T2 sequence in the early detection of cervical spondylotic myelopathy. Tractography has better sensitivity compared to plain and conventional T2 sequence in the early detection of cervical degenerative myelopathy, as it shows abnormalities in the spinal cord before the development of T2 hyperintensity in patients with cervical degenerative myelopathy. Tractography patterns are not related to the severity of myelopathy, but postoperative neurologic improvement was more common in patients with intact fiber tractography than in those with disrupted fiber tractography. Fiber tractography also revealed that traced fibers were laxly organized in myelopathic spinal cords, with short or disoriented fibers (Figure 7)[, compared with normal spinal cords [19,20,21].

Several reports on diffusion tensor tractography in cervical myelopathy have been published recently and it was reported that the parameters were significantly different in compressive myelopathy and normal volunteers, and that diffusion tensor tractography is more sensitive than conventional T2-weighted imaging. Quantitative fiber tractography analysis is a reliable approach to detect cervical spondylotic myelopathic lesions compared with healthy spinal cord [20].

Figure 7.

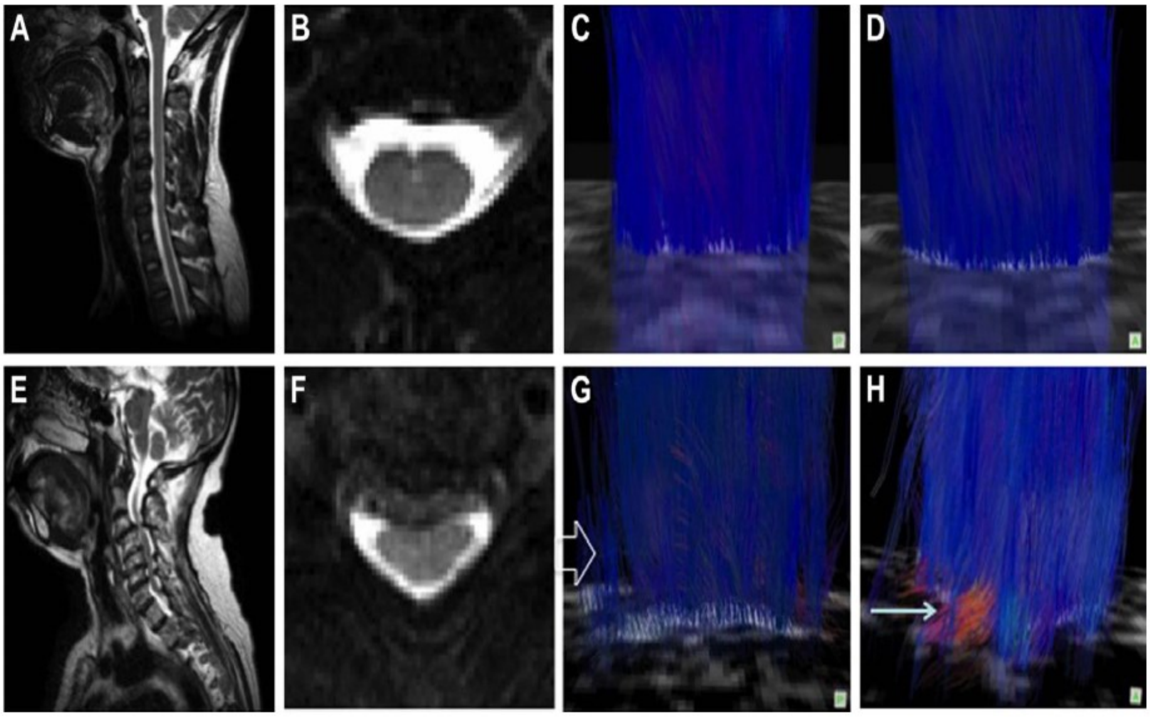


Figure 7. Representative T2-weighted anatomical images (A, B, E, F), diffusion tensor fiber tractography (C, D, G, H) showed microarchitecture of healthy (A~D) and myelopathic (E~H) spinal cord. The traced fibers were observed to be freely arranged in the myelopathic spinal cord (block arrow) or disoriented (white arrow) from the ventral (C, G) or dorsal (D, H) view of the spinal cord. [20]

Differential diagnoses

Several conditions may present similarly to cervical degenerative myelopathy. An alternative diagnosis should be suspected if the sensorimotor findings do not correspond with the degree of spondylosis and/or cervical spinal cord compression seen with magnetic resonance imaging. Absence of sensory symptoms indicates the possibility of motor neuron disease (e.g., amyotrophic lateral sclerosis), neuromuscular junction disease (e.g., myasthenia gravis), or myopathy (e.g., inclusion body myositis). Muscle and fasciculations occur more frequently in amyotrophic lateral sclerosis. Peripheral nerve entrapments, such as carpal tunnel syndrome or cubital tunnel syndrome, may mimic cervical degenerative myelopathy; however, these conditions cause sensory and motor symptoms only in the mid and ulnar area, whereas cervical degenerative myelopathy usually causes long tract signs, sensory symptoms in a dermatome, gait deficits, bladder dysfunction and/or bowel dysfunction. Other differential diagnoses include demyelination. Diseases (for example, multiple sclerosis or neuromyelitis optica), other causes of spinal cord degeneration (for example, subacute combined degeneration), neoplasms (for example, epidural spinal cord metastatic compression or intradural tumor), spinal vascular malformations (for example, arteriovenous malformation or cavernous malformation), infectious spinal diseases (for example, epidural abscess), hereditary spinal diseases (for example, hereditary spastic paraplegia or hereditary spastic paraplegia), spinal vascular malformation (for example, spinal abscess), arteriovenous malformation or cavernous malformation), infectious spinal diseases (for example, epidural abscess), hereditary spinal diseases (for example, hereditary spastic paraplegia or spinal cerebellar atrophy) and other CNS disorders (for example, normotensive hydrocephalus) [8].

Treatment

Since these patients appear to have a typical natural history, there are some particular indications for surgical treatment. Thus, patients with gradual neurological deficits and those over 60 years of age derive significant benefits from surgical treatment. These advantages are clearer in disabled patients, although patients with mild neurological deficits have a greater tendency for their deficits to deteriorate when nonsurgical treatment is chosen [22].

Non-surgical treatment

When tailoring treatment to each patient, the initial focus should be directed at pain control and restoration of movement. Pain is usually the first complaint; Patients will often limit their activities or even immobilize themselves to prevent pain exacerbation. Immobility can quickly lead to deconditioning, resulting in further declines in activity, further deconditioning, and chronic pain. Therefore, it is crucial to encourage participation in physical therapy to regain strength and retrain proper alignment [23].

Immobilization

Activity can often lead to exacerbation of pain, causing the patient to decrease participation. A short course of cervical spine immobilization may be used initially to decrease local swelling of painful joints and soft tissues around nerve roots. While the use of collars has theoretical benefits, there is no evidence to suggest their efficacy. Their use has not limited the duration or severity of radiculopathy or decreased the degree or duration of neck pain after whiplash injury. Since their use has not been statistically delineated, we believe that the use of collars should be reserved for short cervical musculature. Overnight collar use may be helpful by maintaining proper cervical alignment throughout the night and protecting the discs from abnormal loads associated with poor posture while the patient is not in control [23].

Temperature therapy

As mentioned, heat from a cervical collar has been shown to provide subjective therapeutic benefits, but cold therapy can also alleviate discomfort due to pain and spasm. In the acute period, inflammatory changes may be exacerbated by external heat sources and should be avoided in favor of cryotherapy. After the acute pain period has begun to subside and movement has begun to return, heat may be of additional benefit [23].

Passive modalities

Massage, ultrasound, and iontophoresis have failed to demonstrate long-term efficacy. Other passive modalities that do not require any effort on the part of the patient may also be of limited value because the patient does not actively participate in his or her own recovery [23].

Traction

In the literature, traction has not been shown to show any long-term benefit. The presence of myelopathy is a contraindication to traction, as it may stretch the spinal cord and cause further damage [23].

Medical therapy

Nonsteroidal anti-inflammatory drugs.

Nonsteroidal Anti-inflammatory Drugs are the most common intervention prescribed for chronic non-malignant pain in the United States and should be considered first-line pharmacotherapy for the patient presenting with cervical spondylosis and radiculopathy. The mechanism of action is aimed at decreasing prostaglandin synthesis, thereby decreasing the inflammatory response. It also has analgesic properties. There are many drugs on the market today that do not require a prescription and have safe side effect profiles, but there are risks associated with long-term use, including hepatic, cardiac, renal and gastrointestinal problems. The low cost and relative effectiveness of these drugs make them an ideal first-line agent. Most non-steroidal anti-inflammatory drugs are over-the-counter inhibitors of cyclooxygenase-1 and cyclooxygenase-2. There is now a range of selective cyclooxygenase-2 inhibitors that avoid the side effects associated with cyclooxygenase-1 inhibition, including gastrointestinal problems and platelet dysfunction. However, selective cyclooxygenase-2 inhibitors have not been shown to be more effective than their nonselective relatives in controlled trials of osteoarthritis [23].

Oral Corticosteroids

Like Nonsteroidal Anti-inflammatory Drugs, corticosteroids are used for their anti-inflammatory properties. However, unlike non-steroidal anti-inflammatory drugs, corticosteroids do not possess analgesic properties. Corticosteroids, used systemically, are often administered to patients with acute neck or arm pain. Oral tapering is used more frequently with good anecdotal results but little clinical data. Theoretically, their anti-inflammatory properties should decrease any inflammation surrounding the affected nerve roots and may decrease radicular pain. They are thought to be more effective in treating radicular arm pain than axial pain, but no long-term benefit has been shown to change the natural history of the disease [23].

Opioids

Opioid analgesics should be used with caution in patients with axial neck pain. There is a role here for their use in the acute setting of pain exacerbation, but because of their addictive nature and because of their tolerance-developing properties, they should not be used by the spine surgeon to treat chronic neck pain. Opioids are best reserved for acute situations as an innovative treatment to supplement nonsteroidal aniti-inflammatory drugs or in patients who cannot tolerate them. Once an acute exacerbation of pain is controlled, weaning should be initiated immediately [23].

Neuropathic pain

Amitriptyline is an antidepressant that is commonly used in patients with cervical disc disease. Its benefit is multifactorial in that it is able to treat depression, insomnia and pain, all of which can be associated with chronic neck pain. Gabapentin is an anticonvulsant drug that is frequently used to treat radicular pain. Although the mechanism has not been fully described, it is an analog of the neurotransmitter γ-aminobutyric acid (GABA) and is currently approved by the Food and Drug Administration (FDA) to treat neuropathic pain.[23] It is also used in the treatment of neuropathic pain.[23] In addition, gabapentin has been shown to be effective in the treatment of pain

Muscle relaxants

Muscle spasm can be a major component associated with degenerative disease of the cervical region, and antispasmodic medications are commonly prescribed. Like opioids, muscle relaxants tend to cause sedation and fatigue, and are increasingly recognized for their abuse potential. Their depressant effect may be more pronounced when administered concurrently with opioids. Muscle relaxants should only be used as short-term treatment because they may affect the patient's ability to participate in rehabilitation [23].

Physical therapy

During the long-term course of the disease, there are inadequate data to demonstrate whether physical therapy can alter the natural history of cervical radiculopathy. However, several shortterm studies have shown good results. In the acute pain period, patients may find it difficult to participate in aggressive therapeutic regimens. A graded program of physical therapy is commonly prescribed for these patients, beginning with initial passive modalities, and progressing to active modalities to regain strength lost during any immobilization. After the initial passive and isometric phase, resistance and active range of motion exercises are usually added as tolerated by the patient. An expanded program may be instituted that addresses whole body weaknesses but focusing on the neck and shoulder girdle to improve biomechanics and posture. Aerobic conditioning can also be helpful in alleviating symptoms, but ideally should be limited to low-impact activities such as walking, biking, swimming, and elliptical bikes. Once the patient has become familiar with the exercises, the program will range from recovery to prevention in a long-term home exercise regimen. It will include simple exercises that can be easily performed on a daily basis with inexpensive equipment found at home [23].

Injections

Based on the current literature, cervical spine steroid injections can be expected to produce 50% to 80% good to excellent results in patients with cervical radiculopathy. However, unlike the lumbar spine, there is a paucity of studies to adequately assess the true efficacy of cervical injections. The effects of steroids are multifactorial: anti-inflammatory effect, with inhibition of prostaglandin synthesis; interruption of nociceptive input from somatic nerves; a direct membrane stabilizing effect; blockade of neuropeptide synthesis; sympathetic blockade; blockade of C-fiber activity in the dorsal root ganglion. Steroid injections into the epidural space are a mainstay of treatment of lumbar degenerative disease. However, in the cervical spine there is little well-designed literature to adequately judge clinical effectiveness. In a variant of epidural steroid injections, selective nerve root blocks are targeted to a specific nerve root in a steroid injection. These injections can be considered more localized. We found 60% good to excellent results 21 months after injection. Like surgery, cervical injection therapies are an invasive measure and there are well-documented complications that can result, including infection (1-2%), neurological impairment, intravascular injections (7.9-11.6%), cerebrospinal fluid fistulas (0.4-11.6%), persistent positional headaches (28%), arachnoiditis (6-16%), hydrocephalus, gas embolism, urinary retention, allergic reactions, stroke, blindness, hematomas, seizures, and death. In practice, the risks of injection. should not be taken lightly; therefore, it is necessary to discuss the risks and benefits with the patient [23].

If injection therapy is continued, there are several strategies to help minimize the incidence of complications. Using an interlaminar approach at C6-C7 or C7-T1 may be safer, because the epidural space is usually larger there [23].

Although it is still unclear whether patients with mild degenerative cervical myelopathy benefit from surgery compared with conservative treatment, patients with moderate to severe degenerative cervical myelopathy or progressive neurological deficits definitely do. The decision to proceed with surgery should consider the patient's age, initial function, severity of symptoms, and historical rate of progression [24].

Surgical treatment

Prolonged spinal cord compression can cause irreversible damage and the results of surgical. treatment are better when early intervention is performed. Surgical intervention can be considered in two anatomical areas: the upper cervical spine (C0-C2) and lower cervical spine (C3-C7), and through three general approaches: anterior, posterior, anterior and posterior (360°). Surgical procedures commonly performed to treat cervical degenerative myelopathy are anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), cervical arthroplasty, laminectomy and laminoplasty. The appropriate choice depends on the presence of preoperative pain (cervicalgia), the level and degree of spondylotic change, sagittal alignment and spinal stability, individual characteristics and surgical experience. Regardless of the procedure chosen, the goals of surgical treatment are to decompress the spinal cord and its circulation, preserve spinal alignment and stability, and prevent further neural injury [25].

In summary, a large body of literature has shown that surgical treatment of cervical degenerative myelopathy has the potential to improve outcomes and to maintain them after a long period of follow-up.[25] In addition, a large body of literature has shown that surgical treatment of cervical degenerative myelopathy has the potential to improve outcomes and to maintain them after a long period of follow-up.[25]

Anterior cervical approach

The anterior cervical approach was described by Smith and Robinson in 1955. It allows for excellent exposure of the ventral aspect of the spinal cord without touching the neural elements[20] . Anterior cervical surgery is one of the most common spine surgeries performed in the U.S. and is used primarily to treat cervical degenerative myelopathy in one-, two-, or three-level disease. With the anterior cervical approach, it is also possible to perform disc space distraction that can enlarge the neural foramen and spinal canal (indirect decompression), direct decompression by removing the damaged disc, vertebral body or ligaments, as well as restoration of cervical lordosis.

The use of autografts or allografts in the disc space is important to achieve fusion [26,27]. Fusion is important to maintain the height of the disc space without collapse, maintaining cervical lordosis, and also for the stabilization of the segments involved, avoiding new additional compressions. The anterior approach allows the elimination of compression, either with a simple discectomy or with more extensive decompression techniques, such as hemicorpectomy, corpectomy or multilevel corpectomies. Foraminotomies can also be successfully performed from an anterior approach by decompressing or completely removing areas of the uncovertebral joint. In cases where ventral cord compression involves a major component of the vertebral body, beyond the limits of the disc, a cervical corpectomy is necessary to adequately decompress the spinal cord, followed by reconstruction and stabilization. An intersomatic device such as titanium, PEEK, allograft or autograft (obtained from the iliac crest or fibula) is used for reconstruction and fusion[28].Certain risks are associated with the Smith-Robinson approach, regardless of the spinal procedure performed. Esophageal perforation is a devastating complication that can occur as a result of inadequate retractor placement or injury.

Esophageal perforation is a devastating complication that can occur as a consequence of inadequate placement of the retractor or inadvertent injury with a sharp instrument or burr. The incidence is estimated to be between 0.2% and 0.4%. Vertebral artery injury is a rare but significant potential complication of anterior cervical spine surgery. Failure to identify preoperatively an aberration in the path of the vertebral artery may increase the risk of inadvertent injury. Excessively wide corpectomies can increase the risk of vertebral artery injury, as can off-center or oblique corpectomies. Dural tears are also a possibility during anterior cervical spine procedures. Radiculopathies have also been attributed to anterior cervical spine procedures. The most frequently reported incidence is 2% to 4%.The risk of dural tear and cerebrospinal fluid fistula is 1%. The recurrent laryngeal nerve is also at risk of injury with this approach, Dysphonia, like dysphagia, is a frequent complication of anterior cervical spine surgery. the reported prevalence ranges from 1% to 51% [24].

Posterior cervical approach

Laminectomy has been the procedure of choice for the treatment of multilevel cervical myelopathy. The actual technique used for laminectomy probably does not affect patient outcome, but it is advisable to avoid placing any instruments below the medial lamina in an area of severe spinal cord compression because of the risk of worsening any neurologic injury [25]. Posterior approaches can directly decompress the posterior elements such as the yellow ligament, lamina, facet hypertrophy and also indirectly decompress the ventral elements by displacing the spinal cord posteriorly. In the posterior cervical approach, preservation of the nuchal ligament at C6 and C7 prevents postoperative cervical kyphosis. Posterolateral arthrodesis concomitant with cervical laminectomy is routinely recommended; otherwise, postlaminectomy kyphosis may occur. The incidence of postlaminectomy kyphosis ranges from 6% to 47% in adults undergoing isolated cervical laminectomy. Emerging evidence suggests that the width of C5 laminectomy performed, as well as the degree of posterior spinal cord decompression, are associated with the incidence of postoperative C5 nerve palsy [24]. Overall complication rates are estimated to range from approximately 15% to 25% in the current literature. The most common immediate complications include anemia from acute blood loss, surgical site infection, C5 palsy, and incidental durotomy[29,30].

Laminectomy

The incidence of postoperative kyphosis after cervical laminectomy can be as high as 50% and depends on many factors, such as preoperative deformity, presence of segmental instability, removal of the C2 and/or C7 lamina, extensive laminectomies, extensive facetectomies, and younger age. Because of the risk of postoperative instability, concomitant instrumented fusion is recommended to avoid deformity and its consequences, especially when treating multilevel spinal cord compression [31,32,33].

However, as previously stated, the main disadvantages of cervical laminectomy are the inability to access ventral pathologies, such as disc herniation and anterior osteophytes, and the high risk of cervical deformity (postoperative kyphosis), which may result in cervical pain [22,23], to avoid this it is advised to perform posterior arthrodesis to lateral or pedicle masses plus posterolateral fusion.

The most common long-term complications include adjacent segment degeneration, junctional kyphosis and pseudarthrosis [30].

Laminoplasty

Laminoplasty is a surgical technique proposed in the early 1970s by Japanese surgeons for the treatment of posterior longitudinal ligament ossification and congenital cervical stenosis. The goal is to widen the cervical spine canal and avoid postoperative kyphosis, but also to preserve motion at the treated levels. This preservation of motion is the potential advantage of laminoplasty compared with laminectomy and instrumented fusion, which can potentially avoid the complications associated with arthrodesis (Table 4) [1, 34] If the spinous process of C7 is not resected for laminoplasty, the lesser rhomboid, serratus posterosuperioris, and splenius of the head can be left intact. All of these muscles play an important role in cervical motion and maintenance of sagittal alignment and axial neck pain.

A radiographic marker known as the K-line, which can preoperatively predict neurologic recovery in patients with posterior longitudinal ligament ossification undergoing laminoplasty. The K-line is a straight line connecting the midpoints of the spinal canal at C2 and C7 on a lateral radiograph. If lesions of posterior longitudinal ligament ossification are found completely anterior to the K-line, they are termed K-line positive; otherwise, they are considered K-line negative. Patients with negative K-line had less posterior spinal cord damage after laminoplasty and worse neurologic recovery; therefore, anterior decompression was recommended (Figure 8). The posterior cervical approach is generally associated with higher rates of wound complications compared to anterior approaches, loss of sagittal alignment in general.

Laminoplasty is avoided in patients with kyphosis, some loss of lordosis may occur after laminoplasty, although it rarely leads to the type of severe kyphosis seen after multilevel laminectomy, neck pain associated with laminoplasty is often cited as a reason for choosing an alternative procedure, spinal cord injury is a rare but devastating complication after any type of spinal cord surgery. A special consideration for the myelopathic patient undergoing laminoplasty includes maintaining adequate cord perfusion during the hinge opening. Recurrent stenosis or premature closure was reported in the early literature at rates of up to 10% and occurred most frequently at the C5 or C6 levels [35].

Figure 8 K line representation. [5]

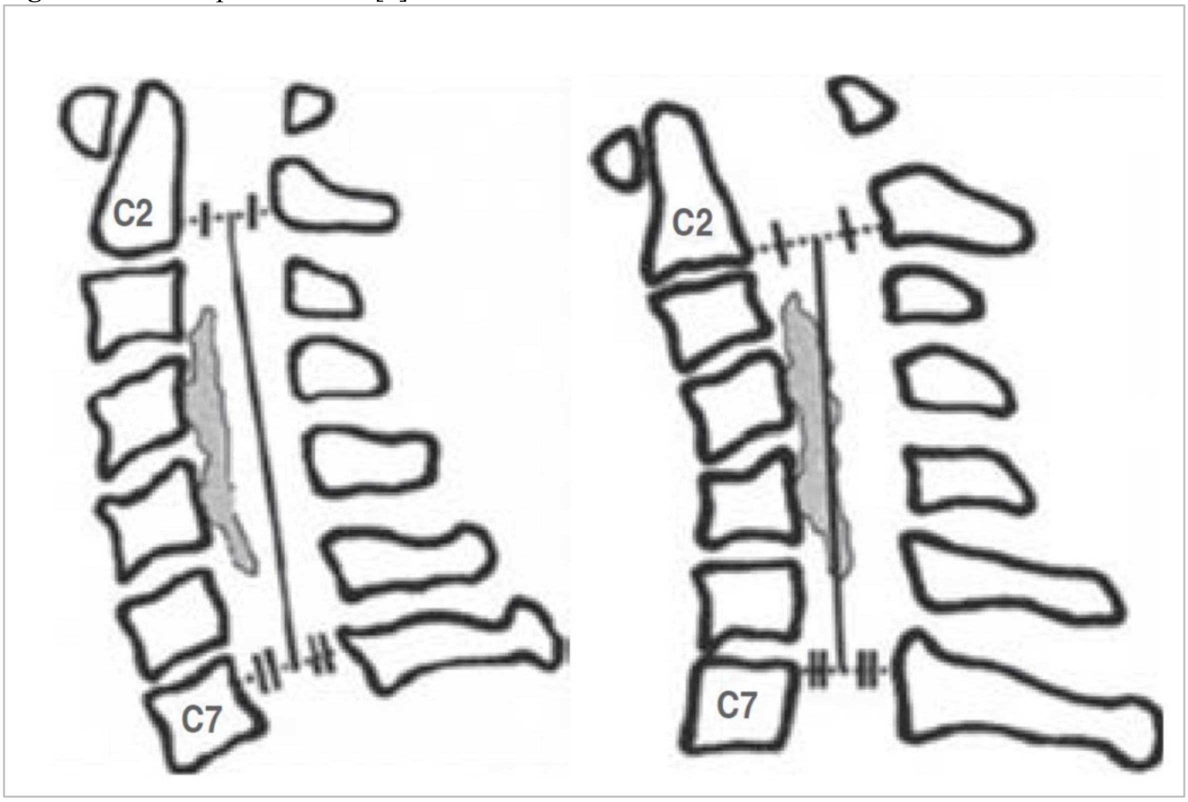


Table 4. Indications and special considerations for anterior and posterior surgery [1]

Indication and Special for anterior and posterior Surgery		
Surgical Approach	**Indications**	**Contraindications or special considerations**
Anterior diskectomy and fusion	Gold standard for treating single – to 2- level disease	Less common in patient with multilevel pathology (> 3 levels)
	Anterior pathology (OPLL, disc herniation, osteophytes)	Congenital stenosis
	Fixed cervical kyphosis> 10 °	Stenosis from posterior pathology
Laminectomy and fusion	Multilevel compression	Irreducible kyphosis
	Fixed cervical kyphosis < 10°	
	Instability is problematic	
Laminoplasty	Multilevel compression	Significant kyphosis
	Fixed cervical kyphosis <13°	Intability resulting from trauma or rheumatologic disease
		Neck pain

CONCLUSION

The diagnosis of made clinically and confirmed with cervical magnetic resonance imaging. Although conventional magnetic resonance imaging is the best modality to evaluate cervical degenerative myelopathy, it is limited by many factors, including acquisition parameters, field strength, spinal cord water content. Therefore, changes in white matter fiber tracts or spinal cord tracts cannot be evaluated. Magnetic resonance imaging is a noninvasive diagnostic imaging that can evaluate the spinal cord in the axial, coronal and sagittal planes as well as spinal narrowing. It can also detect changes in myelomalacia due to cervical spondylotic myelopathy. But CT is considered superior for evaluating spinal canal narrowing. Tractography is considered an adjunct to T2 sequence, it could reveal spinal cord deterioration in subjects with early-stage cervical spondylosis before those changes were visible on conventional MRI, thus improving clinical outcome and patient management.

The most used scales to evaluate the severity of degenerative cervical myelopathy are the Nurick scale and the modified Japanese Orthopedic Association score. Surgical treatment is the main treatment modality. The main goals of surgery are to decompress the spinal cord, maintain stability, and achieve good cervical alignment with an anticipated outcome of neurological preservation or improvement. The choice of one approach or another depends on the clinical characteristics of the patient and the surgeon's preference. Surgeons must be aware of the pros and cons of each strategy and its prognosis and must be able to propose the best possible care for each patient.

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