O r i g i n a l i n v e s t i g a t i o n s / c o m m e n t a r i e s

# Assessment of Cervical Spondylotic Myelopathy by Dynamic MRI and its Advantages over Routine MRI

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**Abstract.** Cervical spondylotic myelopathy (CSM) is the most common disease of the spinal cord that occurs during and after middle age. It has been thought that static and dynamic compressions to the spinal cord were responsible for CSM. The cervical spine is frequently examined with magnetic resonance imaging (MRI), a great non-invasive diagnostic technique. Traditional MRI tests of the spine are often carried out with the patient supine. With the outstanding soft tissue contrast and multiplanar capabilities of traditional MRI, dynamic MRI is a cutting-edge imaging method that enables patients to be studied in various positions.A prospective study was done including 35 patients. Adult patients with symptoms of CSM and were referred to undergo cervical MRI examination in Ain Shams University Hospitals MRI unit. Mean age was 50.23 ± 8.98 years. The most severe level of stenosis was found at the C5/6 level (14 cases ,40%), followed by C4/5 (8 cases, 22.9%).Total CSS score was significantly higher in extension than in neutral ($p<0.001$) and significantly higher in neutral than in flexion positions ($p=0.001$).A strong and significant negative correlation between the tCSS and MCCD in extension images was observed (Spearman's rho = -0.652, p value<0.001).A moderate and significant negative correlation between the tCSS and MCCD in flexion and neutral images was detected (Spearman's rho = -0.519 and -0.579, p value= 0.001and <0.001 respectively).Dynamic MRI is a useful tool to investigate the CSM. It provides information that can guide the treatment strategy of the patients.

**Keywords:** Dynamic MRI; cervical spine; flexion; extension.

## Background

Cervical spondylotic myelopathy (CSM) is the most common disease of the spinal cord that occurs during and after middle age which may result in a decrease in function and quality of life [1].

CSM is caused by both static compressions as well as dynamic compressions during cervical motion. Static compressions can be caused by herniated discs, spondylotic spurs, ossification of the posterior longitudinal ligament and hypertrophy of the ligamentum flavum. During flexion, the spinal cord may become compressed against osteophytic spurs and protruding discs. With hyperextension, the ligamentum flavum or laminae can pinch the spinal cord posteriorly, causing a pincer effect. Therefore, the mechanical consequences of dynamic compression on the spinal cord should not be neglected [2,3].

The rate and severity of neurologic degeneration might vary, and the best treatment practices are difficult to implement. For best results, CSM must be identified and treated quickly, before spinal cord injury develops [4].

For the examination of CSM, a plain radiograph and computed tomography (CT), which provides an exact assessment of the bone, are employed as imaging modalities. When a patient has suspected CSM, an MRI of the cervical spine is often recommended as the preferred investigation. Assessing pathological alterations in the spinal cord, vertebrae, discs, ligaments, and facet joints is made much easier by it [4,5].

Dynamic x-rays can be utilised to examine the changes that happen during flexion and extension. This test is reliable and helpful for determining the curvatures of the spine, but it has limits for disc structures [6].

Dynamic MRI can reveal movement and in-situ kinematics that conventional MRI might not be able to show. Significant contributors to the onset of CSM include cervical spinal stenosis (CSS) and dynamic changes in the spinal canal space during cervical motion [7,8].

## Aim of the study

Our research aims to compare dynamic MRI to conventional MRI to evaluate cervical spine alterations and to measure changes in the severity of cervical spine stenosis in flexion and extension compared to neutral position.

## Methods

### Study population

This study included 35 patients with cervical spondylotic myelopathy were referred for MRI assessment from September 2021 to August 2022. This prospective study was carried out after the approval of our institute's Ethical Committee of Scientific Research. All participants in this study provided informed consent and confidentiality was ensured.

The inclusion criteria included adult patients with symptoms of cervical spondylotic myelopathy and referred for MRI evaluation.

Exclusion criteria included: patients with history of recent cervical trauma, patients with previous cervical spine operations, patients with sudden onset of paraplegia or quadriplegia, patients younger than 18 years and patients with contraindications to MRI, e.g.: claustrophobic patients, pacemaker

**MRI examination**

MRI examination was performed using one of 1.5 T machines (Achieva, Philips medical system or Enginea, Philips medical system). Detailed explanation of the procedure. Patients were subjected to full history taking and informed consents were obtained. The patients were asked to remove any metallic structure before entering the MRI room.

**Nurick score**

The original six-grade disability classification proposed by Nurick is based on difficulty of walking on presentation. These grades are rated as follows: **Grade 0,** signs or symptoms of root involvement without evidence of spinal cord disease. **Grade 1**, signs of spinal cord disease but no difficulty in walking. **Grade 2,** slight difficulty in walking which did not prevent full-time employment. **Grade 3,** difficulty in walking which prevented full-time employment or the ability to do all housework, but which was not so severe as to require someone else's help to walk. **Grade 4,** able to walk only with someone else's help or with the aid of a frame. **Grade 5,** chair-bound or bedridden.

**Imaging Technique**

The patient was positioned supine and had a 20 channel dedicated phased array coil installed on his neck. He remained in this posture until the conclusion of the standard axial T1 and T2 WIs and sagittal T1 and T2 WIs of the traditional MRI sequences. The patient was then instructed to bend his neck, at which point T2 sagittal WIs were acquired, and then to extend his neck, at which point T2 sagittal WIs were acquired. The rigidity of each patient's cervical spine restricted the angles of flexion and extension to prevent any neurological affliction. The angles were not uniform for all individuals since each patient selected his or her most comfortable flexion and extension postures.

**Data Interpretation**

Image data were interpreted by at two radiologists

- **The total cervical spinal stenosis (tCSS) score** was defined as the sum of CSS grades from the vertebral segments C2/3 to C7/T1. It is a semi quantitative score MRI-based grading system that measures the degree of spinal canal stenosis that ranges from 0 (no stenosis) to18 (severe stenosis). Total CSS score was determined in sagittal T2 in flexion, neutral, and extension positions by two observers, and was used as a measure of spinal stenosis.

**The CSS grade was categorized as follows:**

**Grade 0,** no spinal stenosis.

**Grade 1**, more than 50% of subarachnoid space obliterated without signs of spinal cord deformity.

**Grade 2,** cord deformity without signal change on the spinal cord.

**Grade 3,** increased signal intensity on the spinal cord in T2-weighted image.

- **Cervical spine Cobb angle (C2–C7)** was measured in flexion, neutral, and extension positions by two observers.
- **Mean cervical canal diameter (MCCD):** The mean of the anteroposterior diameters of the cervical canal in the mid-sagittal magnified (x3) T2 MRI images measured in mm from the midpoint of the posterior margin of the disc space to the posterior hypo intense ligamentum flavum and perpendicular to the cord oppositeC2/3 to C6/7 discs.
- **Disc height (at the stenotic level):** The greatest distance between the inferior and superior endplates of two adjacent vertebrae is where this is measured.
- **Statistical analysis**

Analysis of data was done using IBM SPSS (Statistical package for social science) program version 23. To describe the studied sample, quantitative data were presented as mean, median and standard deviations. Qualitative data were presented as count & percentage. The Fisher's exact testwas used for testing relationships between qualitative variables. The Paired t-test was used to assess the statistical significance of the difference between two means measured twice for the same study group. The Correlation analysis (using Spearman's rho method) was used to assess the strength of association between two quantitative variables.

## Results

### Demographic Data

Out of the 35 adult patients participated in the study, 18 were males (51.4 %) and 17 were females (48.6%) **(Figure 1)** with age ranging from 30 to 68 years (mean age was 50.2 years with SD of 8.9).

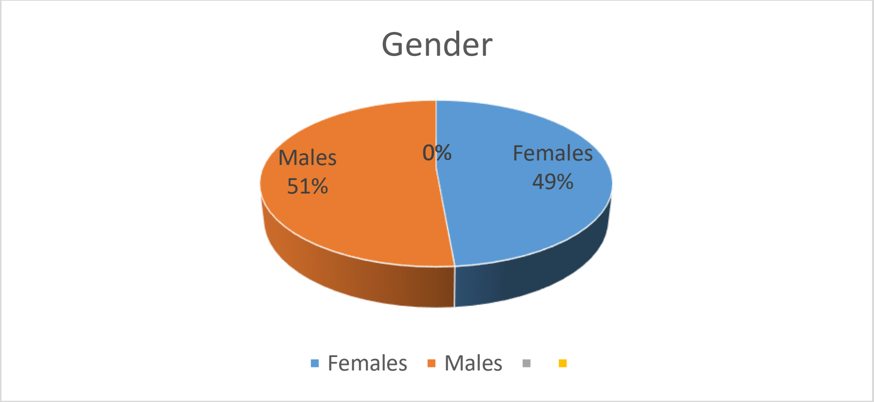


**Figure 1.** Shows sex distribution for the study group.

### Clinical data

Most patients (82.9%) manifested mild symptoms of Nurick grade 0 to 1. (Figure 2).

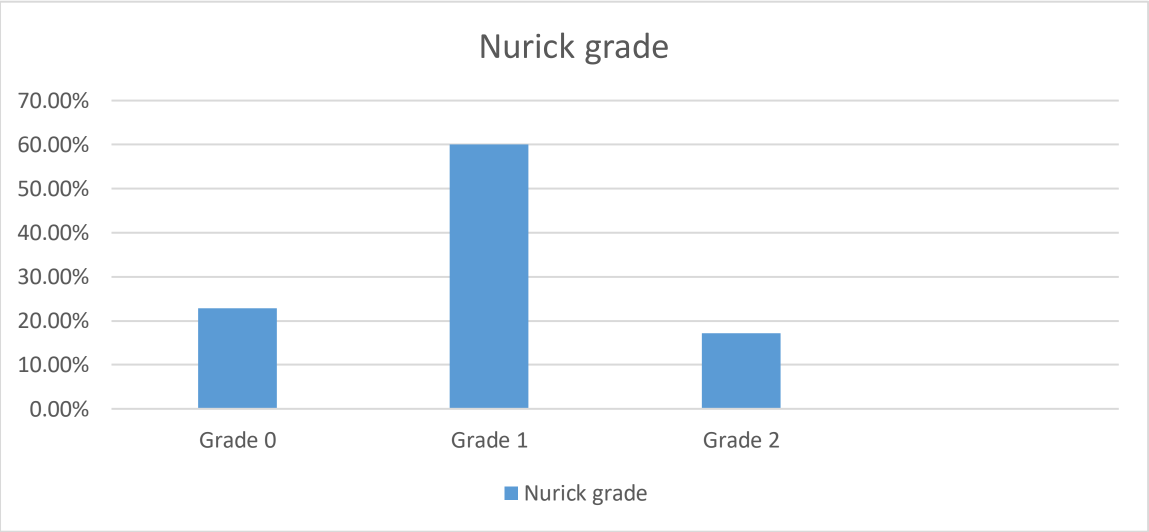


**Figure 2.**Shows Nurick grade the study group.

The neck pain was the most common complaint of the patient (32 cases, 91.4 % cases), followed by upper limb sensory symptoms (16 cases, 45.7%) (Figure 3). The median symptom duration of 5 months, ranging from 1-24 months.

Hypertension was the most frequent comorbidity among the patients of the study (12 cases, 34.28 % cases), followed by diabetes mellitus (8 cases, 22.85%).(Table 1).

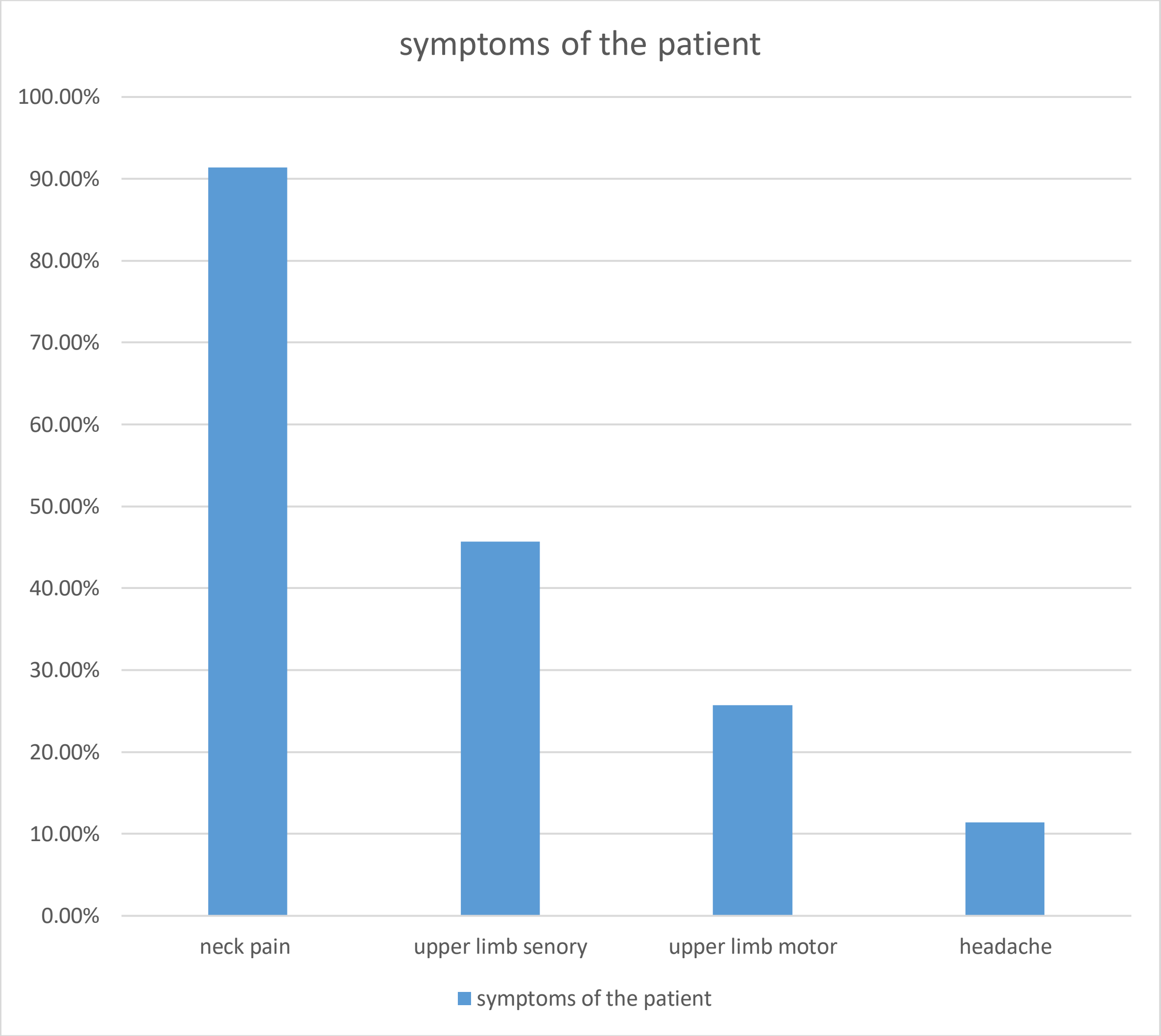


**Figure 3.** Symptoms of the patients.

**Table 1.**Comorbidities of the patients.

| **Comorbidities** | **Number of cases** |
|---|---|
| Hypertension | 12 cases, 34.28 % |
| Diabetes mellitus | 8 cases, 22.85% |
| Dyslipidemia | 3 cases, 8.57% |
| Hypothyroidism | 1 cases, 2.8% |

## Analysis of the MRI findings

### Intervertebral discs

The greatest Pfirrmann grade between C2/3 and C7/T1 segments was noted when the intervertebral cervical discs' degradation was evaluated. (Figure 4).

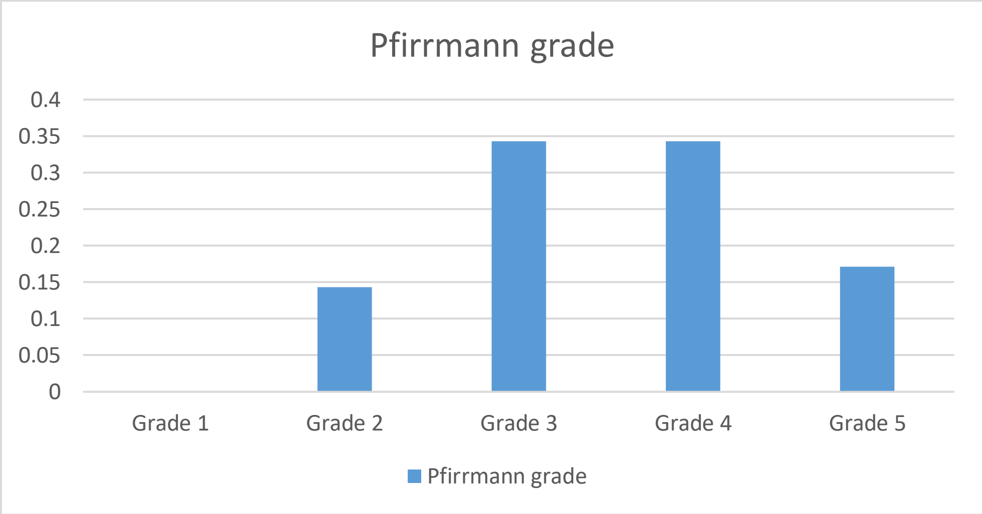


**Figure 4.** Highest Pfirrmann grade of the intervertebral discs.

### Most severe disc affection

The levels of stenosis in the cervical intervertebral discs were identified and documented. If cervical canal stenosis of the same degree was discovered at more than one level, further levels were recorded. The C5/6 level was the level with the greatest amount of stenosis (14 cases, 40%), followed by the C4/5 level (8 instances, 22.9%), while the C6/7disc level was the level with the greatest amount of stenosis in 7 patients (20%) and in 5 patients (14.3%), respectively. (Figure 5).

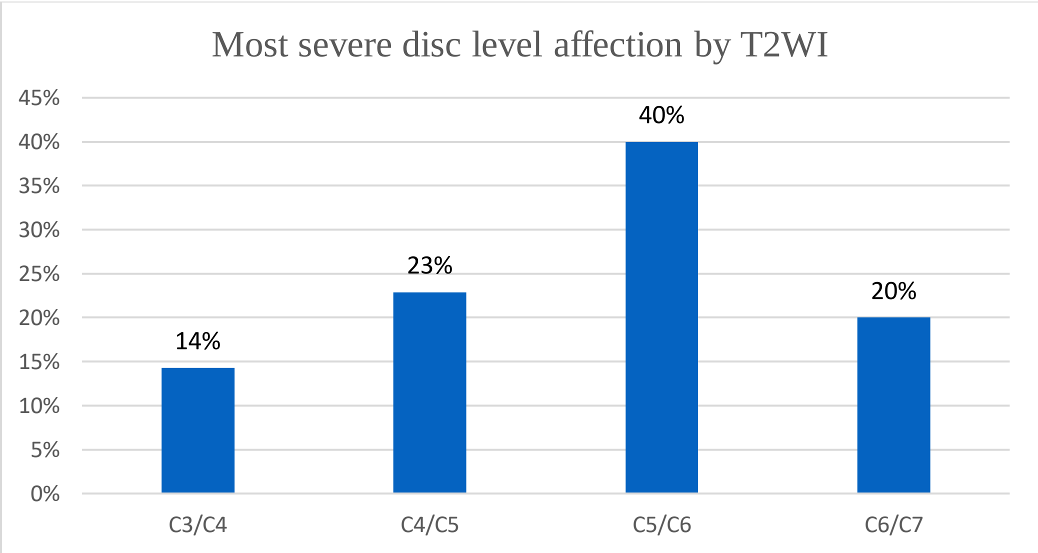


**Figure 5.** Shows most severe disc level affection by T2WI.

### Total cervical spinal stenosis (tCSS)

Between the two observers and at various MRI locations, the tCCS was compared. The measured tCCS for each MRI location did not reveal any appreciable interobserver variation. The Total CSS score was, however, considerably greater

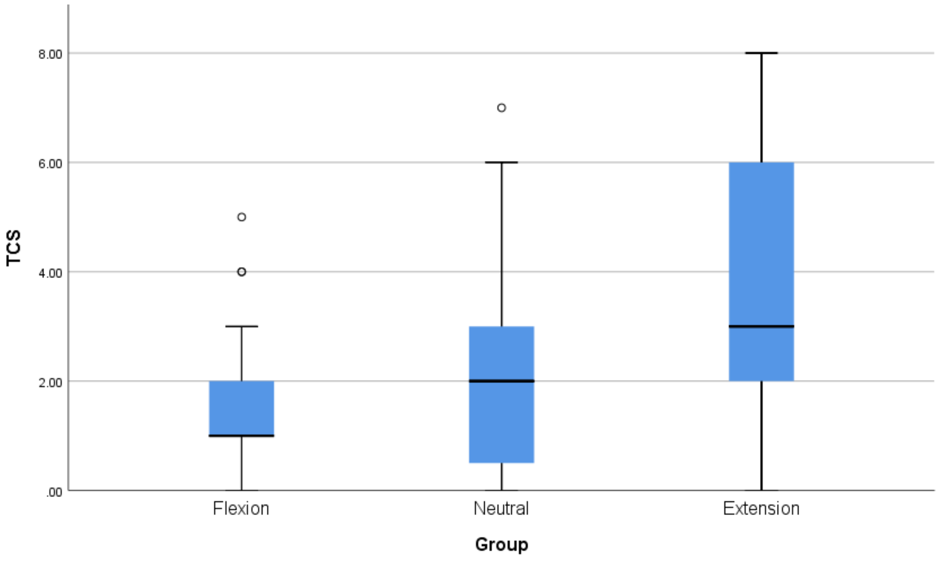


**Figure 6.**Total cervical spinal stenosis (CSS) score in flexion, neutral, and extension positions.

for each observer in the neutral position compared to the flexion position (p=0.001) and in the extension position compared to the neutral position (p0.001).(Table 2, Figure 6).

**Table 2.** Total cervical spinal stenosis (CSS) score in flexion, neutral and extension positions

| **(tCSS)** | **Mean ± SD** | **Median (IQR)** | **Range** |
|---|---|---|---|
| Neutral position | 2.14 ± 1.85 | 2 (0 - 3) | (0 -7) |
| Flexion position | 1.70 ± 1.37 | 1.5 (1 - 2) | (0 - 6) |
| Extension position | 3.69 ±2.15 | 3 (2 - 6) | (0 - 8) |

## Mean cervical canal diameter (MCCD)

One radiologist assessed the MCCD and looked for correlations with the tCCS in the flexion, neutral, and extension positions. In both neutral and flexion postures, the measured MCCD was considerably lower in neutral than in extension (p=0.001) and lower in neutral than in flexion (p0.001).

In extension photos, there was a high and significant negative correlation between the tCSS and MCCD (Spearman's rho = -0.652, p value0.001). In flexion and neutral pictures, a considerable and significant negative correlation between the tCSS and MCCD was found (Spearman's rho = -0.519 and -0.579, p values of 0.001 and 0.001, respectively). This indicates that as the MCCD decreased, the tCCS grade increased.

## Illustrative cases

**Case No (1)**

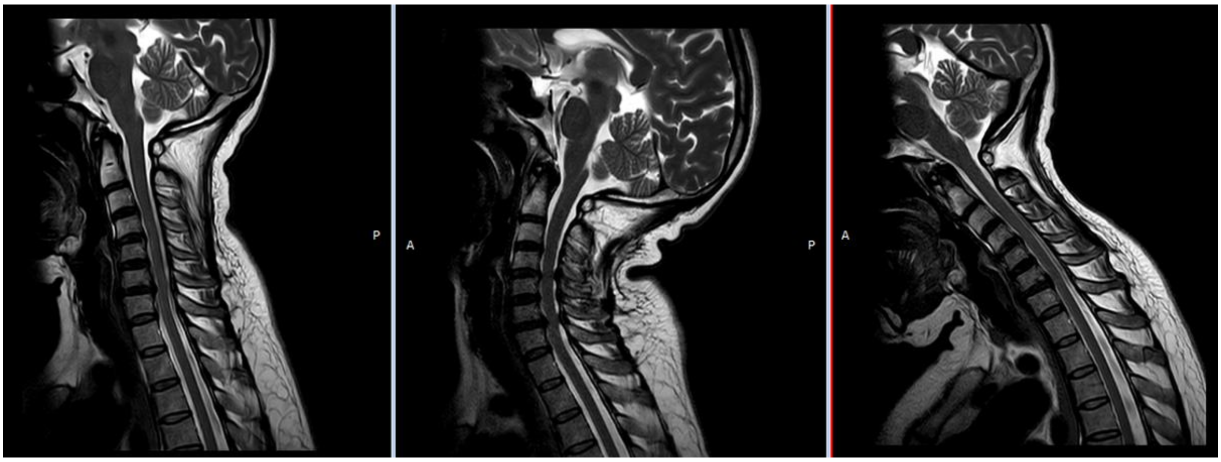


**Figure 7.** Illustrative case of cervical dynamic magnetic resonance imaging in left-to-right neutral, extension and flexion positions. In neutral and flexion positions mid sagittal images show C6-7-disc lesion touching the cord. While extension mid sagittal image demonstrates C4-5 and C6-7 disc lesions indenting the cord and buckling of the ligamentum flava opposite C4-5, C5-6 and C6-7 levels.

**Case No (2)**


**Figure 8.** Illustrative case of cervical dynamic magnetic resonance imaging in left-to-right neutral, extension and flexion positions. In neutral and flexion positions mid sagittal images show C3-4-disc lesion just touching the cord. While extension mid sagittal image demonstrates C3-4disc lesion indenting the cord.

**Case No (3)**

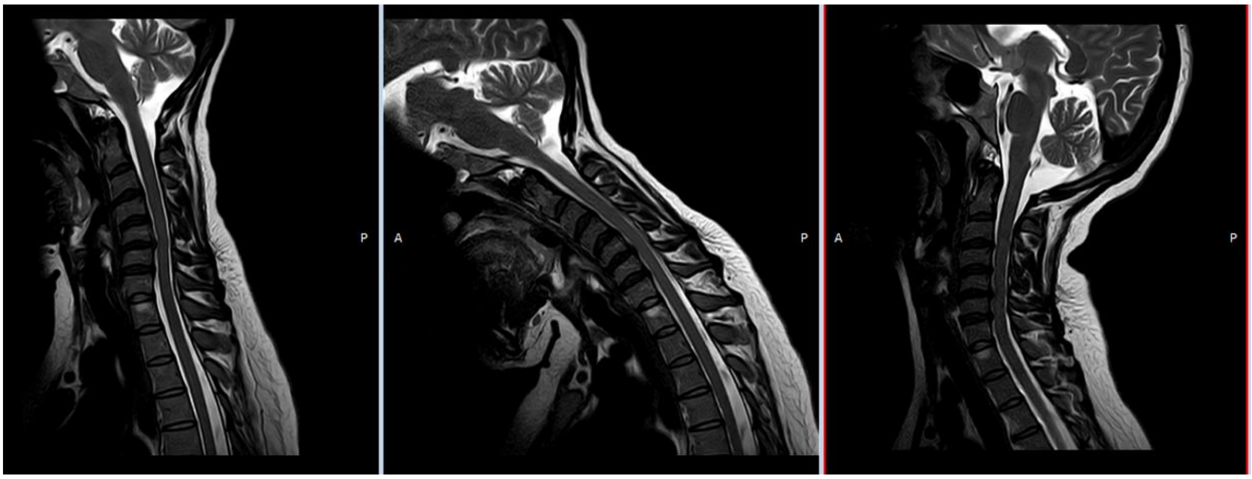

**Figure 9.** Illustrative case of cervical dynamic magnetic resonance imaging in left-to-right neutral, flexion and extension positions. In neutral and flexion positions mid sagittal images show C5-6-disc lesion touching the cord. While extension mid sagittal image demonstrates C3-4 through C6-7 disc lesions indenting the cord.

## Discussion

The most common cervical spine condition during and beyond middle age is thought to be degenerative cervical stenosis. Combining disc protrusion, facet joint degeneration, ligamentum flavum hypertrophy, and osteophyte production results in acquired cervical stenosis. These degenerative processes can affect the cord directly or indirectly by secondary ischemia alterations brought on by static compression or made worse by dynamic motions [9]. They can also occur at one or more levels.

Cervical spondylotic myelopathy (CSM) commonly leads to spinal cord (SC) injury as well as motor and sensory dysfunction and can significantly affecting the patient life [10].

The pathogenesis of CSM, a prevalent illness, is complicated and up for debate. Dynamic elements have a significant impact on CSM, as has been shown. Due to the cervical spine's flexibility, volume changes during flexion and extension are observed in the cervical canal and are most likely higher than those in the remainder of the spine. Authors have conducted kinematic MRI investigations to describe the physiological changes in the cervical cord during flexion and extension, and these studies show that the dynamic changes are reflected in the spinal canal diameter, spinal cord diameter, and subarachnoid space [9].

MRI is noninvasive and is the test of choice to evaluate cervical spondylotic myelopathy. However, careful correlation of the history and examination with imaging studies is mandatory because asymptomatic degenerative changes in the cervical spine are very common findings on advanced imaging, in particular MRI [11].

Assessment of the CSM is usually done by use of static MRI performed with the neck in a neutral position. However, the degree of radiological compression detected often does correlates poorly with clinical severity [12].

Assessing pathological alterations at the spinal cord, vertebrae, discs, ligaments, and facet joint using dynamic magnetic resonance imaging (MRI) of the cervical spine is very helpful. The accuracy of the cervical spondylotic myelopathy diagnosis is often improved by imaging the spine in flexion and extension postures [6,9].

Although dynamic cervical MRI is not in routine clinical use for assessment of CSM, it has been proven to be a good choice for assessment of the cervical spine in patient with unexplained neck pain with false negative findings in neutral position MRI examination and in cases that will undergo surgical intervention [12].

In this study, our aim was to assess changes occur during flexion and extension and compare the findings in dynamic positions with the information obtained from neutral position.

As regards the age distribution in this study population, age ranged from 30 to 68 years (mean age = 50), with the mean age being similar to the study conducted by Alkosha et al. (2022) [12] , (mean age = 50), while other study groups had a higher mean age as in the study conducted by Nigro et al. (2017) [5], where the mean age was 67 and the study conducted by Lee and Kim (2018)[8]and Makhchoune et al.(2022) [9] ,where the mean age was 57 and 57.9 respectively.

Regarding the Nurick score of the patients of the study population, we found most of the patients ranging from score 0 to 1 representing 82.9% (29 patients).The findings are similar to Lee and Kim (2018)[8], were patients ranging from score 0 to 1 representing 84.7 % ,but the results were quite different from Alkosha et al. (2022) [12] , where patients ranging from 0 to 1 only representing 54% (13 cases).

While C2/C3 disc levels were found to be unaffected in all patients included in this study and were the most distant healthy disc level, C5/6 was found to be the most severely affected disc level, affecting 40% of the patients included in the study group (n=14). These results were almost similar to Lee and Kim (2018)[8],where C2/C3 disc levels were found to be least affected levels 3.3% and C5/C6 were found to be most affected levels 70%. Makhchoune et al. (2022) [9], found almost similar results, C2-3 disc levels were found to be unaffected in all study population and C5-6 level was reported to be the most stenotic level in about 66.7 % cases. Other conducted studies such as Alkosha et al. (2022) [12] , didn't provide statistical data regarding the disc levels affection in order of severity in the study population.

Our investigation showed that the cervical canal narrowed more in the extension position and less in the flexion position when viewed from the flexion and extension perspectives. The findings are in agreement with Lee and Kim (2018) [8] and Muhle et al (1998) [13], who found that when one moved from flexion to neutral and extension postures, the severity of CSS increased. According to Lao et al. (2014) [14], cervical stenosis increased from neutral to extension views but did not significantly increase from flexion to neutral views. On the other hand, Kim et al. (2017) [15] discovered that extension improves disc prolapse by reducing spinal stenosis caused by anterior migration of the nucleus pulpous. Other studies such as Alkosha et al. (2022) [12]

demonstrated higher grades of stenosis in both flexion and extension views.

As regard the cervical spinal canal diameter, our study revealed that the canal diameter increased on flexion and decrease on extension view with inter observer agreement. The results agrees with Pratali et al. (2019)[16] found in their study about 18 cases that spinal canal diameter worsening in extension and increased in flexion.

Comparing mean cervical canal diameter and total cervical canal stenosis in different positions neutral, extension and flexion, we found strong significant negative correlation between MCCD and tCSS in extension views and moderate significant negative correlation between MCCD and tCSS in flexion and neutral positions. ***Alkosha et al. (2022) [12]*** demonstrated significant negative correlation between MCCD and tCSS in flexion, extension and neutral positions.

## Conclusions

In conclusion dynamic cervical spine MRI is considered to be an important tool for assessment of the CSM especially in cases that findings on conventional MRI did not match with clinical manifestation of the patient or before surgical intervention. In the future, flexion and extension MRI is expected to be included in the evaluation of the different cases of the CSM.

## List of abbreviations

**CSM:** Cervical spondylotic myelopathy
**CSS:** Cervical spinal stenosis
**MRI:** Magnetic resonance imaging
**tCSS :** Total Cervical spinal stenosis
**MCCD**: Mean cervical canal diameter

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