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Assessment of cervical spondylosis by dynamic MRI and its advantages over routine MRI

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ABSTRACT

Background and objectives. Cervical spondylosis is an age-related condition that influences the various components of the spine. Attributed to its exceptional tissue contrast, magnetic resonance imaging (MRI) is the preferred diagnostic modality for assessing cervical spondylosis. Dynamic MRI examination adds diagnostic information obtained from imaging the patient in flexion and extension. Our study had the purpose of evaluating the flexion-extension MRI's diagnostic utility.

Materials and methods. 40 patients with cervical spondylosis joined our prospective cross-sectional study. The patients were examined by flexion and extension sagittal T2 weighted images (Dynamic MRI) in addition to static MRI cervical spine protocol. The study was carried out in our department and lasted for two years.

Results. Total central spinal stenosis (TCSS) was considerably higher in extension in comparison to neutral MRI (Mean ± SD =6.1± 1.45 compared to 4.7 ± 1.29) ($p<0.001$) showing that extension raises the severity of the cervical spinal stenosis. TCSS was significantly decreased in flexion compared to neutral MRI (Mean ± SD = 3.2 ± 0.79 compared to 4.7 ± 1.29) ($p<0.001$) assuming flexion reduces the radiological severity of stenosis.

Conclusion. Dynamic MRI is a valuable imaging modality. It provides useful information by highlighting more central spinal stenosis, particularly in the extension position, which enhances the treatment regimens for patients with cervical spondylosis.

Keywords: dynamic MRI, cervical spondylosis, degenerative, disc bulge

List of abbreviations (in alphabetical order):

CS – Cervical spondylosis
CSS – Central spinal stenosis
GRE – Gradient recalled echo
MRI – Magnetic Resonance Imaging
P value – Probability value
SD – Standard deviation
T1WI – T1 weighted image
T2WI – T2 weighted image
TCSS – Total Central spinal stenosis

INTRODUCTION

Cervical spondylosis (CS) describes a wide range of degenerative alterations affecting every component of the cervical spine, such as the facet joints, ligaments, and intervertebral discs [1].

CS is the most prevalent spinal disease that strikes people in and after middle age. Even though CS is most frequently observed in older adults, a number of other factors such as obesity, recurrent occupational trauma, genetic predisposition, and smoking can exacerbate the illness [2].

Diagnosing CS encompasses an integrated approach that consists of a detailed history, physical examination, and radiological investigations [3].

For the examination of spondylodegenerative changes, a plain radiograph and computed tomography (CT) provide an exact assessment of the bone;

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nevertheless, magnetic resonance imaging (MRI) is frequently advised as the preferred inquiry evaluating pathogenic changes in the facet joints, ligaments, discs, spinal cord, and vertebrae with higher accuracy [4,5].

Since the cervical spine is dynamic and exhibits variations in spinal canal diameter during flexion and extension, static MRI images of the cervical spine can be not accurate enough to evaluate the CS [6].

Dynamic MRI is done by imaging the participant in extension and flexion postures. It offers extra diagnostic information that aids in improving the clinician's diagnostic accuracy and the patient's treatment plan [7].

Our research aimed to estimate alterations in the grade of cervical spine stenosis during flexion and extension MRI.

MATERIALS AND METHODS

This two-year cross-sectional prospective study was carried out in our department between August 2021 and August 2023.

Study population: 40 patients were included in our study, with ages ranging from 30 to 68 (mean age 42.2 ±6.9 years). There were 17 females (42.5%) and 23 males (57.5%) in the study group.

Inclusion criteria: any adult patient (above the age of eighteen) who was referred for MRI evaluation to assess symptoms of cervical spondylosis, such as headache, neck pain, upper limb paresthesia, numbness, and/or weakness without any preference for a particular sex.

Exclusion criteria:

- Patients having a history of recent cervical trauma.
- Those who had undergone prior cervical spine operations.
- Those who had suddenly developed paraplegia or quadriplegia.
- Pediatric patients (below the age of eighteen).
- Those with MRI contraindications (such as pacemaker patients or claustrophobic patients)
- Those who could not tolerate flexion and/or extension examination.

This study was carried out after the approval of our institute's Ethical Committee of Scientific Research. Confidentiality was maintained, and informed consent was given by each study participant.

Patient preparation for MRI examination: Patients were subjected to full history taking and informed consents were obtained after clarification of the details of the examination. The patients were asked to remove any metallic structure before entering the MRI room.

Study tools and procedures:

MRI examinations were carried out in 1.5 Tesla machine, Inginea, Philips medical system using Ds head spine coil. The patient was positioned supine and maintained a neutral posture during the standard protocol including sagittal T1 weighted images (T1WIs), T2 weighted images (T2WIs) and axial T2-weighted gradient recalled echo (GRE) images.

Additional Sagittal T2WIs were taken during flexion and extension after the patient was instructed to flex his neck by placing a cushion under his posterior head and subsequently to extend it by placing a cushion under his posterior neck.

The angles of flexion and extension were not uniform for all individuals since each patient selected his or her most comfortable flexion and extension postures.

The average exam duration for a dynamic cervical spine MRI was about 18–20 min.

Imaging acquisition: The values applied in sagittal T2WIs obtained in neutral, flexion, and extension were as the following: Time to repetition /time to echo (TR/TE) = 2533/100 ms; field of view (FOV) 250 × 39 mm; flip angle 90°; slice thickness 3 mm; gap 0.3 mm. In sagittal T1WIs: the TR/TE = 417/7.8 ms; FOV 250 × 39 mm; flip angle 90°; slice thickness 3 mm; gap 0.3 mm. In axial T2 GRE the TR/TE =500/9.21 ms; FOV 170 × 155 mm; flip angle 15°; slice thickness 4 mm, gap 0.5 mm.

Image interpretation: Images were independently analyzed by three observers, of 7, 10, and 14 years of expertise in musculoskeletal radiology.

1-Neutral, flexion, and extension Sagittal T2WIs for each case were compared and levels with disc bulge were recorded with a comment on the degree of central spinal stenosis (CSS) in different positions using the Kang grading system as follows:

Grade 0, < 50% subarachnoid space narrowing or no spinal stenosis.

Grade 1, > 50% of subarachnoid space was narrowed with no signs of deformity of the cord.

Grade 2, cord indentation without T2 signal alteration.

Grade 3, high T2WI signal within the spinal cord [8].

2- The total central spinal stenosis (TCSS) score was calculated by summation of CSS degrees from C2/3 to C7/T1. It is a semi-quantitative grading system based on MRI that quantifies stenosis of the spinal canal. It ranges from zero (no stenosis) to eighteen (severe stenosis) [9].

Statistical analysis: The Statistical Package for Social Science (SPSS 27) was utilized to analyze the data. The mean, median, and standard deviation (SD) of the quantitative data were displayed. The counts and percentages were used to display the qualitative data.

The tests that were employed were as follows:

- The statistical importance of the variation between two means estimated twice for the same research group was assessed using the Paired t-test.
- The probability value (P value) was non-significant if >0.05, and significant if < 0.05.
- To ascertain inter-observer agreement, the weighted kappa (k) statistic was employed.

  Good agreement is indicated by a k value > 0.8.

  Moderate agreement is indicated by a k value of 0.8 to 0.6.

  Fair agreement is indicated by a K value of 0.6 to 0.2.

  Poor agreement is indicated by a K value< 0.2.

RESULTS

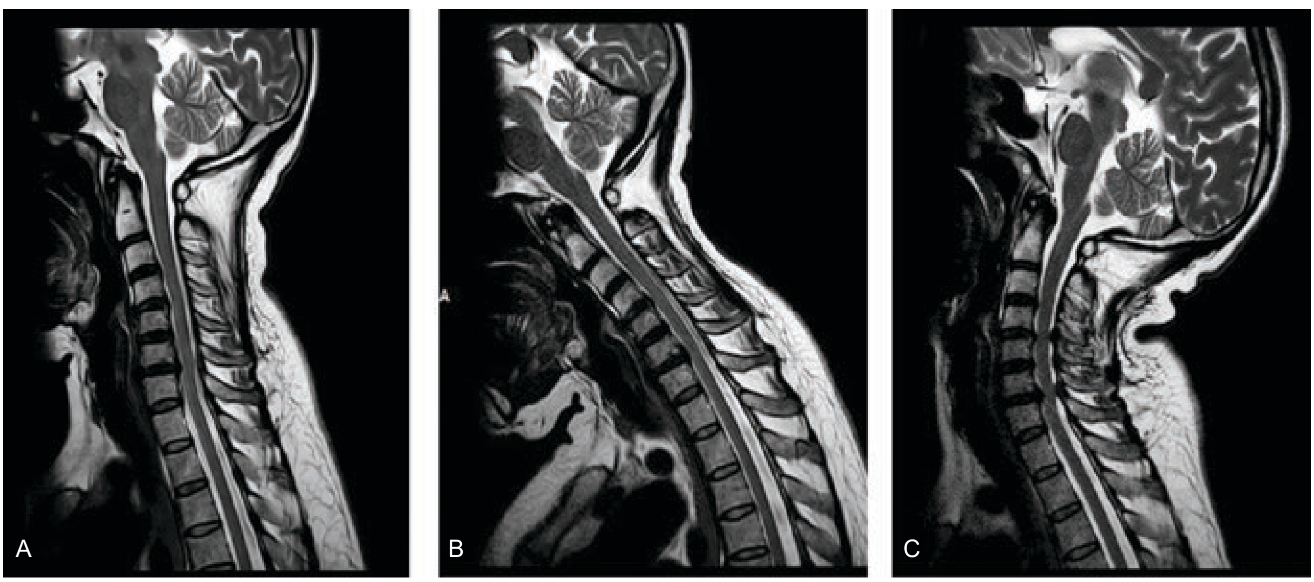
Forty participants were involved in this prospective cross-sectional study. The age range of the participants was 30 to 68 years old, with a mean ± SD of 42.2 ±6.9 years. With 57.5% of the study population being male and 42.5% being female, the male-to-female ratio was 1.35:1 (Table 1).

TABLE 1. Demographic and clinical data of the study group (Total=40)

		Mean / N	SD / %
Age		42.2 years	±6.9
Sex	Male	23	57.5%
	Female	17	42.5%
Clinical data	Headache	15	37.5%
	Neck pain	31	77.5%
	Neuropathic symptoms	22	55%
	Motor symptoms	3	7.5%
Duration of symptoms		5.66 months	±4.66

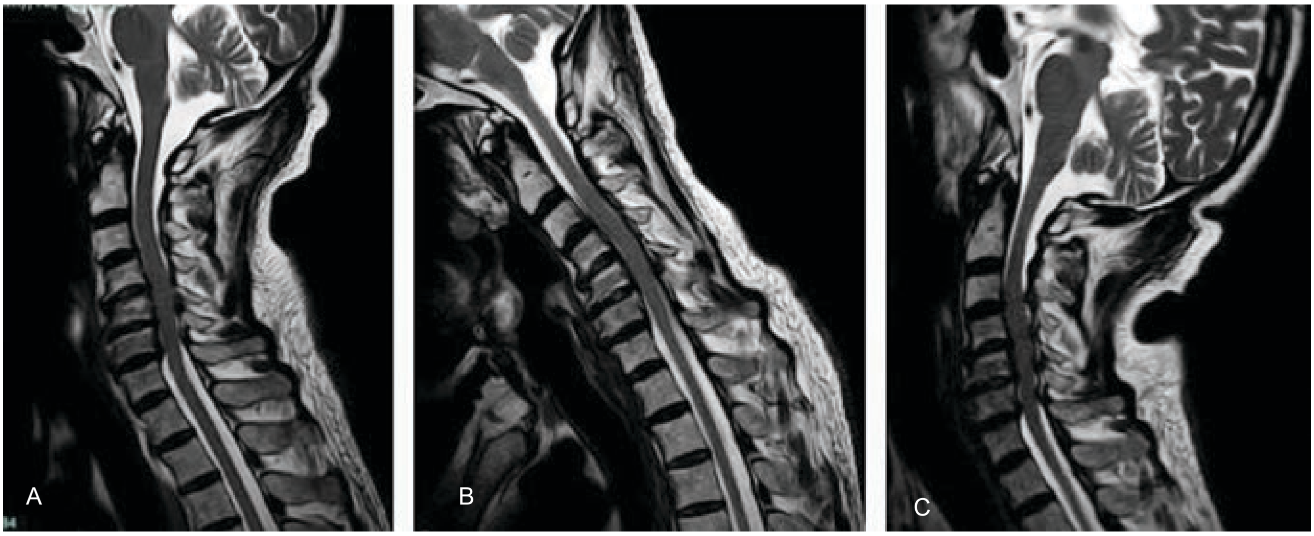
Based on the analysis of the clinical information of the included participants, neck pain was the most common symptom (31 cases, 77.5 %), followed by neuropathic symptoms (22 cases, 55%). The median symptoms' duration was 5 months, ranging from 1-24 months (Table 1).

The study included 40 patients with 6 disc levels for each (from C2-3 to C7-T1), with a total of 240 levels. Using mid-sagittal T2 WI, the levels of disc bulges in the cervical intervertebral discs were identified and graded with the Kang grading system for CSS in neutral, extension, and flexion postures (Figures 1, 2, 3, and 4).



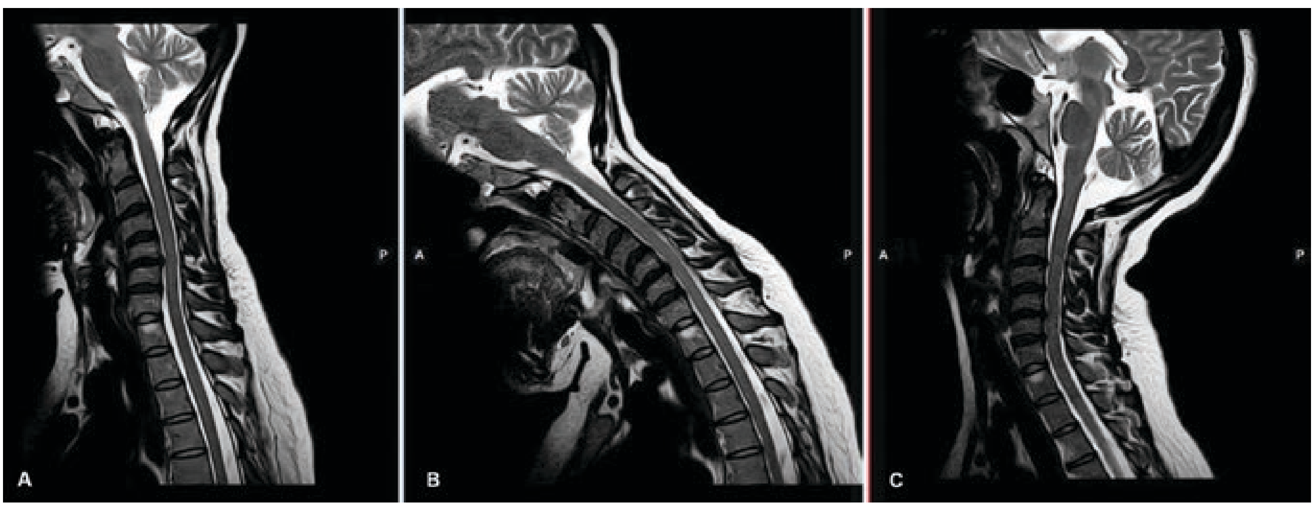
	Neutral	Flexion	Extension
C2-3	0	0	0
C3-4	1	0	1
C4-5	1	1	2
C5-6	0	0	1
C6-7	2	1	2
C7-T1	0	0	1
TCSS	4	2	7

FIGURE 1. A 36-year-old male patient complained of bilateral upper limb numbness. Mid-sagittal T2WIs in (a) Neutral, (b) Flexion, and (c) Extension positions showed degenerative disc lesions with TCSS being higher in the extension position



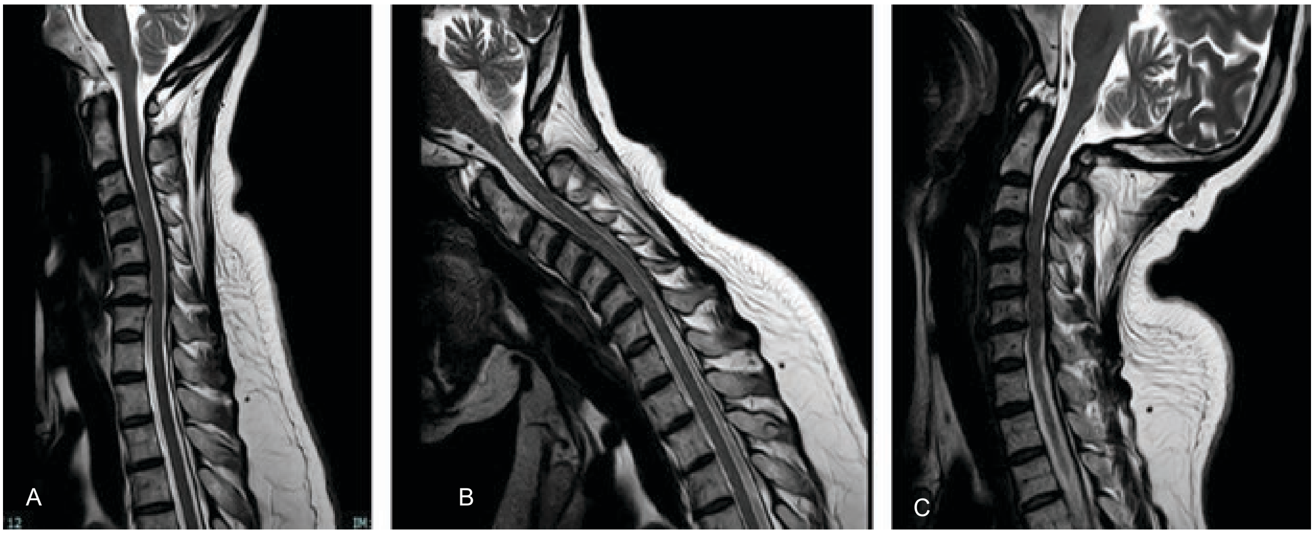
	Neutral	Flexion	Extension
C2-3	0	0	0
C3-4	1	1	2
C4-5	2	1	2
C5-6	2	1	2
C6-7	1	0	2
C7-T1	0	0	0
TCSS	6	3	8

FIGURE 2. A 53-year-old female patient presented with neck pain and right upper limb numbness. Mid sagittal T2WIs in (a) neutral, (b) Flexion, and (c) extension positions showing spondylodegenerative changes with TCSS increased in extension position



	Neutral	Flexion	Extension
C2-3	0	0	0
C3-4	0	0	1
C4-5	0	0	2
C5-6	2	1	2
C6-7	1	1	2
C7-T1	0	0	0
TCSS	3	2	7

FIGURE 3. A 42-year-old male patient presented with bilateral upper limbs numbness. Mid sagittal T2WIs in (a) neutral, (b) Flexion, and (c) extension positions showing degenerative disc lesions with the TCSS increased in extension MRI



	Neutral	Flexion	Extension
C2-3	0	0	0
C3-4	0	0	2
C4-5	1	1	2
C5-6	1	1	2
C6-7	2	1	2
C7-T1	0	0	0
TCSS	4	3	8

FIGURE 4. A 42-year-old female patient presented with neck pain. Mid sagittal T2WIs in (a) neutral, (b) Flexion, and (c) extension positions showing degenerative disc lesions with the TCSS increased in extension MRI

C2-3 disc was found to be unaffected in all the study patients and different postures (Table 2).

C3-4 level bulge was found to be of grade 0 (n=4 cases, 10%), grade 1 (n=35, 87.5%), and grade 2 (n=1, 2.5 %) in neutral position, grade 0 (n=28, 70%), grade 1 (n=12, 30%) in flexion position and grade 0 (n=1, 2.5%), grade 1 (n=36, 90%) and grade 2 (n=3, 7.5%) in extension position (Table 2).

C4-5 level bulge was found to be of grade 0 (n=3, 7.5%) grade1 (n=35, 87.5%), and grade 2 (n=2, 5%) in neutral MRI and grade 0 (n=4, 10%) and grade 1(n=36, 90%) in flexion position and grade 0 (n=2, 5%), grade 1 (n=12, 30 %) and grade 2 (n=26, 65 %) in extension position (Table 2).

C5-6 level bulge was found to be of grade 0 (n=3, 7.5%), grade 1 (n=13, 32.5%), grade 2 (n=24, 60%) in neutral position, grade 0 (n=3, 7.5%), grade 1 (n=20, 50%) and grade 2 (n=17, 42.5%) in flexion position and grade 0 (n=1, 2.5%), grade 1 (n=2, 5%) and grade 2 (n=37, 92.5%) in extension position (Table 2).

C6-7 level bulge was found to be of grade 0 (n=12, 30%), grade 1 (n=20, 50%), grade 2 (n=8, 20%) in neutral position, grade 0 (n=22, 55%), grade 1 (n=17, 42.5%), grade 2 (n=1, 2.5%) in flexion position and grade 0 (n=8, 20%), grade 1 (n=20, 50%), grade 2 (n=12, 30%) in extension position (Table 2).

C7-T1 level bulge was found to be of grade 0 (n=28, 70%), grade 1 (n=12, 30%) in a neutral position, grade 0 (n=40, 100%) in a flexion position, and grade 0 (n=23, 57.5%) and grade 1 (n=17, 42.5%) in the extension position (Table 2).

TABLE 2. Grades of cervical disc lesion in different MRI positions

Disc level		Neutral	Flexion	Extension
		N (%)	N (%)	N(%)
C2-3	Grade 0	40 (100%)	40 (100%)	40 (100%)
C3-4	Grade 0	4 (10%)	28 (70%)	1 (2.5%)
	Grade 1	35 (87.5%)	12 (30%)	36 (90%)
	Grade 2	1 (2.5%)	0	3 (7.5%)
C4-5	Grade 0	3 (7.5%)	4 (10%)	2 (5%)
	Grade 1	35 (87.5%)	36 (90%)	12 (30%)
	Grade 2	2 (5%)	0 (0%)	26 (65%)
C5-6	Grade 0	3 (7.5%)	3 (7.5%)	1 (2.5%)
	Grade 1	13 (32.5%)	20 (50%)	2 (5%)
	Grade 2	24 (60%)	17 (42.5%)	37 (92.5%)
C6-7	Grade 0	12 (30%)	22 (55%)	8 (20%)
	Grade 1	20 (50%)	17 (42.5%)	20 (50%)
	Grade 2	8 (20%)	1 (2.5%)	12 (30%)
C7-T1	Grade 0	28 (70%)	40 (100%)	23 (57.5%)
	Grade 1	12 (30%)	0 (0%)	17 (42.5%)

Grade 3 was not found in the study population possibly attributed to the relatively young age of the study population.

The TCSS was calculated for each patient in different positions. Our study revealed an excess in the spinal stenosis represented by TCSS from neutral to extension (Mean ± SD = 4.7 ± 1.29 compared to 6.1 ± 1.45) which was statistically significant. The flexion MRI showed a decrease in the TCSS compared to the neutral position (Mean ± SD = 3.2 ± 0.79 compared to 4.7 ± 1.29) which was statistically significant (Table 3).

TABLE 3. Comparison between three positions regarding TCSS

		Flexion	Neutral	Extension	Paired t-test		
					N-F	N-E	F-E
TCSS	Mean ± SD	3.2 ± 0.79	4.7 ± 1.29	6.1 ± 1.45	<0.001	<0.001	<0.001
	Median (IQR)	3 (3 - 4)	5 (3 - 5)	6 (5 - 7)			
	Range	(2 - 6)	(3 - 7)	(3 - 8)			

Three radiologists evaluated all MRI images with an 88% degree of concord, with a k value>0.8, indicating good agreement.

DISCUSSION

Assessment of the cervical spondylodegenerative changes during flexion and extension by dynamic MRI usually adds diagnostic information; however, dynamic cervical spine MRI is not routinely done [10].

Our study aimed to assess changes that occur during flexion and extension and compare the results obtained from dynamic MRI with static MRI examination. The study included 40 participants and their mean age was 42.2 ± 6.9 years.

The Kang grading system was used when assessing cervical spinal stenosis, mid-sagittal T2 WI in different positions was analyzed and TCSS was calculated for each patient by summation of the degree of stenosis in 6 levels from C2-3 to C7-T1. The same grading system was used by Park et al (2012) and Lee and Kim (2018) [9].

TCSS was more in extension than in the neutral MRI (Mean ± SD = 6.1 ± 1.45 compared to 4.7 ± 1.29) revealing that extension movement caused more stenosis among the study population.

TCSS was increased in neutral than in flexion (Mean ± SD = 4.7± 1.29 compared to 3.2 ± 0.79) indicating flexion movement can eliminate the stenosis severity.

Our results assumed extension worsened the cervical stenosis and flexion partially eliminated the degree of the stenosis. The findings agreed with Lee and Kim (2018) [9], who found an increase in TCSS from neutral to extension (Mean ± SD = 5.25 ± 2.47 compared to 6.04 ± 2.68) and a decrease in TCSS from neutral to flexion (Mean ± SD = 5.25 ± 2.47 compared to 4.4 ± 2.45).

Our study agreed with Abdalhak et al. (2023) [10] who found higher stenotic grades were noticed on extension MRI versus neutral MRI and a non-significant increase in the spinal stenosis in flexion compared to neutral postures. The findings of the flexion MRI ran counter to our findings.

In both the flexion and extension views, Alkosha et al. (2022) [11] showed higher grades of stenosis. These results were in contradiction with our findings in flexion, but they concurred with our findings in extension MRI.

In contrast to the neutral MRI, cervical disc lesions were significantly more common in the extension (P< 0.05) according to Lao et al. (2014) [12], which supported our study results but this study assumed that there was no significant difference (P > 0.05) in the flexion position ran counter to our findings.

In contrast to our results, Kim et al. (2017) [13] discovered that extension improved disc prolapses by reducing spinal stenosis caused by anterior migration of the nucleus pulpous.

Many studies with variable results were conducted on dynamic cervical MRI, so there is a need for several studies using quantitative parameters for accurate evaluation.

One of our study's limitations was the small sample size. Second, patients underwent MRIs while lying supine. Outcomes in the upright position could vary. Third, axial pictures in all three postures are not included in our hospital's dynamic cervical spine MRI routine due to time and financial constraints, and we only assess stenosis in the sagittal plane rather than the axial one. Lastly, there is no correlation with the results of surgery.

CONCLUSION

Flexion-extension cervical MRI is an innovative noninvasive diagnostic tool for assessment of the cervical spondylosis. It demonstrates increased cervical stenosis degree in extension position compared to neutral and flexion MRI. We recommend adding at least an extension MRI in evaluation patients with CS.

Author's contributions:
A.O.M proposed the study design, followed the MRI scans, analyzed the images, and wrote the manuscript. N.M.O analyzed the data and revised the results data. H.I.A. participated in data analysis and reviewed the manuscript. M.I.F established the study design.

Ethics approval and consent to participate:
Our institute ethical committee under Fedral wide assurance approved study no. FWA000017585 (FMASU MD 126/2021).

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Availability of data and materials:
The data enrolled and analyzed during the Research is accessible with the corresponding author when requested.

Consent for publication:
The study participants gave informed consent for publication of the research results.

Competing interests:
No competing interests.

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