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RESEARCH

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Reliability and clinical validity of the Kang MRI grading system for cervical central spinal stenosis

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Abstract

Background The Kang MRI grading system for central cervical spinal stenosis has been previously explored in literature. The aim of the current study was to re-visit the system before adopting it into our institute's cervical spine MRI reports and to evaluate its reliability through measuring the degree of agreement between radiologists of different levels of experience. The secondary aim was to evaluate its clinical validity by correlating between the radiological grade and the clinical symptoms as well as the subsequent treatment received by the patients.

Results A total of 82 patients (21 males and 61 females, mean age = 42.8 years) that underwent cervical spine MRI in our institute were included in the study. Two specialized musculoskeletal radiologists and two radiology residents at different levels of experience independently graded the central cervical spinal stenosis at the narrowest level using the Kang grading system. Substantial agreement was found between all the participating radiologists (K = 0.665–0.799, percentage of agreement = 78.04–86.58%). Correlation between radiological grade and the presence of neuropathic symptoms (upper extremity paresthesias and/or numbness), motor affection (upper extremity weakness and/or weak hand grip), and treatment received by the patients was moderate, with R ranging from 0.325–0.440, 0.420–0.506, and 0.452–0.592 respectively. Correlation between grade and the presence of cervical pain was weak, with R = 0.197–0.253. On subdividing the grade 2 patients into grade 2a (demonstrable spinal cord deformity at the anterior or posterior aspects of the cord only) and grade 2b (demonstrable spinal cord deformity at both the anterior and posterior aspects of the cord), a statistically significant difference was found regarding the prevalence of motor affection among the patients in both sub-groups ($P < 0.001$).

Conclusion Despite being reliable and clinically valid, the Kang grading system needs revision of the use of sagittal T2 images only as well as the definition of grade 2. We showed that the current definition of grade 2 to be rather broad, putting a wide array of patients into a single category. Sub-dividing it might increase the accuracy of the grading system.

Keywords Magnetic resonance imaging, Cervical canal stenosis, Spondylosis, Cervical vertebrae

Background

Central cervical spinal stenosis (CCSS) is a relatively common disorder caused mainly by degenerative cervical spondylosis, where herniated discs and/or hypertrophied, calcified, or even ossified ligaments cause narrowing of the central canal. This stenosis poses the

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risk of compressing the spinal cord resulting in myelopathy that eventually leads to neurological disability [1].

Diagnosis of cervical spondylosis is made by combining clinical symptoms, neurological signs and radiological investigations including plain radiographs, computed tomography (CT) scans and magnetic resonance imaging (MRI) [2].

Previous studies have described various methods of assessing the degree of CCSS. Early studies used plain radiographs; whether by measuring the sagittal cervical canal diameter on a lateral film [3], or by measuring the ratio between the sagittal cervical canal diameter and the corresponding diameter of the vertebral body [4, 5].

The imaging modality of choice for assessment of CCSS resulting from spondylosis is MRI. However, reporting of the imaging findings was found to be obscure and sometimes even misleading to the clinicians, necessitating the development of a method for standardization for those findings to provide a clearer communication with the clinicians. At first, many quantitative tools were explored. However, they proved to be too complicated and time-consuming for everyday use, leading to the development of simpler MRI grading systems [6].

Several MRI grading systems for CCSS have been proposed over the years, but there is no universally accepted system.

We plan to integrate the Kang grading system into our institute's cervical spine MRI reports. Based on our experience and a review of the existing literature, grading systems typically require regular reassessment to validate their ongoing applicability, encompassing how they are applied, their reliability, and clinical validity. For example, the Kang system utilizes only sagittal T2-weighted images (T2WIs) to assess the grade of CCSS. Also, it's definition for grade 0 was re-defined by park et al. from absence of canal stenosis to subarachnoid space reduction < 50% [7].

Thus, we wanted to re-visit the system before adopting it into our institute's MRI cervical spine reports, by assessing the inter-observer agreement among specialized musculoskeletal radiologists as well as radiology residents with different levels of experience. We also wanted to evaluate the correlation between the grading system and the clinical symptoms as well as the subsequent treatment received by each patient, to determine whether this grading system can help in the clinical decision making.

Methods

This is a retrospective study over the course of 2 years from August 2021 till August 2023. A total of 82 patients, aged between 18 and 70 (mean age 42.8 ± 13.1 years), who underwent cervical spine MRI, were retrospectively evaluated. They included 21 males (25.6%) and 61 females (74.4%). The process for the inclusion of the patients is illustrated in the flowchart in Fig. 1.

Inclusion criteria were any adult patients (above 18 years old) who underwent cervical spine MRI at our institute for evaluation of neurological symptoms including pain, neuropathic symptoms (upper extremity paresthesia and/or numbness), or motor affection (upper extremity weakness and/or weak hand grip) with no sex predilection. Written consent was waived by the institute's ethical review board on account of the study's retrospective design.

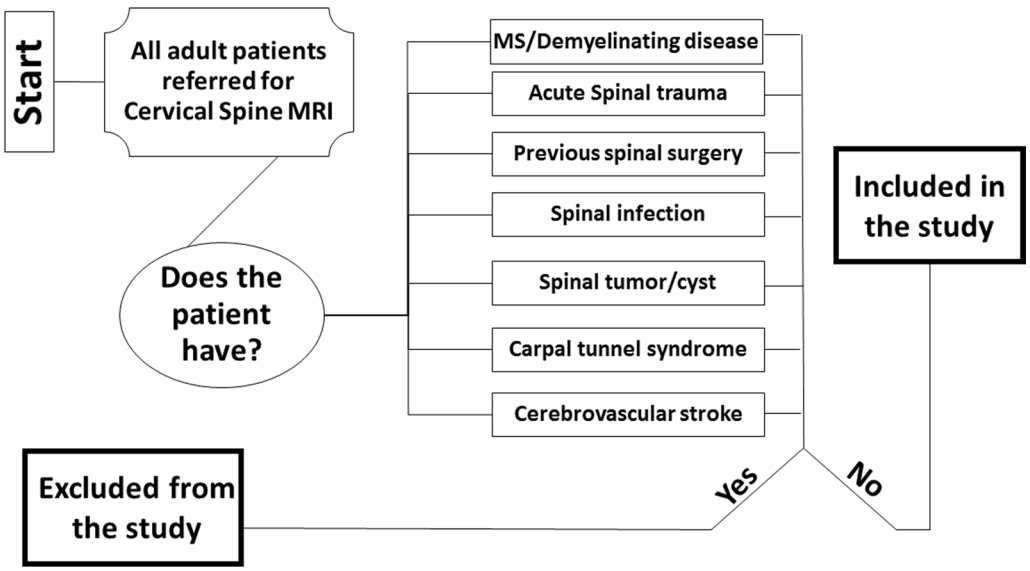

Fig. 1 Flowchart showing patient selection

Exclusion criteria were pediatric patients (less than 18 years old), or patients with positive history of another condition that might present with similar symptoms including Multiple Sclerosis or other demyelinating diseases, acute spinal trauma, previous spinal surgical intervention, spinal infection, spinal tumors or cysts, carpal tunnel syndrome, or cerebrovascular stroke.

MRI cervical spine protocol

MRI of the cervical spine in our MRI unit is performed in Enginea, Philips medical system, 1.5 T machine.

Routine MRI images are obtained as sagittal T2WIs and T1-weighted images (T1WIs) as well as axial T2-weighted gradient recalled echo (GRE) images. The Time to repetition and time to echo (TR/TE) values used in axial T2 GRE images are 500/9.21 ms with slice thickness 4 mm, gap 0.5 mm, flip angle 15° and field of view (FOV) 170×155 mm. The TR/TE values used in sagittal T1WIs are 417/7.8 ms with slice thickness 3 mm; gap 0.3 mm; flip angle 90°; FOV 250×39 mm. The TR/TE values used in sagittal T2WIs are 2533/100 ms with slice thickness 3 mm; gap 0.3 mm; flip angle 90°; FOV 250×39 mm. Average scan time for a conventional MRI of the cervical spine is about 8–10 min.

Clinical correlation

Clinical history of the included patients was obtained from the Synapse version 5.7.002 (Fujifilm medical systems, U.S.A., Inc.) picture archiving and communications system (PACS) of our institute as regards the presence of cervical pain, neuropathic symptoms (upper extremity paresthesias and/or numbness), and motor affection (upper extremity weakness and/or weak hand grip). The symptoms were recorded as either present or absent.

Patients were interviewed about the treatments that they have received and, furthermore, their verbal informed consents were obtained. The treatment outcome was classified as no treatment prescribed, medical treatment only (including muscle relaxants and analgesics), physiotherapy, or surgical intervention.

Image interpretation

Images were independently interpreted using the Kang grading system by a musculoskeletal (MSK) radiologist with 6 years of experience (designated MSK radiologist 1), an MSK radiologist with 12 years of experience (designated MSK radiologist 2), a radiology resident with two years of radiology training (designated resident 1), and a radiology resident with five years of radiology training (designated resident 2). They all assessed the presence and grade of central canal stenosis. In cases of multilevel narrowing, the level of maximum narrowing was selected and graded. No post-processing of the images was required.

The Kang grading system classified CCSS based on T2-weighted sagittal images into four grades: grade 0, absence of canal stenosis (which was later redefined by Park et al. into subarachnoid space reduction < 50%) (Figs. 2 and 3); grade 1, subarachnoid space reduction ≥ 50% without demonstrable deformed cord (Fig. 4); grade 2, demonstrable deformed cord without cord signal change at the level of deformity (Fig. 5); and grade 3, spinal cord compression with signal change at the level of compression denoting myelopathy (Fig. 6) [7, 8].

Therefore, the images were reviewed by four different radiologists, all blinded to each other's reports and to the clinical information to eliminate any bias.

Statistical analysis

The statistical analysis was performed using Statistical Package for Social Science (SPSS statistics for windows, V. 29).

a. Inter-reader agreement between the four participating radiologists was assessed using percentage of agreement as well as kappa statistics.

K values were interpreted as follows [9]:

Poor agreement: k<0.1

Fig. 2 Example of grade 0 stenosis. A 50-year-old female with cervical pain. Sagittal T2-weighted image shows no detectable narrowing of the subarachnoid space. No demonstrable cord deformity or cord signal change

Fig. 3 Another example of grade 0 stenosis. A 21-year-old female with cervical pain radiating to left shoulder. Sagittal T2-weighted image shows shallow disc lesions at C5–6 and C6–7 levels (arrows) causing < 50% narrowing of the subarachnoid space. No demonstrable cord deformity or cord signal change

Fig. 5 Example of grade 2 stenosis. A 26-year-old female with cervical pain. Sagittal T2-weighted image shows ≥ 50% narrowing of the anterior subarachnoid space at C5–6 level (arrow) with corresponding cord deformity at its anterior aspect. No cord signal change

Fig. 4 Example of grade 1 stenosis. A 50-year-old female with cervical pain. Sagittal T2-weighted image shows ≥ 50% narrowing of the anterior subarachnoid space at C4–5 and C5–6 levels (arrows). No demonstrable cord deformity or cord signal change

Fig. 6 Example of grade 3 stenosis. A 62-year-old female with cervical pain, bilateral upper limb neuropathy and bilateral upper limb weakness. Sagittal T2-weighted image showing cord compression with corresponding cord signal change (high T2 signal intensity) at C5–6 and C6–7 levels (arrows)

Slight agreement: $0.1<k \leq 0.2$
Fair agreement: $0.2<k \leq 0.4$
Moderate agreement: $0.4<k \leq 0.6$
Substantial agreement: $0.6<k \leq 0.8$
Almost perfect agreement: $0.8<k \leq 1$

b. Correlation between radiological grade and clinical findings as well as clinical outcome was calculated using spearman correlation statistics and classified as follows [10]:

Weak correlation: $0.1 < R \leq 0.3$.
Moderate correlation: $0.3 < R \leq 0.7$.
Relatively high correlation: $0.7 < R \leq 0.9$.
Very high correlation, $0.9 < R$.

c A *P*-value ≤ 0.05 was considered statistically significant.

Results

A total of 82 patients were included in the final analysis. Their clinical data are demonstrated in Table 1.

The point of maximum narrowing was found at C5-6 level in most of the included patients (40, 48.8%) followed by C6-7 level (13, 15.8%).

The distribution of CCSS for each grade evaluated by the four readers is shown in Table 2. The most frequently observed grade was grade 1 (41.47–51.22%).

Table 1 Clinical data of the patients

Clinical data	*n* = 82
Reported symptoms	
Cervical pain	74 (90.2%)
Neuropathic symptoms	48 (58.5%)
Motor affection	11 (13.4%)
Treatment	
No treatment	18 (22%)
Medical treatment only	36 (43.9%)
Physiotherapy	25 (30.5%)
Surgery	3 (3.7%)

Table 2 Cervical Central Spinal Stenosis Grade by each reader

Reader	CCSS grade			
	0	1	2	3
Resident 1	20 (24.40%)	36 (43.91%)	23 (28.04%)	3 (3.65%)
Resident 2	15 (18.29%)	35 (42.69%)	29 (35.37%)	3 (3.65%)
MSK radiologist 1	18 (21.95%)	34 (41.47%)	27 (32.93%)	3 (3.65%)
MSK radiologist 2	18 (21.95%)	42 (51.22%)	19 (23.18%)	3 (3.65%)

Table 3 depicts the inter-reader reliability evaluated by kappa statistics. There was substantial agreement between all the participating radiologists (K ranging from 0.665 to 0.799) with percentage of agreement ranging from 78.04 to 86.58%.

Correlation analysis between the grade and clinical symptoms as well as treatment showed the following (Table 4):

(a) Weak correlation between grade and pain, with R ranging from 0.197 to 0.253.
(b) Moderate correlation between grade and neuropathic symptoms, with R ranging from 0.325 to 0.440.
(c) Moderate correlation between grade and motor affection, with R ranging from 0.420 to 0.506.
(d) Moderate correlation between grade and treatment, with R ranging from 0.452 to 0.592.

Table 3 Inter-reader reliability

Reader	Kappa value	Percentage of agreement (%)
MSK Radiologist 1 vs Resident 1	0.709	80.48
MSK Radiologist 1 vs Resident 2	0.762	84.14
MSK Radiologist 1 vs MSK Radiologist 2	0.705	80.48
MSK Radiologist 2 vs Resident 1	0.665	78.04
MSK Radiologist 2 vs Resident 2	0.722	81.70
Resident 1 vs Resident 2	0.799	86.58

Table 4 Correlation coefficient between grade and symptoms as well as treatment outcome for each reader

Reader		Correlation coefficient (R)	*P* Value
Resident 1	Pain	0.197	0.076
	Neuropathic Symptoms	0.375	< 0.001
	Motor affection	0.485	< 0.001
	Treatment	0.452	< 0.001
Resident 2	Pain	0.253	0.022
	Neuropathic Symptoms	0.414	< 0.001
	Motor affection	0.444	< 0.001
	Treatment	0.529	< 0.001
MSK Radiologist 1	Pain	0.225	0.43
	Neuropathic Symptoms	0.325	< 0.001
	Motor affection	0.506	< 0.001
	Treatment	0.493	< 0.001
MSK Radiologist 2	Pain	0.200	0.072
	Neuropathic Symptoms	0.440	< 0.001
	Motor affection	0.420	< 0.001
	Treatment	0.481	< 0.001

Discussion

Grade 1 stenosis (Fig. 7) was the most frequently observed grade by the four readers in this study (41.47–51.22%), while grade 0 was observed in 15–20%. This came in agreement with the study conducted by Lee et al. where grade 1 was the most frequently observed grade (35%-64%) while grade 0 was observed in 14–35%. This agreement is despite the fact that the mean age of included patients in this study is lower than the study conducted by Lee et al. (42.8 vs 56 years) [8]. These results might indicate a lower age of incidence of cervical spondylosis among Egyptian population, warranting further demographic studies on larger numbers of Egyptian patient.

In this study, the inter-observer agreement between two specialized musculoskeletal radiologists of different levels of experience (12 and 6 years), and two radiology residents at two different points of training (year 2 and year 5) was calculated. It showed substantial agreement between all radiologists (K ranging from 0.665 to 0.799) with percentage of agreement ranging from 78.04% to 86.58%. These values were slightly lower than previous studies [7, 8]. Yet, the kappa values were higher than what Kang found [11]. We postulate that the values were different mostly because axial images were used in evaluation of most of the patients, especially by the musculoskeletal radiologists, unlike in the previous studies. We observed that using axial images sometimes gave a clearer evaluation of cord deformity than sagittal images alone, affecting the final grade given to each patient, and the specialized MSK radiologists resorted to using them based on their experience of such fact. Also, we used the modified system by Park et al. where the definition of grade 0 was changed from total absence of stenosis to < 50% narrowing of subarachnoid space [7].

Fig. 7 Another example of grade 1 stenosis. A 42-year-old female with cervical pain and right upper limb neuropathic symptoms. Sagittal T2-weighted image shows ≥ 50% narrowing of the anterior subarachnoid space at C3–4, C4–5, and C5–6 levels (arrows) No demonstrable cord deformity or cord signal change

As for the clinical correlation, we decided to assess for the correlation between radiological grade observed by each reader and each positive symptom individually. This is unlike the other studies found in literature. Waheed et al. considered the presence of more than one symptom as positive neurological symptom [2]. On the other hand, Park et al. considered patients with more than one neurological sign plus more than one neurological symptom to have a positive clinical manifestation and grouped them all into one group [7], while Lee et al. considered patients with more than one neurological sign or symptom to have a positive clinical manifestation and grouped them all into one group [8].

In this study, correlation between the presence of pain and the CCSS grade was found to be non-significant (*P*: 0.006–0.15) and weak (*R*: 0.197–0.253). This is likely attributed to the fact that pain was reported as a subjective symptom in most of the included patients ($n=74$, 90.2%) as it's the most common complaint in patients referred for cervical spine MRI. Also, no scoring tool was used in evaluation of the pain, which is one of the limitations of this study. As for the presence neuropathic symptoms and motor manifestations, they both showed significant correlations ($P<0.001$) with CCSS grade, giving moderate correlations with R for neuropathic symptoms ranging from 0.325 and 0.440, while for motor manifestations R ranged from 0.420 to 0.506.

This came in agreement with Lee et al. that found moderate correlation between positive clinical manifestations and radiological grade, with R ranging from 0.380 to 0.566 [8]. Yet the correlation level in this study was lower than in the study conducted by Park et al. that found relatively high correlation between positive clinical manifestations and radiological grade with R ranging from 0.808 and 0.846 [7], mostly owing to the difference in the definition of positive clinical manifestations as opposed to our study as previously mentioned.

On the other hand, correlation between the CCSS grade and the clinical outcome which represents the treatment protocol decided for the patient was found to be a significant ($P<0.001$) and moderate (R: 0.452–0.592). No studies to our knowledge correlated the CCSS with the final decision made for the treatment of the patients. This, in our experience, provides a more in-depth and reliable correlation between the imaging findings and the clinical data, as the symptoms are reported by the patients but

the treatment decision is made by experienced clinicians taking into account the symptoms, clinical signs, and imaging findings of each patient.

During working on the study, we noticed that some patients with cord deformity had more affection than others, yet after applying the Kang grading system they all fell into grade 2 **(**Fig. 8**)**. We wanted to ascertain whether that difference in cord deformity was significant. A total of 24 (29.2%) patients that were given grade 2 CCSS by at least three out of the four readers were chosen for analysis. Pain was reported in all 24 patients (100%), neuropathic symptoms was reported in 22 patients (91.6%), and motor affection was reported in 9 patients (37.5%). They were sub-divided into patients where there was deformity only at the anterior or posterior aspect of the cord ($n=15$, 62.5%) and patient's where there was deformity at both the anterior and the posterior aspects of the cord ($n=9$, 37.5%). A statistically significant difference was found between the two groups regarding the presence of motor affection, where 6 out of the 9 patients (66.6%) that had both anterior and posterior cord deformity reported motor affection, yet only 1 out of the 15 patients (6.6%) that had anterior or posterior cord deformity reported motor affection ($P<0.005$). On the other hand, no statistically significant difference was found between the two groups regarding the presence of neuropathic symptoms, as it was reported in all 9 patients (100%) that had both anterior and posterior cord deformity, and in 13 out of the 15 patients (86.6%) that had anterior or posterior cord deformity ($P=0.253$).

These findings suggest that grade 2 CCSS by its current definition in the Kang system might be too broad, containing patients that might show more severe symptoms than others. We suggest the sub-division of this grade into grade 2a; where there's demonstrable spinal cord deformity only at its anterior or its posterior aspects, and grade 2b; where there's demonstrable cord deformity at both its anterior and posterior aspects.

One of the limitations of this study was the use of cervical spine MRI done in only one posture, which is the neutral position. Various studies have demonstrated the impact of flexion and extension on central canal stenosis and concluded that it's a process affected by dynamic changes of the cervical canal diameter during movement [1]**.**

Other limitations included lack of quantification of clinical symptoms, as they were only reported by the patients as present or absent. Also, no correlation with neurological signs or results of electroneurography studies were done. This limitation was partly compensated for

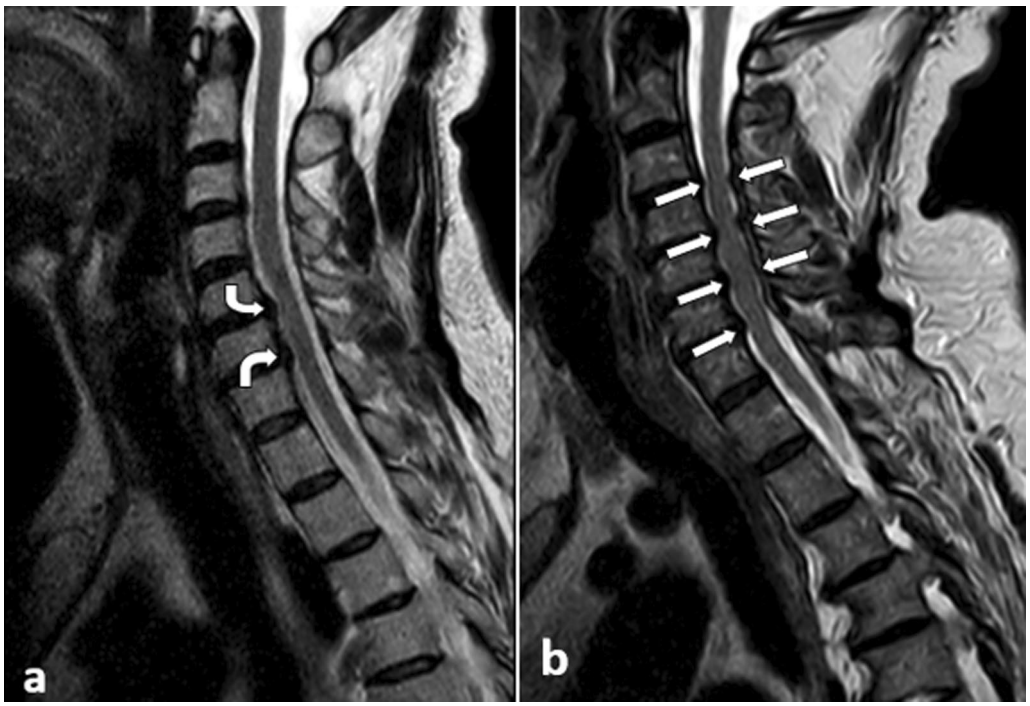

Fig. 8 Sagittal T2-weighted images in two patients with grade 2 CCSS. **a** is a 60-year-old male with cervical pain and bilateral upper limb neuropathy. No motor affection. MRI showing cord deformity at the anterior aspect only at C5–6 and C6–7 levels (curved arrows) without cord signal change. **b** is a 71-year-old male with cervical pain and bilateral upper limb neuropathy and weak hand grip on both sides. MRI showing multi-level narrowing with spinal cord indentation at its anterior and posterior surfaces (arrows) without cord signal change

by correlating the radiological grade to the treatment, in an effort to get a parameter more representative of the clinical situation.

Conclusions

Although the Kang MRI grading system shows substantial reliability and moderate clinical validity, it needs re-visiting in terms of using only sagittal images. Also, grade 2 needs re-defining, as we found it to be broad in categorizing a wide array of patients into a single category. However, this need further studies on larger patient cohorts to assess its usefulness.

Furthermore, we recommend the evaluation of the CCSS grade and its clinical correlation using MRI done in flexion and extension positions in addition to the usual neutral position, to better reflect the reality of central canal stenosis as it is a process influenced by the positional changes of the cervical spine.

Abbreviations

CCSS	Central cervical spinal stenosis
CT	Computed tomography
FOV	Field of view
GRE	Gradient recalled echo
MRI	Magnetic resonance imaging
MSK	Musculoskeletal
PACS	Picture archiving and communications system
SPSS	Statistical Package for Social Science
T1WIs	T1-weighted images
T2WIs	T2-weighted images
TE	Time to echo
TR	Time to repetition

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by YF, KAAS and SEE. The first draft of the manuscript was written by YF. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee of Faculty of Medicine, Ain-Shams University (FMASU REC) under Fedral wide assurance No. FWA00017585 (FMASU MD 121/2021).

Consent for publication

Identifying information about participants (patients' identity) did not appear in any part of the manuscript; therefore, consent for publication was not required.

Competing interests

The authors declare that they have no conflict of interest.

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