Suez Canal University Medical Journal Vol. 26 (9), 2023
Pages 13-20

Evaluation of Magnetic Resonance Diffusion Tensor Imaging in Early Detection of Cervical Spondylotic Myelopathy

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Abstract

Background: **Cervical spondylosis is a very common disorder of the spine. Its prevalence is more than 75% in patients aged above 65 years. Cervical spinal cord myelopathy is a long-term complication of cord compression by degenerative cervical spine changes (discs/osteophytes). The presence of abnormal spinal cord signals on conventional MRI indicates either reversible or irreversible parenchymal changes in the spinal cord.** ***Aim:*** **to evaluate the efficacy of MR diffusion tensor imaging technique in the early detection of cervical spinal cord myelopathic changes in symptomatic patients with cervical spondylosis.** ***Subjects and Methods:*** **A cross-sectional study was conducted at the Radiology Department of Suez Canal University Hospital 2019- 2022, including 50 participants.** ***Results:*** **FA value was significantly lower at disc protrusion (0.45 ±0.083) with p<0.001, and ADC value was significantly higher at disc protrusion (1.23 ±0.14) with p<0.001. Fractional anisotropy was found to be significantly abnormal in 29 (64.5 %) of patients with normal T2WI.** ***Conclusion:*** **DTI of the cervical spine can detect early myelopathic changes in the spinal cord caused by degenerative spondylosis.**

Keywords: DTI, fractional anisotropy, cervical spine.

Introduction

Cervical spinal cord myelopathy is a complication of cord compression by degenerative cervical spine spondylotic changes. The presence of abnormal spinal cord signals on conventional MRI suggests reversible or irreversible parenchymal changes in the spinal cord[1,2]. The clinical significance of intramedullary signal changes on MRI has not been fully established, especially in patients with mild cervical myelopathic degenerative changes. The sagittal diameter of the cervical spinal canal less than 6 mm is a definite risk factor for myelopathy, but patients with a residual sagittal diameter of 6 to 14 mm are affected by dynamic factors. Intramedullary spinal cord hyperintense T2-weighted MRI signal represents cystic degeneration of the gray matter[3,4]. Advanced MRI techniques such as diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) made a revolution in the management of acute cerebral ischemia and the assessment of brain lesions. Its ability to visualize and segment white matter fiber bundles has opened new perspectives for neurosurgeons. Diffusion tensor

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imaging can assess spinal cord microstructure by tracing the diffusion of water molecules. The changes in fractional anisotropy (FA), apparent diffusion coefficient (ADC), and diffusivity reflect microstructural nerve damage (demyelination or axon damage)[5]. DTI technique can obtain information about microstructure and present it with a few simple quantitative diffusion-derived parameters. This can be used to compare patient groups with normal individuals or quantify changes over time, which may explain the disease processes[6]. Some studies correlated the changes in fractional anisotropy and ADC value with the clinical severity of myelopathy and suggested its value in detecting early myelopathic changes before they appear on conventional T2-weighted images[7].

Subjects and Methods

Study setting and Study population
The study was conducted at the MRI unit in the Suez Canal University Hospital radiology department from 2019 to 2021. The *inclusion criteria* included: Age ≥18 years, the presence of symptoms of cervical radiculopathy, and the presence of cervical spondylotic changes on conventional MRI. The *exclusion criteria* included: the presence of MRI-incompatible implanted devices, contraindications to MRI, and post-operative patients with spinal fixation.

Study design and sample size
It was a cross-sectional study, and the estimated sample size was 50 patients.

Equipment and tools of the study
Magnetic resonance system (Achieva Stream 1.5T, Phillips Medical Systems, Best, The Netherlands) using head and neck coil.

Methods

1) Clinical Assessment
History: Symptoms of brachialgia, side of radiculopathy, cervical pain, upper limb numbness, and motor weakness. According to the (Neurosurgical Cervical Spine Scale NCSS) for degenerative cervical spine diseases: The total score is (3-14) indicating total disability to normal[8]

Lower extremity motor function (score 1-5):
1: Total disability: chair-bound or bed-ridden.
2: Severe disability: needs support in walking on a flat, and unable to ascend or descend stairways.
3: Moderate disability: difficulty in walking and needs support in using stairways.
4: Mild disability: no difficulty in walking on a flat, but mild difficulty in using stairways.
5: Normal: normal walking with or without abnormal reflexes.

Upper extremity motor function (score 1-5):
1: Total disability: total unable to perform daily activities.
2: Severe disability: severe difficulty in daily activities with motor weakness.
3: Moderate disability: moderate difficulty in daily activities with hand and/or finger clumsiness.
4: Mild disability: no difficulty in daily activities but mild hand and/or finger clumsiness.
5: Normal: normal daily activities with or without abnormal reflexes.

Sensory function and/or pain (score 1-4):
1: Severe disturbance: severe difficulty in daily activities and severe sensory disturbance +/- pain.
2: Moderate disturbance: moderate difficulty in daily activities with sensory disturbance +/- pain.
3: Mild disturbance: normal daily activities but mild sensory disturbance and/or pain.
4: Normal: neither sensory disturbance nor pain.

2) MRI Procedure

-Conventional cervical spine MRI including (T1WI & T2WI).

-Diffusion tensor imaging (DTI) of the cervical cord: Sagittal image acquisition, Echo-planar imaging, b-value= 800 s/mm, slice thickness= 3, scan time=2.5 min [9]

3) Imaging analysis

Conventional MRI: Spondylotic signs. Diffusion tensor imaging: Fractional anisotropy (FA) & (ADC) at sites of spinal cord compression. Tractography: Completely intact- fiber indentation - partially interrupted- or completely interrupted [10].

Results

Patients' ages ranged from 40 to 78 years old. Females were more predominant (54%) than males (46%) (Table 1) and (Figure 1). Table 2 illustrates the clinical examination of patients and found that patients had a mean sensory score of (2.78 ±0.62), ranging from 1-4: severe sensory disturbance to normal sensory function.

Table 1:- Baseline data of the patients (n=50).

Variables	N=50
Age (years)	
Median (Range)	46 (40-78)
Gender	
Male	23 (46%)
Female	27 (54%)

Data was presented as mean ±SD when it was quantitative. and number (percentage) when it was qualitative.

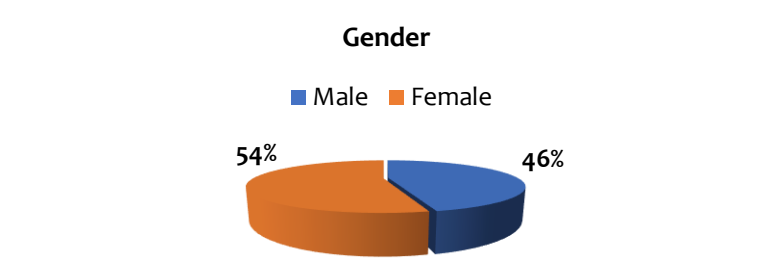

Figure 1: Gender distribution among the study patients.

The mean score of motor function of the right upper limb was (4.24 ±0.74), the left upper limb (4.19 ±0.76) and the lower limb (4.92 ±0.39): ranging from moderate disability to normal motor function. No cases of total motor disability. Disc protrusion was left posterolateral in 12 (24%), posterior central in 27(54%), and right posterolateral in 11(22%). T2WI of the spinal cord showed hyperintensity in 5(10%) of patients. There were osteophytes compressing the cord in 20 (40%) of patients, Spinal canal stenosis in 7 (14%) of patients, and spinal cord indentation/compression in 33 (66%). Regarding the level of disc affection, 8 (16%) had affection at the C3-C4 level, 18 (36%) at C4-C5, 16 (32%) at C5-C6, 7 (14%) at C6-C7, and 1(2%) at C7-D1 (Table 3). The mean cord axial area at the site of compression in DTI was 0.63±0.1, and on T2WI was 0.58±0.1. this means that the measurement of the cord axial area was more precise on T2WI than with tractography (Table 4). FA was significantly lower at disc compression/protrusion level (0.44±0.08) with $p<0.001$, while ADC value was significantly higher at disc compression/protrusion level (1.22±0.14) with $p<0.001$ (Table 5).

Table 2:- Clinical data of the patients (n=50).	
Sensory function score	
Mean ±SD	2.78 ±0.62
Median (Range)	**3 (1-4)**
Motor function score	
Rt Upper limb	
Mean ±SD	4.24 ±0.74
Median (Range)	**4 (3-5)**
Lt Upper limb	
Mean ±SD	4.19 ±0.76
Median (Range)	4 (3-5)
Lower limb	
Mean ±SD	4.92 ±0.39
Median (Range)	5 (3-5)
Sphincter disorders	0(0%)
Chronic cervical pain	50 (100%)
Side of brachialgia	
Right	14 (28%)
Left	15 (30%)
Bilateral	21 (42%)

Data was presented as mean ±SD when it was quantitative and number (percentage) when it was qualitative.

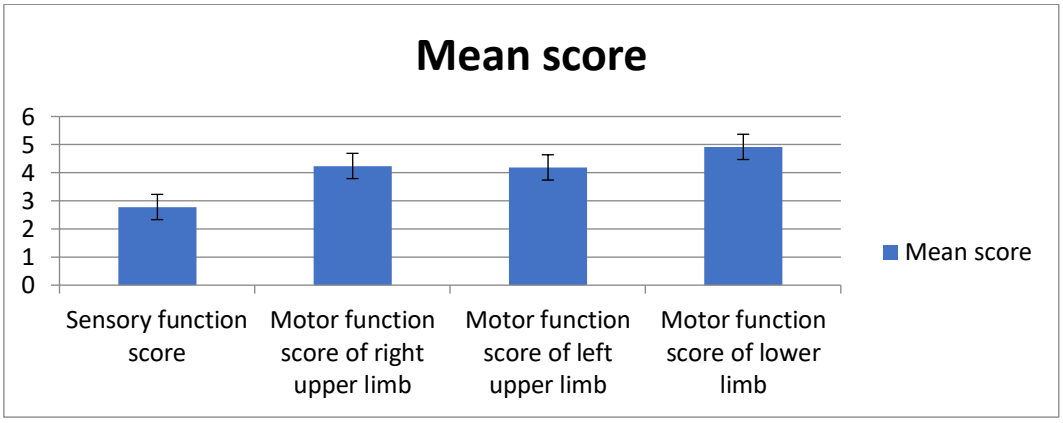

Figure 2: Neurosurgical Cervical Spine Scale among the study patients.

Discussion

Cervical spondylosis is the most common spinal disorder, and it is a part of the natural aging process that affects about 60-70 % of the world population[11]. The degenerative changes can remain asymptomatic with episodes of neck pain or may progress to a disability due to spinal cord dysfunction and spondylotic myelopathy. MRI is now the modality of choice for the assessment of cervical spondylosis; however, the role of conventional MRI sequences is still limited in the early evaluation of spinal cord myelopathy. T2WI sequence was the only method for assessing the spinal cord abnormalities[12]. All patients in this study complained of chronic neck pain.

Table 3:- Radiologic evaluation findings of the the study patients (n=50)	
Variables	N=50
Disc protrusion/herniation side	
Left posterolateral.	12 (24%)
Posterior central	27 (54%)
Right posterolateral	11 (22%)
T2WI spinal cord hyperintensity	5 (10%)
Osteophytes compressing cord	20 (40%)
Spinal canal stenosis	7 (14%)
Spinal cord indentation/compression	
Yes	33 (19%)
No	2 (4%)
Touching	15 (30%)
Level of the affected disc	
C3-4	8 (16%)
C4-5	18 (36%)
C5-6	16 (32%)
C6-7	7 (14%)
C7-D1	1 (2%)

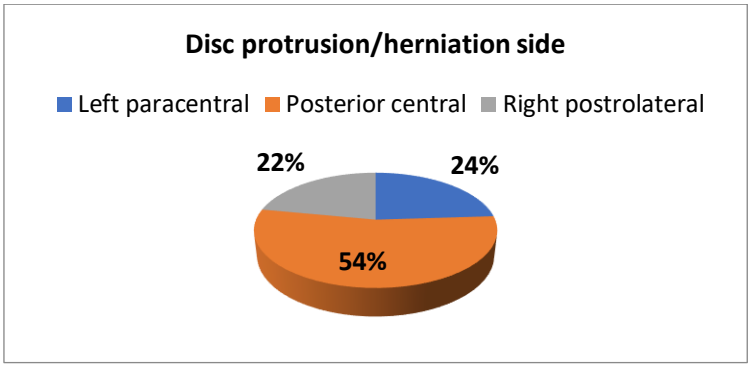

Figure 3: Side of disc protrusion/herniation among the study patients.

The mean sensory score by the Neurosurgical Cervical Spine Scale (NCSS) was about 3, ranging from severe sensory disturbance to normal sensory function. The mean score of motor function was about 4 for each of the rights and left upper limbs and that of the lower limbs was also about 4; ranging from moderate motor disability to normal motor function. No cases of total motor disability were present. No patients had sphincteric disorders. 42% of patients had bilateral brachialgia, 30% had left-sided brachialgia and 28% of patients had right brachialgia. Other studies used the modified Japanese Orthopedic Association score for assessment of clinical myelopathic signs and disability degree[12]. Studies showed that the most common level of spondylotic changes and compressive myelopathy was C5-C6, followed by C6-C7 and C4-C5 levels. Our study showed that the most affected disc level was C4-C5 (36% of study patients), 16% had affection at C3-C4 level, 32% at C5-C6, 14% at C6-C7, and 2% at C7-D1. Disc protrusion was left posterolateral in 12 (24%), posterior central in 27 (54%), and right posterolateral in 11 (22%) of patients.

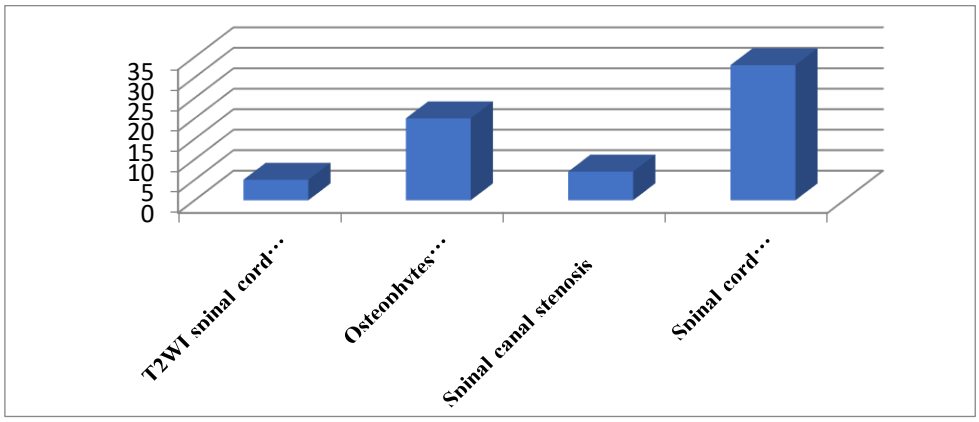

Figure 4: Spinal cord MRI abnormalities among the study patients.

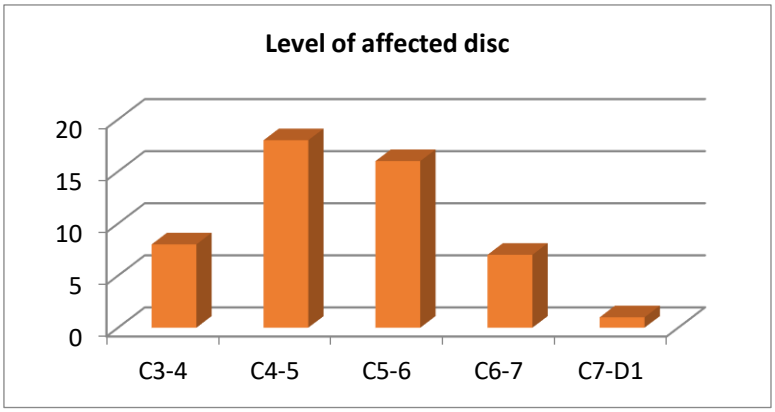

Figure 5: Affection level among the study patients

There were osteophytes compressing the cord together with the disc compression in 40% of patients. Associated spinal canal stenosis was found in 7 (14%) of patients, and spinal cord compression in 33 (66%) in our study. By analyzing the acquired DTI data of our patients; we found that FA value was significantly lower at disc compression/protrusion level (0.44±0.083) with p<0.001 (ranging from 0.12 to 0.64), while ADC value was significantly higher at disc compression/ protrusion level (1.22±0.14) with p<0.001 (0.92-1.46). As it denotes the presence of myelopathy; the FA value was found to be significantly lower at compression/protrusion level in patients with T2WI spinal cord hyperintensity (0.34±0.12, p=0.003), while ADC value was significantly higher at compression/ protrusion level in patients with T2WI spinal cord hyperintensity (1.34±0.035, p=0.007). Also, the FA value was significantly lower below the compression level with p<0.001, compared to the normal cord FA values measured at C2 levels in all patients. The fractional anisotropy was found to be significantly abnormal in (64.4%) of patients who showed no signal abnormalities on conventional T2WI. The cut-off value for abnormal FA in the spinal cord was different among different studies. According to Martin Noguerol, et al., the normal FA values of the spinal cord may vary from 0.5 to 0.7. The cutoff value for DTI parameters; according to Lee, et al., the mean diffusivity and radial diffusivity were $1.079x10^3$ and $0.749x10^3$ mm^2/sec, respectively, and that of FA was 0.475[10,11]. Hassan, et.al reported that 6.7% of their cases had myelopathic changes on T2WI,

Table 4:- cord axial area at the site of compression of the study patients (N=50)	
	N=50
Cord axial area at site of compression in DTI (cm2)	
Mean ±SD	0.63±0.10
Median (Range)	0.65 (0.395-0.781)
Cord axial area at site of compression in T2WI (cm2)	
Mean ±SD	0.58±0.11
Median (Range)	0.59 (0.371-0.762)

Data was presented as mean ±SD when it was quantitative and number (percentage) when it was qualitative.

In the study of Hassan, et.al; 6.7% of their cases showed myelopathic changes on T2WI, while 93.3% showed abnor3al cord signal. By DTI, 90% of cases showed myelopathy, while 10% showed no myelopathy. In our study; By T2WI sagittal imaging, the spinal cord showed hyperintensity in 5 (10%) of patients[9].

Table 5:- FA and ADC values of the study patients (N=50)				
	At C2	At level of Compression	Below compression	P-value
FA				
Mean ±SD	0.62±0.085	0.44±0.083	0.58±0.068	**<0.001***
Median (Range)	0.60(0.45-0.75)	0.43(0.12-0.64)	0.58(0.43-0.70)	
ADC				
Mean ±SD	1.03±0.09	1.22±0.14	1.04±0.09	**<0.001***
Median (Range)	1.0(0.9-1.23)	1.23(0.92-1.46)	1.01(0.9-1.4)	

*Data was presented as mean ±SD when it was quantitative and number (percentage) when it was qualitative. Repeated measurement ANOVA test used. *Statistically significant as p<0.05.*

The study of Hassan., et al on a 1.5 T scanner found that the mean FA of the cervical spinal cord is most decreased opposite and below the affected disc with the least FA value opposite the 12 o'clock axial location of the disc[9]. Neha et al, found that the mean FA was significantly lower in most spinal cord stenotic segments, (0.5009± 0.087 versus 0.655.7±0.104, *p*<0.001), and the mean ADC value was significantly higher (1.196.5±0.311 versus 0.9370±0.284, *p*<0.001) than that in the non-compressed levels[16]. Another study on 3T DTI also proposed the optimal cut-off value to discriminate stenotic from non-stenotic cervical cord levels to be < 0.491 for FA (sensitivity: 78.8%, specificity: 89.5%) and > 1.145 109 m2/s for ADC (sensitivity:81.8%, specificity: 89.5%)[16]. Tractography pattern analysis of our study patients showed intact fibers in 14 (28%), partially interrupted fibers in 13 (26%), and anterior fiber indentation in 23 (46%). We measured the axial area of the spinal cord at the site of cord on both conventional T2WI and DTI axial images and found that the mean cord axial area at the site of compression on DTI was 0.63±0.10 and on T2WI was 0.58±0.11. This means that the measurement of the cord axial area with tractography was less precise than on T2WI due to aliasing. The cord axial area at the site of compression showed a statistically significant indirect moderate correlation with ADC values at the compression/protrusion site.

Conclusion

DTI imaging and tractography of the cervical spine reveal early myelopathic changes in the spinal cord before its appearance on conventional MRI.

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