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Research Article

Diagnostic Value of Diffusion Tensor Imaging Indices in Assessment of Cervical Spondylotic Myelopathy

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Abstract

Background: Cervical spondylotic myelopathy (CSM) develops progressively resulting from spinal cord's long-term segmental compression and it is identified by degenerative alterations to the vertebrae, intervertebral discs, facets, and related ligaments. Imaging is the most important modality to confirm the diagnosis of CSM and Magnetic resonance imaging (MRI) has become the preferred screening method for evaluation of cervical spine myelopathy. Now there is a direction to use advanced MRI techniques for more confirmation of diagnosis and better image quality, Diffusion tensor imaging (DTI) now become the most important advanced technique and diffusion properties can be assessed using the quantitative indices, apparent diffusion coefficient (ADC) and fractional anisotropy (FA), FA and ADC are the most important metrics in assessing the CSM because they are more sensitive and specific than the conventional MRI. **Method:** This study enrolled 30 patients with cervical spondylotic myelopathy who was diagnosed based on mJOA grading system then MRI was conducted and DTI quantitative and qualitative maps were obtained. **Results:** We observed a significant difference between FA & ADC metrics at stenotic and non stenotic segments and higher sensitivity and specificity of FA and ADC in diagnosing CSM over the conventional T2 hyper intense signal. **Conclusion:** DTI metrics are a very effective tool for quantitative evaluation of degenerative CSM.

Key words: MRI, Diffusion tensor imaging (DTI), Cervical spondylotic myelopathy, Apparent diffusion coefficient (ADC), Fractional anisotropy (FA)

Introduction

The cervical spondylotic myelopathy, which affects adults, is one of the most common spinal cord pathologies. (1) Recognizing early indications of CSM and providing appropriate care to patients before the onset of irreversible spinal cord damage is necessary to preserve the patient's quality of life. (2) MRI has proven to be a useful method for defining the architecture of the cervical spine due to its capacity to distinguish with great resolution between osseous, neuronal, and soft tissue properties. (3) The conventional MRI protocol usually consists of:

- Sagittal T1-weighted, fast spin-echo imaging (T1WI).
- Sagittal T2-weighted, FSE (T2WI).
- Axial T2W FSE images(4) .

Sagittal imaging is used to assess the vertebrae, ligaments (most importantly the ligamentum flavum and posterior longitudinal ligament), intervertebral discs, facet articulation, spinal canal, and spinal cord. Axial imaging is used to confirm and assess the central canal stenosis, cord signal alteration, disc herniation, spinal cord compression, and compression of the nerve root. (4) Several novel MRI techniques have emerged in the recent years, and resolution and image quality have both greatly improved. These methods can be used to determine the prognosis of the condition and the effects of

surgical interference in addition to helping in CSM diagnosis. (5) Diffusion tensor imaging is one of the most intriguing new methods. DWI, a well-known MR technique which measures the diffusion of free water molecules, is where the DTI gets its name from. (6) Diffusion qualities can be assessed using the quantitative measurements (ADC and FA). ADC reflects the average water molecule diffusivity in all directions. The ADC rises as tissue water molecule diffusion increases. On the other hand, the ADC falls when the tissue's capacity for water molecule diffusion is compromised. ADC values are higher in tissues with less resistance to water transport and more water mobility. The FA parameter, which has values of 0 for completely isotropic diffusion and 1 for highly restricted diffusion in a single direction, is rotationally invariant to ADC .
These two DTI measurements are more sensitive and specific than conventional MRI because they can recognize damaged white matter tracts even before a T2 hyper intensity signal appears(7) .

Aim of the work
Our research intends to determine the diagnostic use of diffusion tensor imaging (DTI) indices in the evaluation of cervical spondylotic myelopathy.

Patients and Methods
Thirty individuals from both sexes with clinically suspected cervical spondylotic myelopathy (CSM) are included in this prospective investigation. Between August 2022 and May 2023, patients were referred from the neurosurgery clinic to the radiology department at Minia university hospital's magnetic resonance imaging unit.

All of the participants in this study underwent Diffusion Tensor Imaging (DTI) in addition to conventional MRI. The study was approved by the ethical committee of the faculty of medicine, Minia University.

Patient's selection:
Inclusion criteria :
Patient with cervical disc prolapse with:
- Common clinical symptoms and indications of CSM.
- MRI results that support cervical disc degeneration.

Exclusion Criteria:
•Patient with other neurological diseases:
- Neoplastic cord lesions (1ry of 2ry) .
-Trauma.
- Inflammatory and infectious processes .
- Neurodegenerative conditions.
- Patients who are ineligible for MRI, such as those with implanted magnetized devices, pacemakers, claustrophobia, cerebral palsy, or radiotherapy to the spine, as well as those with spinal fixation by screws that can cause metal artifacts to interfere with the diffusion sequence.
- Refusal to participate in our study.

Each patient in this study was subjected to :
1-Full history taking.
2-All patients gave a consent to participate in the study.
3-Clinical examination .
-Cervical myelopathy was diagnosed by performing neurological tests on each patient according to the modified Japanese Orthopaedic Association (mJOA) clinical grading system.
4-Cervical MRI examination:
-Conventional MRI:
•Technique: cervical spine coil was used in the cervical MRI examination, which was performed using a closed 1.5 Tesla MRI system (Ingenia-Philips medical system).
-Images acquisition:
The protocol of MRI of the cervical spine based on standard conventional MRI protocol by Farshad-Amacker, Nadja A., et al. 2015:(4)
1- Axial T2WI.
2- Sagittal T2WI.
3- Sagittal T1WI.
Diffusion tensor imaging (DTI):
•DTI acquisition:
o Sagittal Diffusion tensor imaging (DTI): 1- with diffusion with b = 800 sec/mm2 and another measurement with no diffusion gradient (b=0 sec/mm2), repetition time (TR)/ echo time (TE) = 3121/99 ms, acquisition matrix (AM) (92x88), field of view (FOV) (224x224 mm2), and b value (800 sec/mm2). 40 slices total, 2 mm in thickness. Slice gap is 0, flip angle is 90o, and acquisition time is 6:33.3.
•DTI post-processing:
The (Philips IntelliSpace Portal V9.0) workstation was used to post-process and analyze the acquired DTI images.

The Fiber-Track package software (Philips, Best, The Netherlands) was used to post-process DTI pictures. By locating areas of interest (ROIs) between 60 and 65 mm2 inside the stenotic and non-stenotic segments, DTI metrics were derived from sagittal images. The mean values of the several measurements were examined.

o DTI interpretation:
1- Quantitative maps (DTI metrics):
o ADC (Apparent diffusion coefficient) .
o FA (Fractional anisotropy).
2- Qualitative maps:
o DTT (Diffusion Tensor Tractography)
o FA color map

Statistical analysis

o The Shapiro-Wilk test was used to statistically test the data's normality, and the data were given as median and interquartile range (IQR) for non-parametric quantitative data and as both a number and a percentage for qualitative data. To compare the data, Wilcoxon signed rank and Spearman's rank correlations were performed. P value less than 0.05 were considered significant.

Results:

I-Demographic and clinical data

30 patients were included in the trial, and their average age was 50 plus 20. Males were the majority (53.3%), while females were (46.7%). Patients underwent cervical spine MRI with DTI protocol and were categorized into mild (No.=22), moderate (No.=8), and severe (No.=0) according to the mJOA grading system.

II-Conventional MRI data

Most of the enrolled patients have multi-level degenerative changes (66.66%) and the levels most affected were C3/4 and C4/6 levels in 22 patients (29.33%), followed by C5/6 in 20 patient (26.66%), C6/7 in 11 patient (14.66%), the most common type of disc herniation was disc protrusion (94.66%) then disc extrusion (6.33%), majority of direction of disc herniation was central protrusion (41.33%), followed by diffuse (34.66%) then para central (22.66%). The number of patients with ligamentous pathology was higher 66.66% while absence and presence of canal stenosis were equal. Most of discs compressions were mild “2nd degree” (56.66%) and (44.33%) were severe “3rd degree” Causing high T2 cord signal (grade II) in 14 cases (46.66%) more opposite C4/5-disc level (8 out of 14 cases). The signal is mostly type I in.(%85.7)

III- DTI data:

In comparison to the non-stenotic segments, the median FA value in the stenotic segments was significantly lower (0.5210 0.1125 versus 0.6917 0.17) with Z value = -4.480 and significant P-value = 0.00 (P value <0.05), and the median ADC value was significantly higher (1.3240 0.485 versus 0.8573 0.2675) with Z value = -4.684 and significant P-value = 0.00 (P value <0.05). ADC was seen to be increasing and FA was seen to be decreasing at stenotic segments (Fig.1 and 2). Using the Wilcoxon Signed Ranks Test, we compared values, with a P value of 0.05 indicating significance. (Table 1)

The FA and mJOA grading systems have a POSITIVE correlation when assessed using the Spearman's rank correlation test, with a "r value of 0.369" and a "P value significant 0.045" (P value 0.05) (Graph.1). ADC and mJOA clinical grading have a negative correlation with a "r value of -0.515" and a "P value significant 0.004" (P value 0.05). (Graph 2)

On testing the accuracy of DTI metrics (FA & ADC) and comparing them with T2 hyper-intense cord signal the sensitivity of FA was 88.89% and ADC was 81% while T2 hyper-intense signal was 46.66%, The specificity of FA was 33.33% and ADC was 55.6% while T2 hyper-intense cord signal was 94.11%. (Table 2)

Table1: Wilcoxon Signed Ranks Test, Z value and statistical significance between FA & ADC at stenotic and non-stenotic levels

Variables		No.	Mean Rank	Sum of Ranks	Z value	P value
Stenotic (FA)- Non stenotic (FA)	Negative Ranks	28	16.07	450.00	-4.480	**0.0001**
	Positive Ranks	2	7.50	15.00		
	Ties	0				
	Total	30				
Stenotic (ADC)- Non stenotic (ADC)	Negative Ranks	1	1.00	1.00	-4.684	**0.0001**
	Positive Ranks	28	15.50	434.00		
	Ties	1				
	Total	30				

Table 2: Comparison between Sensitivity & Specificity of FA, ADC & T2 hyper-intense signal

Variable	Sensitivity	Specificity
FA	88.9%	33.3%
ADC	81%	55.6%
T2 hyper-intense signal	46.66%	94.11%

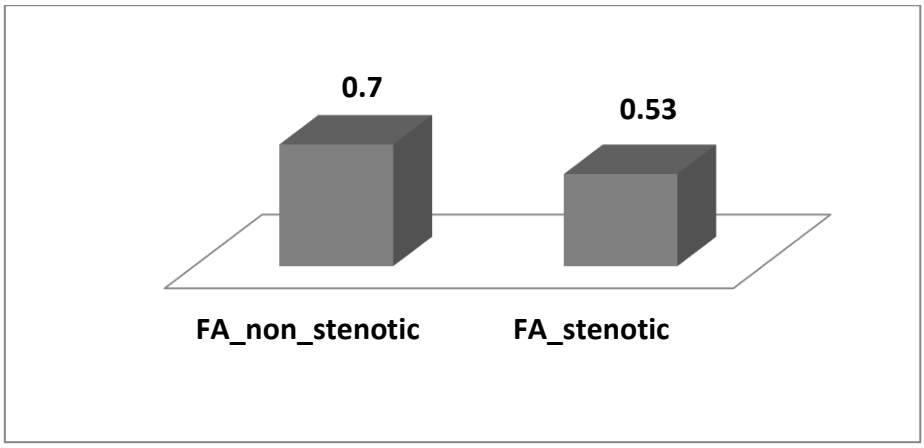

Figure1. Median values FA at stenotic and non-stenotic levels

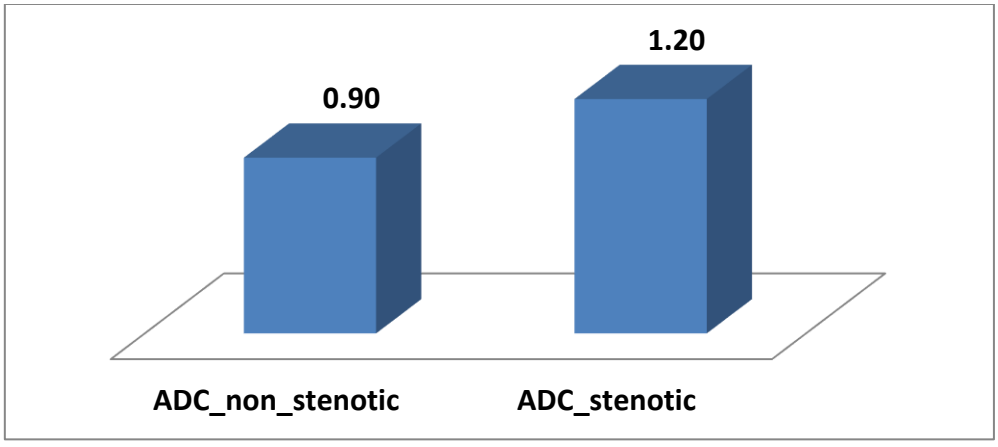

Figure2. Median values of ADC at stenotic and non-stenotic levels

Discussion

Myelopathy is one of the spinal cord abnormalities caused by degenerative CSM. The preferred imaging method for diagnosing cervical spondylosis is MRI, but its impact on the assessment of cord pathology is minimal . (8)

Prior to the development of DTI, only T2WI could be used to identify anomalies in the intrinsic cord. In situations like CSM, where the white matter tracts are deformed this result in lower FA values and higher ADC values at stenotic segments, DTI now is a more sensitive evaluation of the spinal cord's microstructure (9).

In this work, we evaluated the diagnostic precision of DTI in detecting alterations in the microstructure of the spinal cord in 30 patients. In one of the initial investigations on the use of DTI in CSM, Demir et al. (2013) (10), using 36 patients with CSM, found that areas of myelopathy had higher ADC values and lower FA, with a sensitivity of 78% compared to 57% at T2WI.

Our study found that FA is typically more sensitive than ADC, with FA sensitivity being (88.9%) and ADC sensitivity being (81%) both higher than that with T2 images (46.66%). Our findings support the findings of the earlier mentioned study. In our investigation, the median stenotic FA value in our study was (0.5210 ± 0.1125) and was significantly lower than the median non stenotic FA value (0.6917±0.17). The stenotic ADC value was significantly increased, with a median value of (1.3240±0.485) as compared to (0.8573±0.2675) at non-stenotic segments. Similar findings were reported by Nischal N., et al. in 2021(11), whose investigation revealed considerably higher mean ADC values (1.196.5±0.311 when compared with non-stenotic ADC 0.9370±0.284).and significantly lower mean stenotic FA (0.5009±0.087 when compared with non-stenotic FA 0.655.7±0.104). Additionally, Budzik, J.F., et al. (2011) (12), Dong, F., et al. (2018) (13), and others supported these conclusions.

The upper limb dysfunction, lower limb dysfunction, and bladder dysfunction of CSM were evaluated using the global clinical grading system known as mJOA, which assigns three grades of severity to the condition: mild, moderate, and severe . in our investigation of the correlation between the mJOA grading system and FA, ADC, and T2 hyper intense signal in CSM patients we discovered a POSITIVE association between FA and the mJOA clinical grading system and a NEGATIVE correlation between ADC and the mJOA clinical grading While median ADC exhibits a NEGATIVE correlation with median FA, T2 hyper-intensity cord signal exhibits a POSITIVE correlation with the mJOA clinical grading system. Supported by prior research such as Nischal N., et al. 2021(11), which discovered a correlation between the mJOA grading score and DTI metrics (FA and ADC), as well as a negative correlation between ADC and FA values (r was 0.63 and P value was significant 0.002), and Kadanka Z., et al. 2007 (15), which discovered a statistically significant difference between mJOA and T2 hyper-intense signal.

Conclusion

In conclusion, DTI measurements are important tools for the quantitative evaluation of CSM, in addition to conventional cervical spine MRI. Even in patients with a mild mJOA grade, the two-assessment metrics (FA more sensitive than ADC) can help diagnose CSM before alterations become irreversible and show up on T2WI. Future research is required for the study's limitations, which include a lack of pathological correlation, reversible change of DTI values in follow up, and post-operative follow up of DTI parameters.

References

1. Iyer, A., Azad, T. D., & Tharin, S. (2016). Cervical spondylotic myelopathy. Clinical spine surgery, 29(10), 408-414.
2. Badhiwala, J. H., Ahuja, C. S., Akbar, M. A., Witiw, C. D., Nassiri, F., Furlan, J. C., ... & Fehlings, M. G. (2020). Degenerative cervical myelopathy—update and future directions. Nature Reviews Neurology, 16(2), 108-124.
3. Harrop, J. S., Naroji, S., Maltenfort, M., Anderson, D. G., Albert, T., Ratliff, J. K., ... & Vaccaro, A. (2010). Cervical myelopathy: a clinical and radiographic evaluation and correlation to cervical spondylotic myelopathy. Spine, 35(6), 620-624.

4. Farshad-Amacker, N. A., Farshad, M., Winklehner, A., & Andreisek, G. (2015). MR imaging of degenerative disc disease. European journal of radiology, 84(9), 1768-1776.
5. Zhang, C., Das, S. K., Yang, D. J., & Yang, H. F. (2014). Application of magnetic resonance imaging in cervical spondylotic myelopathy. World journal of radiology, 6(10), 826.
6. Sąsiadek, M. J., Szewczyk, P., & Bladowska, J. (2012). Application of diffusion tensor imaging (DTI) in pathological changes of the spinal cord. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research, 18(6), RA73.
7. Dula, A. N., Gochberg, D. F., Valentine, H. L., Valentine, W. M., & Does, M. D. (2010). Multiexponential T2, magnetization transfer, and quantitative histology in white matter tracts of rat spinal cord. Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine, 63(4), 902-909.
8. Zhang, C., Das, S. K., Yang, D. J., & Yang, H. F. (2014). Application of magnetic resonance imaging in cervical spondylotic myelopathy. World journal of radiology, 6(10), 826.
9. Hesseltine, S. M., Law, M., Babb, J., Rad, M., Lopez, S., Ge, Y., ... & Grossman, R. I. (2006). Diffusion tensor imaging in multiple sclerosis: assessment of regional differences in the axial plane within normal-appearing cervical spinal cord. American Journal of Neuroradiology, 27(6), 1189-1193.
10. Demir, A., Ries, M., Moonen, C. T., Vital, J. M., Dehais, J., Arne, P., ... & Dousset, V. (2003). Diffusion-weighted MR imaging with apparent diffusion coefficient and apparent diffusion tensor maps in cervical spondylotic myelopathy. Radiology, 229(1), 37-43.
11. Nischal, N., Tripathi, S., & Singh, J. P. (2021). Quantitative evaluation of the diffusion tensor imaging matrix parameters and the subsequent correlation with the clinical assessment of disease severity in cervical spondylotic myelopathy. Asian Spine Journal, 15(6), 808.
12. Budzik, J. F., Balbi, V., Le Thuc, V., Duhamel, A., Assaker, R., & Cotten, A. (2011). Diffusion tensor imaging and fibre tracking in cervical spondylotic myelopathy. European radiology, 21, 426-433.
13. Dong, F., Wu, Y., Song, P., Qian, Y., Wang, Y., Xu, L., ... & Yu, Y. (2018). A preliminary study of 3.0-T magnetic resonance diffusion tensor imaging in cervical spondylotic myelopathy. European Spine Journal, 27, 1839-1845.
14. Tetreault, L., Kopjar, B., Nouri, A., Arnold, P., Barbagallo, G., Bartels, R., ... & Fehlings, M. G. (2017). The modified Japanese Orthopaedic Association scale: establishing criteria for mild, moderate and severe impairment in patients with degenerative cervical myelopathy. European Spine Journal, 26, 78-84.
15. Kadanka, Z., Kerkovsky, M., Bednarik, J., & Jarkovsky, J. (2007). Cross-sectional transverse area and hyperintensities on magnetic resonance imaging in relation to the clinical picture in cervical spondylotic myelopathy. Spine, 32(23), 2573-2577.