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Original Research Article

Diffusion Tensor Imaging as a novel technique in early detection of cervical spondylotic myelopathy

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Abstract

Introduction: Diffusion tensor imaging (DTI) is an advanced MR imaging technique which helps in early detection of cervical spondylotic myelopathy (CSM). Decompressive surgery performed during early stages of the disease was reported to be more successful when compared with later stages. **Aim**: To evaluate the usefulness of diffusion tensor imaging (DTI) in early stages of cervical spondylotic myelopathy (CSM) and to aid in better surgical outcome. **Materials and methods**: This prospective observational study included 25 patients with clinical diagnosis of cervical spondylotic myelopathy who underwent routine MRI of the cervical spine. Conventional MRI sequences along with diffusion tensor imaging (DTI) were performed. Quantitative fractional anisotropy (FA) and apparent diffusion coefficient (ADC) values were compared at stenotic and nonstenotic segments. **Results**: A statistically significant difference in mean FA and ADC values were seen at stenotic and nonstenotic segments. In the most stenotic segments, the mean FA value was 0.415 ± 0.203 and in the nonstenotic segment**,** the mean FA value was 0.717 ± 0.160, which was statistically significant (P < 0.001). The mean ADC value in the most stenotic segments was 1.777 ± 1.005 x 10^{-3} mm^2/s and that of the nonstenotic segments was 1.010 ± 0.458 x 10^{-3} mm^2/s**.** The difference in the mean ADC value was statistically significant (p <0.001). **Conclusion**: Use of diffusion tensor imaging (DTI) along with conventional MRI sequences enables early detection of the disease and helps in appropriate timing of surgery.

Keywords: Diffusion tensor imaging (DTI), cervical spondylotic myelopathy (CSM), apparent diffusion coefficient (ADC), fractional anisotropy (FA).

Introduction

Cervical spondylosis is a common degenerative disease of the spine seen in elderly population. Cervical spondylosis often results in compressive myelopathy of the spinal cord affecting 60% of the population above 40 years of age [1,2]. Most of the patients with CSM show characteristic magnetic resonance imaging (MRI) findings such as increased signal intensity of the spinal cord on T2-weighted imaging.

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This cord signal changes appear late in the course of the disease and predicts poor neurological outcome following surgery [3]. Conventional MRI was found to be less sensitive when compared to DTI in detection of early microstructural changes of the spinal cord [4]. Diffusion tensor imaging (DTI) showed better sensitivity in the early detection of cervical spondylotic myelopathy (CSM) when compared to the conventional T2WI sequence [5]. Decompressive surgery is the main stay of treatment in patients with CSM. Early diagnosis of CSM is important, as early surgical intervention is associated with good prognosis and better neurological outcome [6,7,8,]. DTI parameters such as fractional anisotropy (FA) and apparent diffusion coefficient (ADC) show higher sensitivity and specificity for early

detection of spinal cord abnormalities when compared with conventional T2WI [5,6]. The objective of this study was to compare FA and ADC values using DTI in most stenotic and nonstenotic cervical spinal segments, to aid in early diagnosis of cervical spondylotic myelopathy (CSM) before the appearance of T2W hyperintense cord signal changes.

Materials and methods

This is a prospective observational study conducted at JSS Medical College and Hospital from May 2018 to January 2019 for a period of 9 months. The study included 25 consecutive patients with clinical diagnosis of cervical spondylotic myelopathy (CSM). Each subject underwent neurological examinations by a neurosurgeon and clinical diagnosis of cervical compressive myelopathy was established based on the clinical manifestations (neck pain, radiculopathy, parasthesia, and weakness). Patient with myelomalacic changes (increased cord signal on T2WI), history of trauma, previous spinal surgery, and general contraindication to MRI (pacemakers, metallic implants and claustrophobic patients) were excluded. MRI images were obtained using a 3-T Philips MRI scanner (Ingenia, Netherlands) with a protocol routinely including sagittal T2W, sagittal T1W, axial T2W fast spin echo (FSE) sequences, and a 15 direction echo planar imaging (EPI)-based DTI sequence in an axial plane. Parameters for DTI were obtained as follows: Using axial plane, slice thickness = 4 mm, slice gap = 0 mm, acquisition matrix = 128 × 128, FOV = 230 mm, and number of acquisitions was 3. Diffusion was measured along 15 noncollinear directions with two b values (0 & 1,000 s/mm^2). Acquired DTI images were processed to produce ADC and FA maps of the acquired axial slices. FA and ADC values of non-stenotic cervical segments (C2-C3) were used as controls, since no difference in FA and ADC existed between segments in healthy controls and non-stenotic C2-C3 segments of subjects with cervical spinal stenosis **[6].** The FA and ADC values were measured using point region of interest in the cervical spinal cord at non-stenotic C2-3 segment and at the most stenotic segments [Figure 1 & 2].

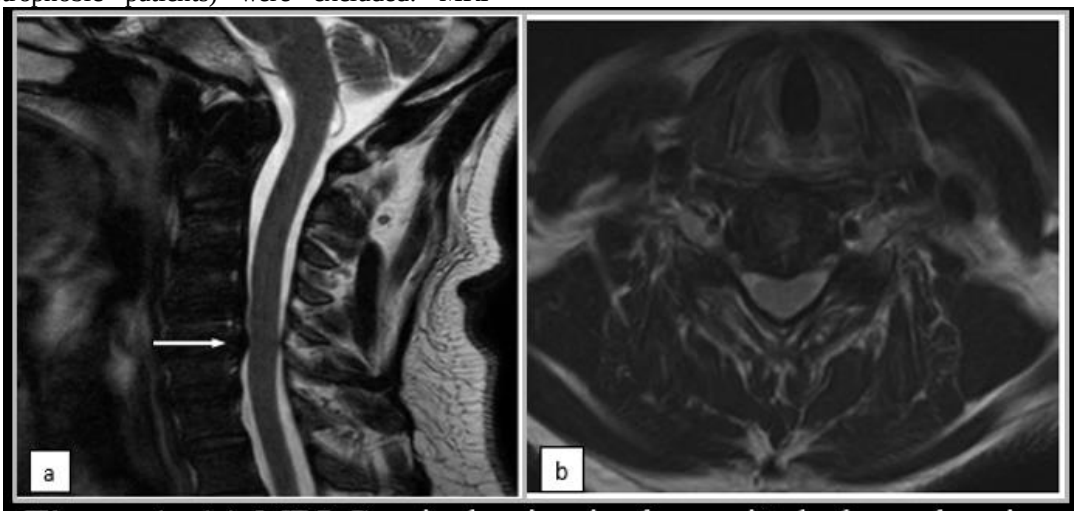

Figure 1: (a) MRI Cervical spine in the sagittal plane showing cervical stenosis at C5 and C6 level, **(b)** axial T2-weighted image where mean FA and mean ADC values are measured from specific ROI at stenotic cervical segment.

Fig 1: T2 weighted MRI of Cervical spine in the Sagittal and Axial plane

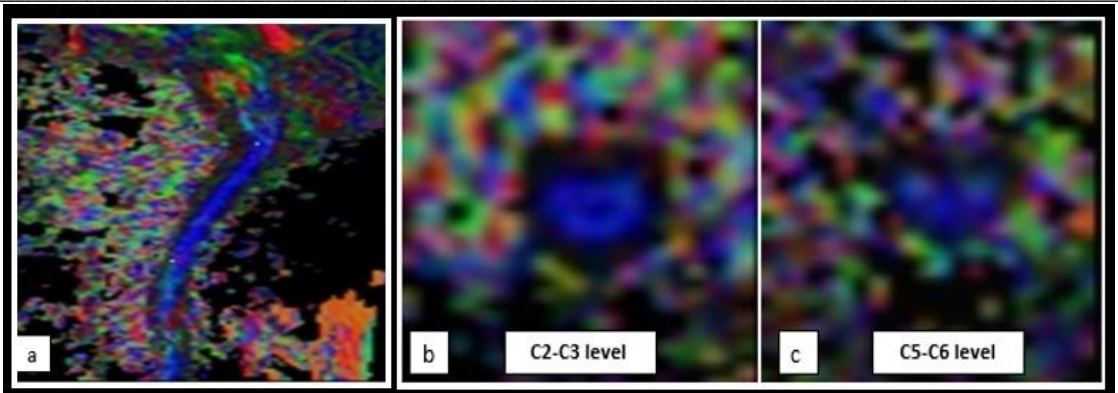

Figure 2: FA coloured maps FA coloured maps (a,b,c) of the same patient with FA values of 0.69 ± 0.11 at non-stenotic segment (C2-C3) and 0.41 ± 0.21 at most stenotic segment (C5-C6) respectively.

Fig 2: FA coloured maps in Sagittal and Axial Plane of the same patient

Statistical analysis: Statistical analysis were performed by using the software SPSS 22.0. Descriptive statistics were used to describe clinical demographics using range, means and standard deviation (mean ± SD). Paired *t*-test was used to analyze comparisons and a difference with a *p* value of less than 0.001 was considered statistically significant.

Results

Twenty five patients (14 female and 11 male) with mean age of 52.2 years (age ranging from 32-71 years). In the most stenotic segments, the mean FA value was 0.415 ± 0.203 and in the non-stenotic segment**,** the mean FA value was 0.717 ± 0.160, which was statistically significant (P < 0.001) [Fig 3]. The mean ADC value in the most stenotic segments was 1.777 ± 1.005 x 10^{-3} mm^2/s and that of the non-stenotic segments was 1.010 ± 0.458 x 10^{-3} mm^2/s**.** The difference in the mean ADC value was statistically significant (p <0.001) [Fig 4].

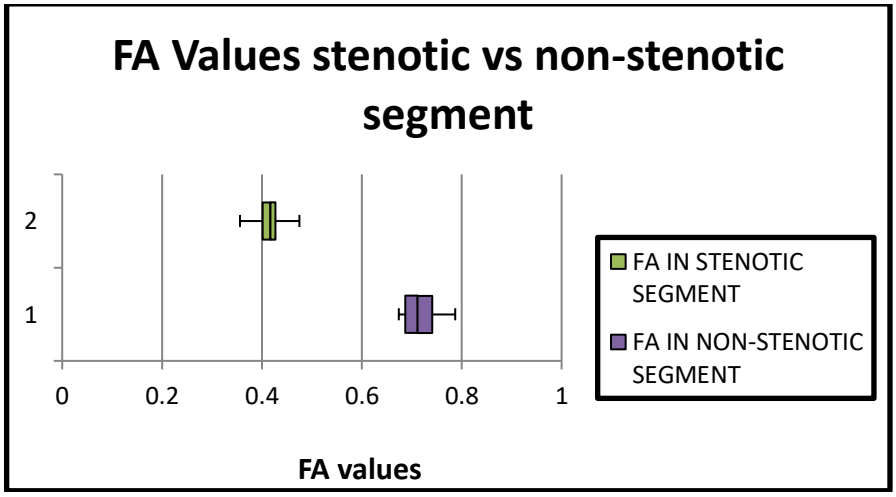

Fig 3: The mean FA value in the most stenotic segment (0.415 ± 0.203) was significantly lower than the non-stenotic segment (0.717 ± 0.160). The difference was statistically significant (P < 0.001).

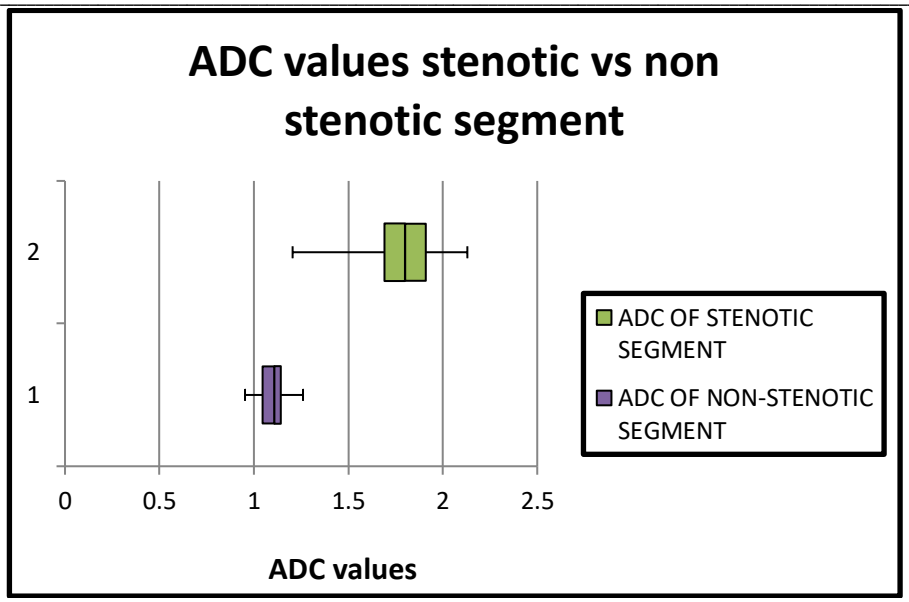

Fig 4: The mean ADC values in the most stenotic segment (1.777 ± 1.005 x 10^{-3} mm^2/s) was higher than the nonstenotic segment (1.010 ± 0.458 x 10^{-3} mm^2/s). The difference was statistically significant (P < 0.001).

Discussion

Conventional MRI is most commonly used to evaluate the morphological changes in cervical spondylosis and spinal cord dysfunction. Major mechanisms responsible for the spinal cord injury in patients with CSM include the spinal cord ischemia and microtrauma which leads to apoptosis of the oligodendrocyte cells. These pathological alterations are often depicted as hyperintense signal on T2W images and represent cord edema or gliotic changes [9]. This increased T2W signal changes in the cervical spinal cord appears late during the course of the disease. There is a weak correlation between clinical symptoms and conventional MR imaging findings as described by Hori M et al., [10]. Diffusion tensor imaging (DTI) is a relatively novel MRI technique which depicts the microstructural changes of white matter fibers better than the conventional MR imaging.Conventional MRI is based on isotropic diffusion in which diffusion of water molecules is equal in all directions. Isotropic diffusion is quantified using apparent diffusion coefficient (ADC) values, which represent average magnitude of molecular displacement. Diffusion tensor imaging (DTI) utilizes anisotropic diffusion parameters describing highly ordered movement of the water molecules occurring along a single direction (bundles of myelinated axonal fibres running in parallel). The differences in the amount and orientation of water diffusion is measured, particularly in the white matter [11]. Anisotropic diffusion is quantified by FA value, which measures the directionality of molecular displacement by diffusion, where a value of 0 represents isotropic diffusion and value of 1.0 represents anisotropic diffusion [12]. Compared with conventional MRI, DTI is sensitive to disease processes altering the movement of water molecules in cervical spinal cord at a microstructural level [13]. The sensitivity of DTI in detection of early myelopathic changes are higher compared to conventional MRI [5,6,17,18].Reduction in FA values at stenotic levels suggests disruption of the white matter tracts (axonal structures) leading to isotropic diffusion and increase in the ADC values [14]. In our study, the mean FA value in the stenotic segments (0.415) was significantly lower than the nonstenotic segments (0.717). The mean ADC values at the stenotic segment (1.777) were significantly increased compared to nonstenotic segments (1.010). Similar results were shown in previous studies as depicted in [Table 1]. No similar studies with larger sample size have been carried out previously, existing studies along with this study indicate that FA & ADC values may provide additional data for the early detection of myelopathic changes and better clinical outcome.

Table 1: Comparison of the results with similar recent studies.

Author (Year)	Mean FA values		Mean ADC values (x 10^{-3} mm^2/s)	
	Non stenotic	stenotic	Non stenotic	stenotic
Toktas ZO (2015) et al.,[15]	0.6884 ± 0.0075	0.4228 ± 0.1090	0.9183 ± 0.1477	1.312 ± 0.2405
Nukala M (2018) et al., [17]	0.729	0.48	0.90	1.25
Hassan Taaeh (2019) et al., [18]	0.742	Significantly Reduced.	-	-

Conclusion

Despite the limitation of a relatively small sample size and lack of long term follow up in our study, DTI is proven to be a useful diagnostic tool for assessing disease severity in CSM. DTI offers increased diagnostic sensitivity as compared to conventional MRI and enables earlier detection of the disease before marked clinical worsening. Hence, quantitative DTI scalar metrics can be used routinely in patients with CSM to detect and enable early intervention for a better clinical outcome.

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