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NORMAL PARAMETERS OF DIFFUSION TENSOR IMAGING OF THE SPINAL CORD IN CHHATTISGARH STATE POPULATION: ORIGINAL ARTICLE

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ABSTRACT

Purpose: Our purpose is to evaluate in vivo normal measurements of parameters of diffusion tensor imaging (DTI) by performing Tractography of spinal cord at various levels of spinal cord and to compare DTI-indices, including fractional anisotropy (FA) and mean diffusivity (MD), between different cord regions. To evaluate normal range of FA and mean ADC values of spinal cord.

Methods: A total of 50 healthy subjects (27 men and 23 women; age, 20-87 years; mean age, 53.5 years) were included in this study in 1 year period between July 2017- June 2018. The patients with the symptoms of myelopathy , radiculopathy or post trauma had excluded. A 3 Tesla MRI scanner Siemens, serial number - 45445 was used to obtain diffusion tensor images. Apparent diffusion coefficient (ADC) and fractional anisotropy (FA) values were measured as DTI parameters on axial sections of several cervical levels. Subjects were divided into two groups: >40 years (n=16) and ≤40 years (n=15). A paired t-test was used to compare significant differences between the groups. ADC and FA values were most stable on axial sections.

Results: For all subjects, mean ADC and FA values were $1.06\pm0.09\times10^{-3}$ mm^2/sec and $0.68\pm0.05\times10^{-3}$ mm^2/sec, respectively. ADC was significantly higher in subjects >40 years of age than in those ≤40 years. There was no significant difference in FA values between the two groups. The mean ADC value was significantly higher in normal subjects >40 years of age than in those ≤40 years.

Conclusions: Diffusion tensor imaging (DTI) of the spinal cord is more sensitive than conventional magnetic resonance imaging (MRI) to evaluate integrity of the nerve fibres. Normal values of DTI parameters were identified in healthy subjects and were both reproducible and stable, which suggested that this method could be useful for patient assessment. Among the study participants, a significant difference was found only in the comparison of ADC by age; and at different levels.

KEYWORDS : DTI, ADC, FA, MRI.

Introduction:

Diffusion tensor imaging (DTI) of the brain is gradually developing into a clinical tool in the imaging of different white matter diseases. Diffusion tensor imaging (DTI) is a relatively new magnetic resonance imaging (MRI) technique capable of depicting micro structural axonal details of the brain and spinal cord white matter. *The diffusion term,* represents translational motion *of* water molecules. This is random thermal motion, also called Brownian motion. *Tensor:* Is a mathematical construct that describes the 3 dimensional properties of an ellipsoid. *Imaging: pictures.* Furthermore, measurements of anisotropy and diffusivity enable the detection of subtle details of the effects of injury that cannot be detected using conventional magnetic resonance techniques.

Recently DTI has been applied to the spinal cord, and results have demonstrated it to be a valuable tool for assessing the extent of white matter damage in numerous spinal cord−related conditions.It can assist visualization of white matter tracts *in vivo* and quantify anisotropy. DTI is computed by tensor analysis, which is a multilinear vector parameter that enables determination of the restricted anisotropic diffusion of water molecules in the structures of living organisms such as white matter nerve fibers.

The two data tools can quantify the results of DTI: the apparent diffusion coefficient (ADC) value, which refers to the overall diffusivity of the tissue irrespective of directional dependence, and the fractional anisotropy (FA) value, which reflects the directional dependence of the diffusion process and is expressed as a relative number.

Diffusion tensor imaging (DTI) of the spinal cord is a promising advanced technique, which may provide additional diagnostic information in analysis of many pathological changes of the spinal cord. There are many technical limitations of DTI, especially in thoracic and lumbar segments. The wider use of 3T scanners, as well as development of acquisition and post processing techniques, should result in the increased role of spinal cord DTI in both research and clinical practice. The aim of this study to calculated normal values of DTI parameters in healthy subjects.

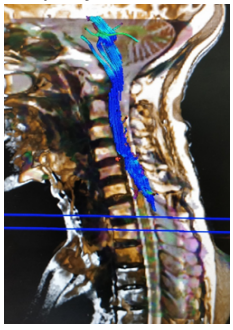


Figure: 3D reconstruction of MRI DTI imaging of cervical spine in sagittal plane. Blue colour depicts the nerve fibres with direction of diffusivity superior-inferiorly.

Materials and Methods:

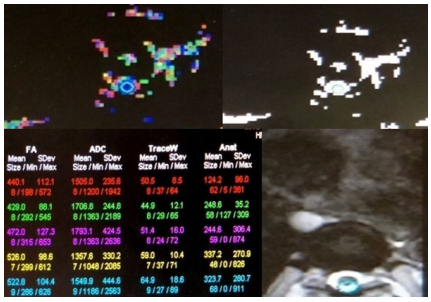
Subjects:

A total of 50 normal subjects (27 men and 23 women; age, 20-87 years; mean age, 53.5 years) were included in this study. All subjects who submitted written informed consent met the exclusion criteria for MRI and exhibited no symptoms of myelopathy, radiculopathy or trauma.

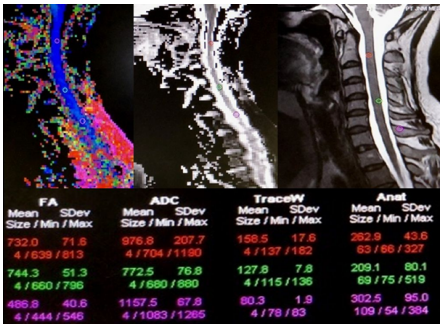
Imaging Method:

A 3 Tesla MR Siemens Magnetom skyra , serial number - 45445 was

used to obtain diffusion tensor images. Apparent diffusion coefficient (ADC) and fractional anisotropy (FA) values were measured as DTI parameters on axial sections of several levels of spinal cord. The protocol included conventional sequences to evaluate the spine and spinal cord morphology including T1 and T2. DTI data were acquired by using SE-type Single-Shot EPI sequences. The following scanning parameters were used: TE, 69 ms; TR, 9,079 ms; number of slices, 30; interslice gap, 0 mm; band width, 1,711.8 Hz/pixel; voxel size, 1.79×1.42×4.00 mm; acquisition matrix, 112×140; and number of excitation, 4. Images were acquired with b values of 0 and 700 s/mm^2. The DTI parameters, ADC and FA, were measured on axial and sagittal sections of several levels of spinal cord – cervical, dorsal and dorso-lumbar junction. ADC and FA values were most stable on axial sections.



Figures: Magnetic resonance imaging techniques. (A) Anatomical scan (T2-weighted fast spin echo image). (B)Apparent diffusion coefficient (ADC map; axial dorsal spine views above and sagittal cervical spine views below). (C) ADC (regions of interest). (D) Fractional anisotropy (FA map; axial view). (E) Fractional anisotropy (regions of interest).



As shown in both the Figures, both ADC and FA images were taken, and ADC and FA values were measured manually in all the levels of cervical, upper dorsal and dorso-lumbar areas level using an axial and sagittal image that gave stable values. The spinal edges were excluded from the region of interest.

Results:

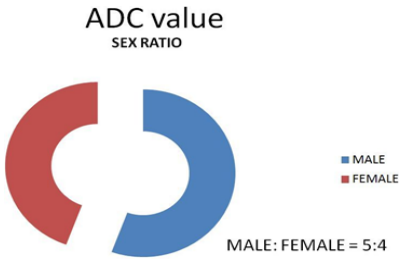
In our study, we noted the trends of ADC and FA values in the 50 healthy subjects. Our normal range of FA and ADC values are 0.542×10-3 mm2/sec to 0.964×10-3 mm2/sec +/-0.112×10-3 mm2/sec, 0.494×10-3 mm2/sec to 0.609×10-3 mm2/sec +/- 0.086×10-3 mm2/sec & 0.329×10-3 mm2/sec to 0.512×10-3 mm2/sec +/- 0.070×10-3 mm2/sec and 1.162×10-3 mm2/sec, 1.274×10-3 mm2/sec & 1.389×10-3 mm2/sec respectively.

DTI VALUES (N) $\times 10^{-3}$ mm^2/sec

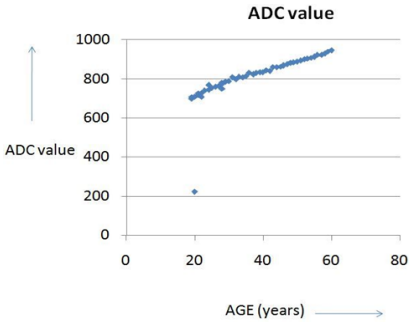
	CERVICAL	DORSAL	DORSO-LUMBAR
MEAN ADC	1.162	1.274	1.389
RANGE FA	0.542-0.964+/-0.112	0.494-0.609+/-0.086	0.329-0.512+/-0.070

Till date, very few studies have been done which clearly describes and standardize the normal values and range of the DTI indices. Our study is an attempt to set a normal range which will be helpful in future research and comparison purpose. Also, it can be used to compare in pathological conditions to detect abnormality in the spinal cord since FA values will be significantly lower.

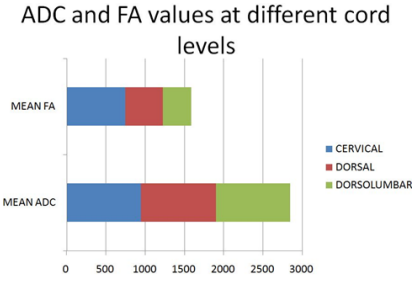
Regarding variations of DTI indices in male and female, we observed high FA values of the spinal cord in males compared to female of same age group as demonstrated in chart below.



In our study, we found that as the age advances, ADC values goes on increasing. The trend of average ADC values in the healthy subjects with age comparison are shown in Figure below:



In our study, reducing values of FA were found, as we moved from cervical level to conus medullaris.



Discussion:

Studying healthy populations in order to determine normal values and their variation is a mandatory prerequisite for the interpretation of DTI measures in patient populations and individual patients. Compared to DTI of the brain, reports of normative DTI data of the spinal cord are at present relatively sparse. In addition, most studies consist of relatively small and arbitrarily enrolled samples of healthy subjects with unrepresentative age and gender distribution. Although some previous studies have compared parameters before and after surgery for compressive cervical disease using DTI [1,4,5], few have reported on normal values. Despite the influence of the imaging environment and individual differences on average ADC or FA values in healthy subjects [3,5], we obtained equivalent and stable normal values, as reported previously [3,6,7].

Mamata et al. [3] explained the mechanism of diffusion in nerve fiber bundles aligned regularly from head to tail. Water molecules diffuse along the component axons resulting in high anisotropic diffusion within the spinal cord white matter, thus facilitating the usefulness of DTI in spinal cord evaluation.

In our study, the values might differ in minor due to the influence of factors like age, the measurement site, the Magnet, and the technique, even in a healthy spine. To correct for individual differences, it is necessary to make comparisons with normal levels described in previous reports [8]. This is similar to the study done by Facon et al. [5]. Mamata et al. [3] reported that in healthy subjects, ADC increased with age, whereas FA tended to decrease. In this study, as in previous reports, ADC was significantly higher in subjects >40 years of age; however, there was no significant difference in FA, and no difference between ADC and FA was found between men and women. It is expected that new trends will emerge as the number of cases increase.
In the study done by Chagawa et al, it was reported that ADC values is independent of age. This is discordant finding with our study. As the age advances, ADC values goes on increasing. The trend of average

ADC values in the healthy subjects with age comparison.

Study done by Rachael et al reported that FA values are constant at different levels. But, our studies revealed reducing values of FA from cervical level to conus medullaris, which was discordant with their findings.

Conclusions:

Diffusion tensor imaging (DTI) of the spinal cord is more sensitive than conventional magnetic resonance imaging (MRI) to evaluate integrity of the nerve fibres.

Till date, very few studies have been done which clearly describes and standardize the normal values and range of the DTI indices. Our study is an attempt to set a normal range which will be helpful in future research and comparison purpose. Also, it can be used to compare in pathological conditions to detect abnormality in the spinal cord since FA values will be significantly lower.

Among the study participants, a significant difference was found only in the comparison of ADC by age; and at different levels. There are many technical limitations of DTI, especially in thoracic and lumbar segments. The wider use of 3T scanners, as well as development of acquisition and post processing techniques, should result in the increased role of spinal cord DTI in both research and clinical practice, which needs further studies.

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