Diffusion Tensor Imaging of the Human Spinal Cord: Determination of Normal Regional Metrics

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INTRODUCTION: Diffusion tensor imaging (DTI) assesses the magnitude and direction of the diffusion of water molecules along three principle eigenvectors. DTI shows promise in the evaluation of white matter tract integrity; *in vivo* DTI interrogation of the human spinal cord has been shown to detect pathologic changes including those associated with multiple sclerosis and spondylosis [1-3], using metric analyses including measurement of fractional anisotropy (FA) and mean diffusivity (MD). In a recent investigation, spatial data obtained in various spinal cord regions was shown to be useful in the evaluation of MS [4]. However, normal values for DTI metrics in the spinal cord have not been established. The purpose of this study is to determine normal values for FA, MD, and the three principle eigenvectors in various regions of the spinal cord white matter and gray matter, in a population of normal patients.

MATERIALS AND METHODS: DTI of the upper cervical spine was performed in 20 healthy volunteers, using pulsed gradient, double spin echo, echo planar imaging (2000/74; 128x128 matrix; 140x140 mm FOV; 10 contiguous 4 mm slices; b= 1000 s/mm^2 at 1.5T). At the C2-3 level, average fractional anisotropy (FA), mean diffusivity (MD) and the three principle eigenvalues (E1—major, E2 and E3 –minor) were calculated within regions of interest at the anterior, lateral, and posterior regions of the spinal cord, with separate bilateral regions of interest at each of these positions, as well as regions of interest in the central gray matter and left and right anterior gray matter.

	Anterior		Lateral		Posterior		Gray Matter		
	Left	Right	Left	Right	Left	Right	Central	Left	Right
FA	0.50 ± 0.09	0.49 ± 0.11	0.71 ± 0.09	0.68 ± 0.09	0.66 ± 0.10	0.66 ± 0.10	0.56 ± 0.05	0.45 ± 0.04	0.45 ± 0.07
MD*	1.00 ± 0.17	0.99 ± 0.18	0.77 ± 0.13	0.78 ± 0.12	0.82 ± 0.14	0.80 ± 0.11	0.81 ± 0.07	0.82 ± 0.08	0.80 ± 0.08
E1	1.60 ± 0.20	1.58 ± 0.27	1.55 ± 0.25	1.53 ± 0.26	1.58 ± 0.28	1.53 ± 0.25	1.39 ± 0.15	1.26 ± 0.16	1.24 ± 0.15
E2	0.82 ± 0.20	0.82 ± 0.19	0.48 ± 0.13	0.50 ± 0.10	0.55 ± 0.11	0.52 ± 0.07	0.61 ± 0.05	0.70 ± 0.09	0.66 ± 0.10
E3	0.57 ± 0.17	0.57 ± 0.17	0.29 ± 0.11	0.32 ± 0.09	0.36 ± 0.11	0.36 ± 0.11	0.43 ± 0.06	0.49 ± 0.05	0.50 ± 0.07

*(x10^{-3}mm^{-2}s^{-1})

Table 1: DTI metrics at the C2-C3 spinal level in 20 normal volunteers.

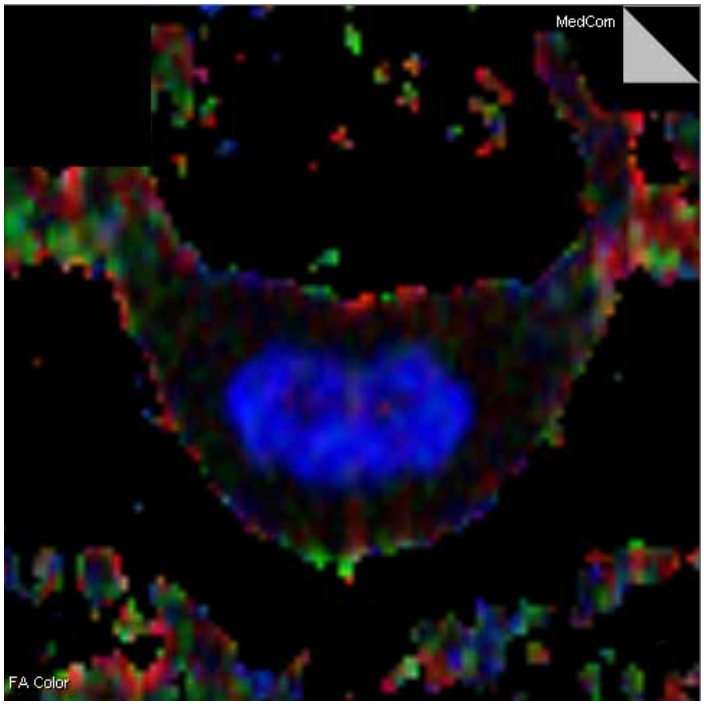

Figure 1. Color FA map generated from axial DTI of the cervical spinal cord in a normal patient showing gray and white matter differentiation.

RESULTS: The average age of the normal patients was 32.9 ± 14.0 years (average ± standard deviation). Regions of interest (ROIs) in the anterior cord white matter (WM) demonstrated significantly lower FA than those in lateral and posterior white matter ($p < 0.001$ and $p = 0.001$, respectively). The anterior WM ROIs also demonstrated increased MD compared to lateral and posterior ROIs ($p = 0.003$ and $p = 0.01$, respectively). GM ROIs showed significantly decreased FA compared to the lateral and posterior WM ROIs ($p < 0.001$) but did not differ significantly from the anterior WM ROIs. No significant difference between left and right-sided measurements was detected.

CONCLUSION: The study demonstrates DTI to be able to evaluate various spinal cord regions in the axial plane. Data (including the three principle eigenvalues) obtained in normal patients may prove useful in the evaluation of patients and for comparison with other pathologic states.

REFERENCES:

1. Clark CT et al. Magn Reson Med 2000; 43:133-8.
2. Facon D et al. AJNR 2005; 26(6):1587-94.
3. Mamata H et al. J Magn Reson Imaging 2005; 22(1):38-43.
4. Hesseltine SM et al. Proc Intl Soc Mag Reson Med 2005; 13:811.