

Diffusional Kurtosis Imaging of the cervical spinal cord in multiple sclerosis patients

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Introduction: Spinal cord (SC) is a site of predilection of multiple sclerosis (MS) lesions and its pathology contributes substantially to disability¹. Previous DTI studies of the SC in MS patients showed significant decrease in fractional anisotropy (FA) compared to healthy controls in both lesions and normal-appearing tissue². However, in gray matter (GM), DTI measurements might be of limited utility because of highly isotropic diffusion properties of this tissue. Diffusion kurtosis imaging (DKI) is a newly developed method based on the measurement of non-Gaussian water diffusion³. Directionally averaged kurtosis (mean kurtosis (MK) has been shown to be sensitive to structural changes in isotropic tissue such as GM and may provide information on tissue microarchitecture not accessible with FA and mean diffusivity (MD)⁴. MK can be regarded as an index of tissue microstructural complexity with increased values pointing to a higher order tissue organization. Using a moderately expanded diffusion sampling scheme, kurtosis metrics can be obtained simultaneously with conventional diffusion tensor-derived parameters. The aim of this study was to investigate global and regional structural abnormalities in the cervical spinal cord of patients with MS using both DKI and DTI.

Materials and Methods: Eight MS patients (mean age 42 ± 11 , range 25-63 yrs) and 8 healthy controls (mean age 40 ± 11 , range 27-62 yrs) underwent MRI of the cervical spine on a 3 T whole body scanner (Siemens Medical Solutions, Erlangen, Germany) with a phased array neck coil. The study was approved by the NYU IRB and informed consent was obtained from all subjects. The MRI protocol included the following sequences: (i) sagittal T2 TSE, (ii) axial T2 FLASH and (iii) twice-refocused-spin-echo (TRSE) diffusion sequence for DKI. DKI sequence parameters were: 30 diffusion encoding directions, 6 b values (0, 500, 1000, 1500, 2000, 2500 s/mm²). TR/TE: 3100/110 ms, 2 averages, FOV: 160×160 mm², matrix size: 128×128, slice thickness 3 mm, 20 contiguous axial slices. In each voxel, diffusion and kurtosis tensors were calculated using in-house software (Diffusional Kurtosis Estimator (DKE) in Matlab (Mathworks, Sherborn, MA, USA) and maps of derived parameters MK, FA and MD were generated. Mean MK, FA and MD values of the entire cross-sectional cord area were measured over five contiguous slices at the level of C1, C2, C3 and C4 (Figure 1b,c,d) using region of interest (ROI) analysis. In addition, mean MK, FA and MD values of normal-appearing GM (2 medial ROIs) and WM (1 posterior ROI) were measured over two slices at the C2 level (Figure 1e).

Results: Ten T2 hyperintense lesions were identified in 6 patients. Mean MK, FA and MD values in patients and controls are presented for the whole spinal cross-section area (Table 1) and for spine GM and WM at the C2 level (Table 2). Compared to controls, FA and MK were significantly decreased and MD was increased in patients. When lesional MD, MK and FA values were compared to the corresponding values in normal-appearing tissue only FA was significantly decreased (0.46 vs. 0.52, p=0.04). In patients, normal-appearing GM and WM MK values were significantly decreased when compared to those in GM and WM of normal controls. Finally, WM MK was significantly associated (r=-0.61, p=0.01) to the Expanded disability status scale (EDSS) score.

Conclusion: Our study demonstrates that DKI can be used to study water diffusion in the human spinal cord *in vivo* and is well-suited to evaluate both WM and GM damage. Since DTI cannot measure non-Gaussian diffusion, DKI can provide additional and complementary information on tissue microstructure. Such information might be exploited for additional empirical discrimination of pathology (Tables 1 and 2), or for more detailed comparison with biophysical models (demyelination, axonal damage, etc.)

References: 1) Tench C *et al.*, J. of Neuroimaging, 2005. 2) Valsasina P *et al.*, Neuroimage, 2005. 3) Lu H *et al.*, NMR in Biomedicine 2006. 4) Jensen JH *et al.*, MRM 2005. **Acknowledgments:** This study was supported by NIH grant 5R01NS051623-04.

	Regions	MS patients	Controls	p-values
FA	C1	0.49 ± 0.04	0.56 ± 0.02	<0.01
	C2	0.50 ± 0.07	0.58 ± 0.02	<0.01
	C3	0.48 ± 0.07	0.58 ± 0.02	<0.01
	C4	0.50 ± 0.06	0.56 ± 0.04	0.14
MK	C1	1.15 ± 0.11	1.22 ± 0.16	0.09
	C2	1.13 ± 0.09	1.17 ± 0.17	0.11
	C3	1.09 ± 0.08	1.14 ± 0.11	<0.01
	C4	0.98 ± 0.07	1.06 ± 0.12	0.11
MD (mm ² /s*10 ⁻³)	C1	0.86 ± 0.06	0.80 ± 0.09	0.04
	C2	0.91 ± 0.07	0.84 ± 0.06	0.03
	C3	0.98 ± 0.06	0.89 ± 0.07	0.03
	C4	1.01 ± 0.07	0.92 ± 0.07	0.04

Table 1 Mean ± SD for FA, MK and MD values averaged over C1, C2, C3 and C4 in patients and controls.

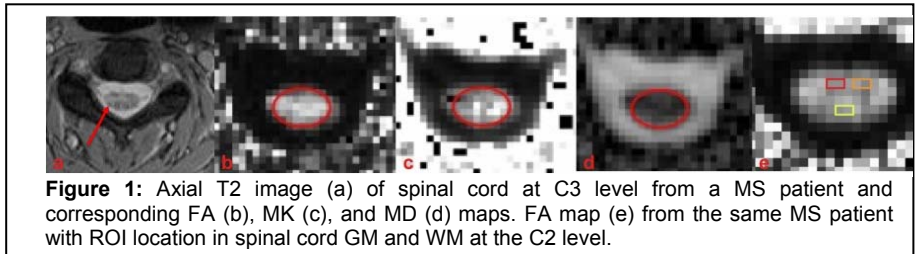


Figure 1: Axial T2 image (a) of spinal cord at C3 level from a MS patient and corresponding FA (b), MK (c), and MD (d) maps. FA map (e) from the same MS patient with ROI location in spinal cord GM and WM at the C2 level.

		Patients	Controls	p-value
FA	GM	0.49 ± 0.09	0.54 ± 0.09	0.13
	WM	0.52 ± 0.10	0.63 ± 0.09	0.04
MK	GM	1.04 ± 0.05	1.16 ± 0.14	<0.01
	WM	1.02 ± 0.12	1.15 ± 0.17	<0.01
MD (mm ² /s*10 ⁻³)	GM	0.94 ± 0.11	0.84 ± 0.15	<0.01
	WM	1.06 ± 0.15	0.89 ± 0.18	<0.01

Table 2: Mean ± SD for FA, MK, and MD values for normal appearing GM and WM at C2 level.