Demyelination in the injured human spinal cord detected with diffusion and magnetization transfer imaging

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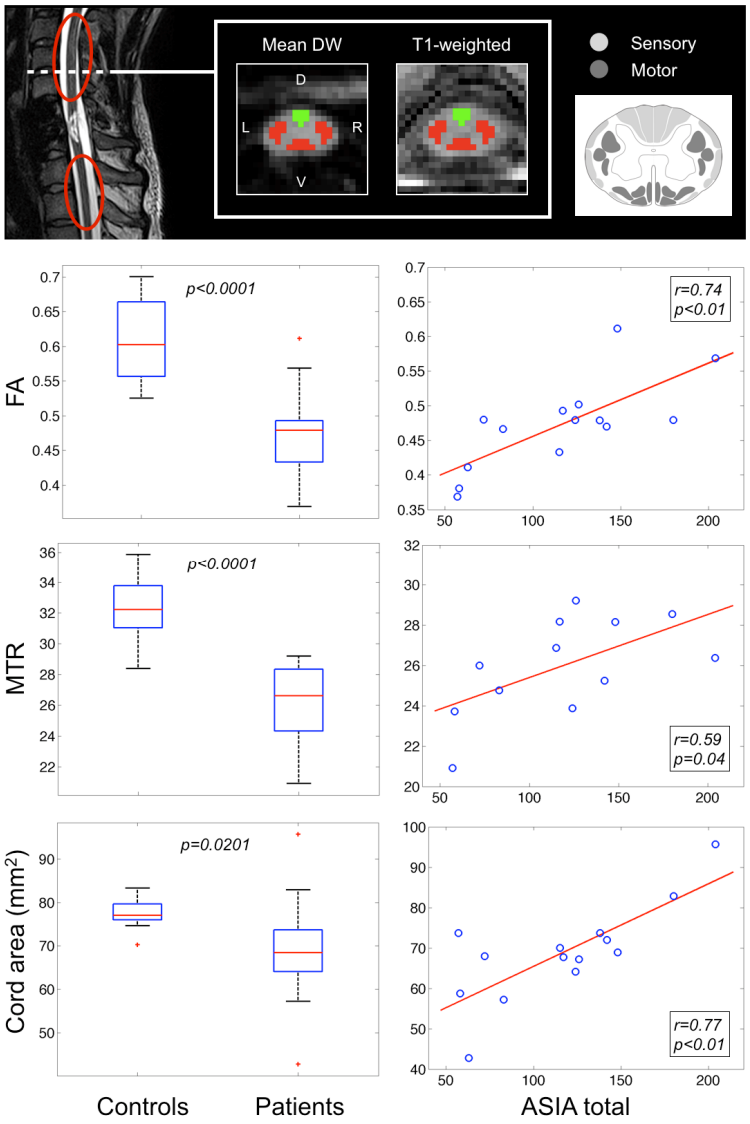
Introduction. Characterizing demyelination/degeneration of spinal pathways in patients with traumatic spinal cord injury (SCI) is important for evaluating the extent of spinal damage and assessing the prognosis of functional rehabilitation. Novel techniques based on diffusion-weighted (DW) and magnetization transfer (MT) imaging provide sensitive and specific markers of white matter pathology [1, 2]. In this paper we combined for the first time high angular resolution DW imaging, MT imaging and atrophy measurements to evaluate the cervical spinal cord of SCI patients.

Methods. Subjects. Patients with chronic cervical SCI (N = 14, age = 45±14 years) and age-matched controls (N=14) were recruited for this study. Patients were clinically assessed and scored using the motor and sensitive ASIA score within a week of MRI acquisition. Data acquisition. Subjects were scanned using a 3T MRI system (Tim Trio, Siemens Healthcare) using a combination of head, neck and spine receive coils (19-channel in total). The imaging protocol was: **1)** T2-weighted 3D turbo spin echo with slab-selective excitation (*52 sagittal slices, FOV=280mm, TR/TE=1500/120ms, 0.9x0.9x0.9mm^3, flip angle=140°, R=3 acceleration factor, BW=744Hz/Px*), **2)** DW imaging (*FOV=128 mm, TR/TE=700/96ms, 1x1x5mm^3, R=2, 64 diffusion directions, b-value=1000s/mm^2, BW=1086Hz/Px, echo spacing=1.04ms, 4 averaging, cardiac gating, advanced shimming*) and **3)** T1-weighted imaging with and without MT pulse (*FOV=230mm, TR/TE=28/3.2ms, 0.9x0.9x2 mm^3, flip angle=23°, BW=400Hz/Pix, Gaussian MT pulse: duration=9984µs, frequency offset=1200 Hz*). Data processing. Cord sectional size was measured from the T2-weighted image at the level of C1-C2 vertebrae using a semi-automatic method [3]. DW data were corrected for motion and diffusion tensors were estimated using FSL [4]. MT ratio (MTR) was computed voxel-wise using the T1-weighted image without (S_0) and with (S_{MT}) MT pulse as follows: $[(S_0 - S_{MT}) / S_0] \times 100$. DW metrics and MTR were quantified in the dorsal and ventrolateral spinal cord of each individual. Manual ROIs were drawn in the normal-appearing white matter, as assessed by a neuroradiologist (S.L.) based on the T2-weighted images (see Figure). Statistics. Two-tailed Student's T-test was performed between controls and patients for fractional anisotropy (FA), axial and radial diffusivities, mean diffusivity (MD), MTR, T1- and T2-weighted signals (normalized by CSF) and cord area. Stepwise regression analysis tested for tract-specificity (dorsal or ventrolateral) with regards to the motor or sensory ASIA scores.



Results. Significant differences were detected between patients and controls for fractional anisotropy (FA, p<0.0001), axial diffusivity (p<0.05), radial diffusivity (p<0.05), MTR (p<0.0001) and cord area (p<0.05). No significant difference was detected in mean diffusivity (p=0.41), T1-weighted (p=0.76) and T2-weighted (p=0.09) signals. These metrics were remarkably well correlated with clinical disability (Pearson's correlations, FA: p<0.01, GFA: p<0.01, radial diffusivity: p=0.01, MTR: p=0.04 and atrophy: p<0.01). Stepwise linear regressions showed that FA (p=0.01), GFA (p=0.006), radial diffusivity (p=0.02) and MTR (p=0.025) measured in the dorsal spinal cord correlated with ASIA sensory disability whereas MTR (p=0.034) in the ventro-lateral cord correlated with motor disability.

Discussion. The axial and radial diffusivity and MTR abnormalities observed in patients suggest that spinal cord lesions included demyelination and degeneration changes [5]. Combining DW with MT imaging is a promising approach to gain specificity in characterizing the extent of the spinal damage in various spinal cord regions and offers the benefit of detecting changes that are not observed readily on conventional images. This method could be applied to other diseases affecting the spinal cord such as ALS [6].

References. [**1**] Budde, M.D., et al., Magn Reson Med, 2007. 57(4): p. 688-95. [**2**] Schmierer, K., et al., Ann Neurol, 2004. 56(3): p. 407-15. [**3**] Lundell, H., et al., Spinal Cord, 2010. in press. [**4**] Smith, S.M., et al., Neuroimage, 2004. 23 Suppl 1: p. S208-19. [**5**] Cohen-Adad, J., et al., Neuroimage, (accepted). [**6**] Pradat, P.F., et al., Proc. ISMRM, 2011.

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