Evidence of Wallerian degeneration in the human spinal cord using in vivo high-resolution DTI and magnetization transfer

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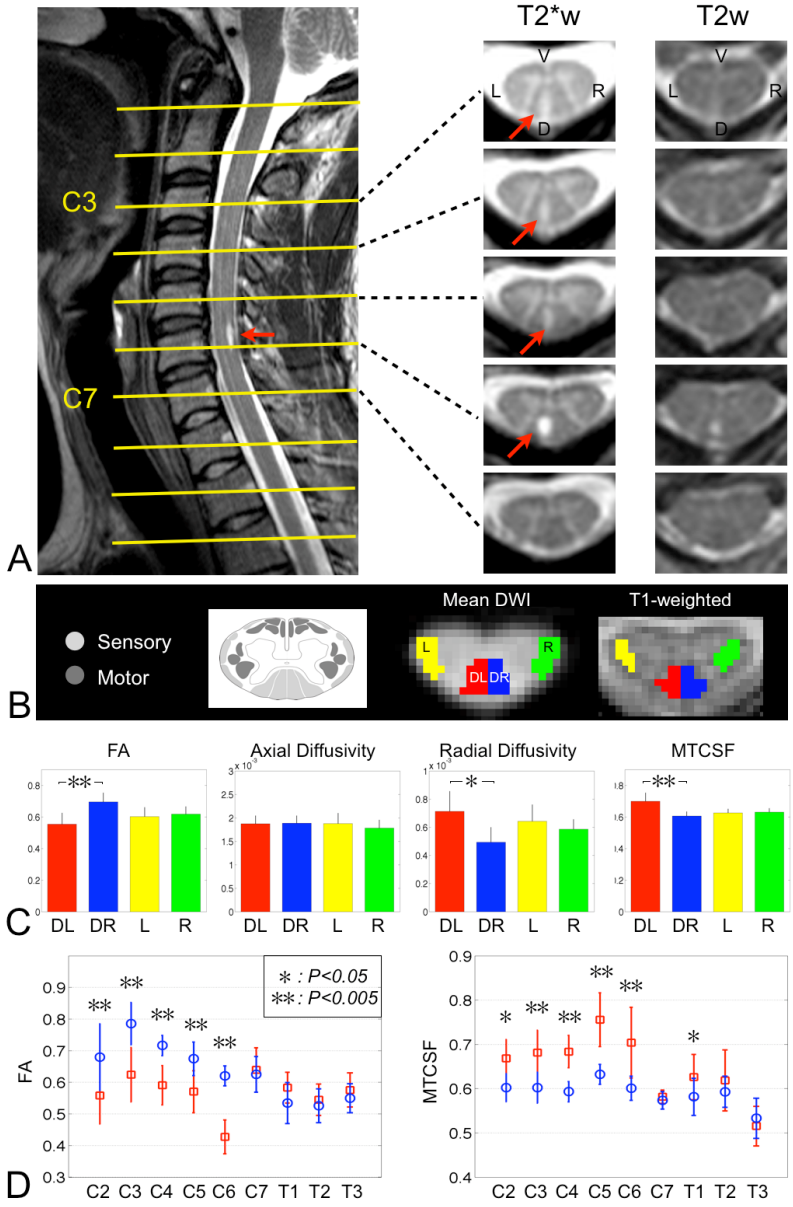
Introduction. Diffusion-weighted (DW) and magnetization-transfer (MT) imaging are improving identification of white-matter brain pathology, with relative specificity for demyelination and degeneration [1, 2]. These techniques have not yet been widely applied to spinal cord imaging, although differentiating between degeneration and demyelination in spinal-cord injured patients might aid functional prognosis. To evaluate potential utility, we compared DW, MT, and conventional imaging for longitudinal study of a patient with well-characterized cervical-cord injury.

Methods. Subject. Using an approved IRB protocol, clinical and radiological data were collected from a 29 year-old woman with C5-6 cord injury from inadvertent intramedullary injection of corticosteroids following car accident. Pre-injury, acute, and chronic post-injury data for up to one year were analyzed. Clinical data were obtained through retrospective medical-record review. Data acquisition. The subject was scanned at 3T (Tim Trio, Siemens Healthcare) using a custom-made 32-channel head/spine coil [3]. Imaging protocol included: **(1)** Sagittal T2-weighted TSE (*TR/TE=3500/104ms, 0.5x0.5x3mm^3*) ; **(2)** T2*-weighted multiecho FLASH (*20 axial slices, FOV=192mm, TR/TE=781/17ms, 0.25x0.25x3mm^3 in-plane interpolation, flip angle=30°, R=3 acceleration factor, BW=260Hz/Px, nav=4*), **(3)** T2-weighted TSE (*20 axial slices, FOV=200mm, TR/TE=2000/102ms, 0.31x0.31x3mm^3 in-plane interpolation, flip angle=150°, R=3, BW=284Hz/Px, nav=3*), **(4)** Diffusion-weighted EPI (*10 axial slices as shown in Fig1A, FOV=83mm, TR/TE=2020/118ms, 0.6x0.6x5mm^3, R=2, 30 diffusion directions, b-value=700s/mm^2, BW=758Hz/Px, nav=4, cardiac gating, advanced shimming*) and **(5)** T1-weighted with and without MT (*FOV=192mm, FOVph=87.5%, TR/TE=1070/2.52ms, 0.6x0.6x5 mm^3, flip angle=60°, BW=313Hz/Pix, Gaussian MT pulse: duration=9984μs, frequency offset=1200 Hz*). Total imaging time was 45min. Data processing. Following motion correction, DTI metrics [4] and Cerebrospinal-fluid-normalized MT (MTCSF) [5] were computed and quantified in the dorsal and lateral cord (Fig1B).

Results. During C5-6 epidural-steroid injection, this patient reported unusual left arm and leg sensations and developed new left-only weakness. On day 1 post-injury, conventional MRI (not shown) revealed T2 signal hyperintensity in the C5-6 left dorsal cord so she was admitted and treated for acute injury. Left-only lower-limb paresis (4/5) and pan-sensory loss below T10 were documented by examination. At 6 weeks post-injury, conventional MRI (not shown) revealed slight enlargement of a C5-6 CSF-intensity cavity. At 8 weeks post-injury, she used a brace and cane to walk, had 5-/5 left-arm weakness, 4/5 left-leg weakness, and early left-leg spasticity. Our experimental MRI performed at 32 weeks post-injury revealed C6 signal hyperintensity on midsagittal TSE (Fig1A arrow). Axial T2*-weighted images showed left dorsal hyperintense signal between C3 to C6 (Fig1A arrows). Quantification of DTI and MTCSF within cord quadrants revealed significant left-right differences (Fig1C). Radial diffusivity was increased, axial diffusivity was unchanged and MTCSF was increased in the dorsal-left quadrant, most consistent with demyelination [1]. DTI and MT metrics quantified along the dorsal cord corroborated the T2*-weighted image, with FA decrease and MTCSF increase at C2-C6, and no major changes below C6 (Fig1D). At 7.5 months post-injury her left hemiparesis persisted and she reported new transient occipital numbness with neck extension.



Discussion. Concomitant analysis of high-resolution conventional, DTI and MT images suggested anterograde (rostral) Wallerian degeneration in the dorsal left pathway from C6 to C2. The correlation between DW and MT measurements and the neurological abnormalities provides incentive to perform multi-parametric spinal MRI to better distinguish demyelination and degeneration after spinal cord injury [6].

References. [**1**] Budde MD, *Magn Reson Med*, 2007. 57(4): p. 688-95. [**2**] Schmierer K, *Ann Neurol*, 2004. 56(3): p. 407-15. [**3**] Mareyam A, *Proc. ISMRM*, 2010. [**4**] Smith SM, *Neuroimage*, 2004. 23 Suppl 1: p. S208-19. [**5**] Zackowski KM, *Brain*, 2009. 132: p. 1200-9. [**6**] Cohen-Adad J, *Neuroimage*, (accepted).

Acknowledgements. NIH-P41RR14075, NIH-K24NS59892.