Diffusion Basis Spectrum Imaging (DBSI) Measures Axonal Integrity after Spinal Cord Injury

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Background: Predicting a patient's potential for recovery after an acute cervical spinal cord injury (SCI) requires an accurate tool to quantify neuronal damage. Currently, there are no imaging biomarkers that can ascertain clinically critical levels of edema or axonal injury responsible for neurological impairments. Diffusion tensor imaging (DTI) measures diffusion properties of water molecules in living tissues and is capable of accurately depicting the microstructural organization of cervical spine white matter. Previous work has revealed that DTI analysis of spinal cord injury is significantly confounded by a spectrum of isotropic diffusion tensor components resulting from inflammation, edema, and chronic tissue loss. To overcome these confounding factors, we have developed a novel data-driven model-selection algorithm known as diffusion basis spectrum imaging (DBSI) to more accurately delineate white matter injury, allowing quantification of axonal injury, demyelination, and inflammation in the acute and chronic SCI setting. In this study we investigate the use of DBSI as a biomarker of axonal injury.

Methods: A prospective non-randomized cohort of 18 cervical spine injury patients and 6 control subjects underwent MR imaging over a 2-year period. DTI and DBSI analyses were performed on whole brain and cervical spine diffusion weighted images. DTI and DBSI-derived indices from the proximal columns and corticospinal tracts were correlated with clinically used grading scale (American Spinal Injury Association (ASIA) Score) and compared between patients and controls. Tractography was used to visualize and corroborate changes in DBSI indices.

Results: Compared with controls and recovered Asia-E patients, severely injured ASIA-A patients showed decreased DTI fractional anisotropy (FA) but elevated radial and axial diffusivity (p < 0.05). DBSI analysis found an elevated water fraction, decreased fiber ratio, decreased FA, decreased axial diffusivity, and increased radial diffusivity (p < 0.05) (Figure 1).

Tractography (Figure 2) revealed the anatomical distribution of regions with decreased fiber-like diffusion.

Conclusion: After a cervical spinal cord injury the degree of altered AD, RD, edema content, and axonal loss derived from DBSI, may correspond more accurately to ASIA Score than AD and RD derived using DTI because DBSI can measure axonal integrity and differentiate axons with and without myelin from edema and inflammation surrounding the fiber tracts. With further refinement DBSI may prove to be a useful clinical tool for monitoring the severity and progression of spinal cord injury patients.
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Figure 1. Comparison of AD values: ASIA-A patients show slightly increased axial diffusivity likely due to edema. When analyzed with DBSI, the same patients show a markedly reduced axial signal (as well as decreased fiber ratio, and FA value, not shown here) consistent with the presence of axonal damage.

Figure 2. Characteristic Tractography: Generated by linking adjacent anisotropic diffusion signals, these images model the tract-like regions of the brain. This image, from a patient, has been colorized with the FA value at each point and clearly shows regions of decreased fiber integrity in yellow.