Diffusion Basis Spectrum Imaging quantifies pathologies in Cervical Spondylotic Myelopathy

Peng Sun[1], Rory Murphy[2], Yong Wang[1], Joanne Wagner[3], Sammir Sullivan[1], Paul Gamble[2], Kim Griffin[1,2], Wilson Z. Ray[2], and Sheng-Kwei Song[1]
[1]*Radiology, Washington University in St. Louis, St. Louis, MO, United States,* [2]*Neurosurgery, Washington University in St. Louis, St. Louis, MO, United States,*
[3]*Physical Therapy and Athletic Training, Saint Louis University, St. Louis, MO, United States*

Background: Cervical spondylotic myelopathy (CSM) is the most common form of spinal cord injury (SCI) that leads to permanent and often-irreversible neurological deficits. Due to the lack of an effective diagnostic approach to stratify treatments and to accurately reflect underlying tissue damage, the outcome prediction of surgical decompression remains elusive. Advanced MRI techniques are being employed to derive noninvasive biomarkers of spinal cord injury in CSM. Unfortunately, none of those approaches is capable of accurately reflecting underlying spinal cord pathologies. In this study, cervical spinal cord white matter pathologies were examined using the newly developed diffusion basis spectrum imaging (DBSI) [1] to accurately delineate axon and myelin injury, quantifying the extent of axon loss and edema of CSM spinal cord.

Methods: The Washington University Human Research Protection Office/Institutional Review Board approved this cross-sectional study, and all subjects provided a written informed consent. Fourteen patients along with seven age-matched controls were enrolled. All participants underwent a neurologic examination by a board-certified neurosurgeon. The neurological exam included the modified Japanese Orthopedic Association (mJOA) and self-reported disability (Myelopathy Disability Index; MDI). Seven patients were mild (mJOA 15-17) and the rest seven patients were moderate or severe (mJOA <15). Moderate and severe patients were combined and identified as severe CSM group for statistical analysis.

MRI acquisition and processing: Data acquisition was performed following previously reported procedures [2]. Diffusion-weighted images (DWIs) were collected with a multi–b-value scheme (4 averages of 25 directions and maximum b-value = 600 s/mm^2) at 3T (Trio; Siemens, Erlangen, Germany) with cardiac-gating, reduced field of view, single-shot spin-echo echo planar imaging sequence with voxel size of 0.9×0.9×5 mm^3. Total 18 slices from cervical spinal cord segments (C1 to C6) were acquired in ~ 45 minutes. DTI and DBSI were computed using the in-house software developed using Matlab. Regions of interest (ROIs) for total white matter (WM) of spinal cord were determined using the FA map and b0 image. The computation was calculated on segment basis and then averaged across all segments for analysis. DBSI derived axon volume was defined as mean DBSI fiber fraction multiply segment white matter volume (mm^3). DBSI edema was defined as mean DBSI non-restricted isotropic diffusion fraction multiply segment white matter volume (mm^3).

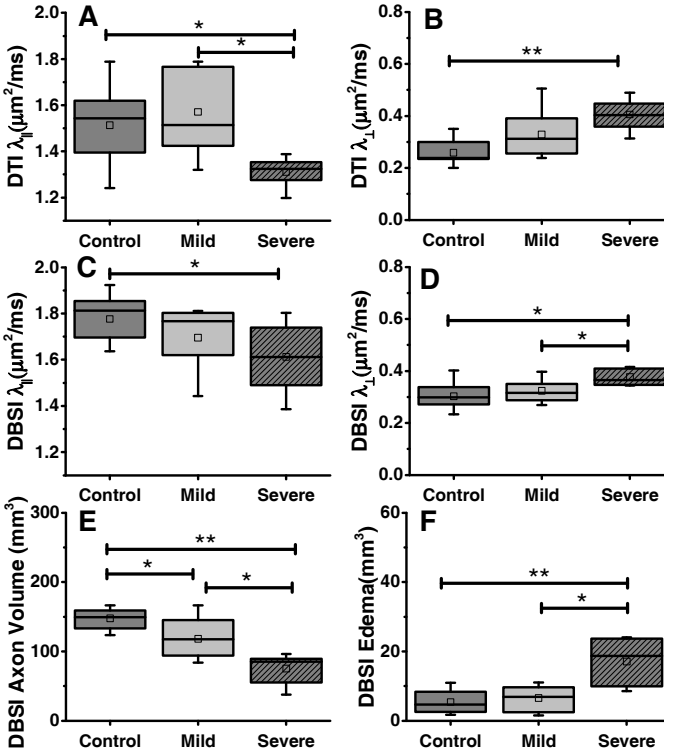

Figure 1. Group analysis of DTI and DBSI metrics. *p<0.05, ** p<0.01

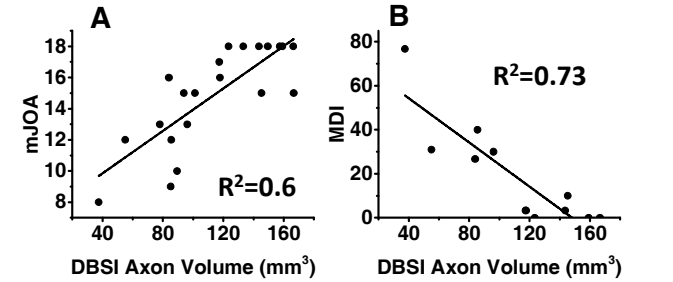

Figure 2. Correlation of DBSI Axon Count with mJOA and MDI.

Results: Both DTI axial (Fig. 1A) and DBSI axial (Fig. 1C) diffusivity significantly decreased in severe CSM group, suggesting injury of residual axons. Significant increase of DTI radial (Fig. 1B) and DBSI radial diffusivity (Fig. 1D) suggested demyelination for severe group. DBSI-derived axon volume revealed significant axon loss in mild CSM that was worse in the severe CSM (Fig. 1E). Significantly increased edema was also observed in the severe group (Fig. 1F). DBSI detected axon loss was correlated well with both mJOA and MDI scores (Fig. 2A and 2B).

Conclusions: DBSI confirmed the axon injury and demyelination seen by DTI. DBSI-derived axon volume and edema provide more quantitative markers for spinal cord pathologies. DBSI-derived axon volume not only successfully detects axon loss in both mild and severe CSM groups, but also strongly correlated with neurological impairments. Findings suggest that axon loss may be the primary contributor to neurological impairment in CSM. The multiple metrics derived by DBSI, could offer an insight to the underlying pathologies responsible for the evolving neurological impairments in CSM.

Reference: [1] Wang, Y. et al. *Brain*, 2011. [2] Xu, J. et al. *Neuroimage*, 2012.