Diffusion Tensor Imaging Parameters of Apparent Diffusion Coefficient and Fractional Anisotropy in the Evaluation of Traumatic Cervical Spine Injury

S. K. Cheran[1], K. Shanmuganathan[1], J. Zhuo[2], S. E. Mirvis[1], and R. P. Gullapalli[2]

[1]Department of Radiology, University of Maryland Medical Center, Baltimore, MD, United States, [2]University of Maryland School of Medicine, Baltimore, MD, United States

Introduction: About 11,000 new spinal cord injuries occur every year in the United States alone.[1] Traumatic spinal cord injury may result in cellular swelling and degeneration and cause disruption to the myelin membranes. Diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) have been extensively used to study experimental spinal cord injury in animals with reasonable success. We performed a retrospective study to evaluate the changes that occur in diffusion tensor magnetic resonance imaging (DT-MRI) parameters of apparent diffusion coefficient (ADC) and fractional anisotropy (FA) in patients with blunt traumatic neck injury.

Methods: Institutional review board approval was obtained and the informed consent requirement was waived for this HIPAA-compliant study. DT-MRI studies were retrospectively analyzed in 50 symptomatic patients (mean age 41.4 ± 17.5 years, 37 male) with blunt cervical spine trauma and 11 volunteers (mean age 31.5 ± 10.7 years, 8 male). MRI studies of patients were obtained because of a neurological deficit on clinical examination localized to the cervical spine, neck pain or tenderness that was unexplained by admission CT examination, or to assess for extent of ligamentous injury following cervical spine fracture demonstrated on the admission CT of the cervical spine.

Both groups were imaged using conventional MRI and DT-MRI. Diffusion weighting was applied in 6 non-collinear directions on a 1.5T Siemens Avanto scanner at an effective b-value of 1000 s/mm^2 in the axial plane. Diffusion tensor images were obtained using an echo-planar imaging sequence at a TE/TR of 76/8000ms at a resolution of 128x128 over a 20cm field of view. A 12 channel head-neck array coil was used on all patients and parallel imaging employed with the phase encoding in the anterior to posterior direction. A total of 67 axial slices at 3mm thickness were obtained to cover from the medullary cervical junction to the cervical-thoracic junction.

Image Analysis: FA and ADC maps were generated with background noise suppressed, using DTI task card which runs on Siemens MR workstation (courtesy Dr. Sorenson, Dr. Benner from Massachusetts General Hospital, Boston). Regions of interest (ROI) were drawn in upper, middle, and lower cervical cord regions using T2-weighted and/or b=0 portion of the DTI images for anatomic reference. The upper cervical cord included the region from the lower brainstem to lower C2 vertebral body level; the middle cervical cord included the region between the upper C3 vertebral body level to lower C5 vertebral body level; and the lower cervical cord included the region from the upper C6 vertebral body level to the lower T1 vertebral body level. ADC and FA were measured for each ROI for both the normal controls and patients.

Data Analysis: A combination of CT and MRI findings was used to categorize patients into four subgroups of expected increasing injury severity[2]:

Group 1. no CT evidence of acute traumatic injury, and no cord contusion on conventional MRI sequences (n=12)
Group 2. CT findings of acute osseous and/or ligamentous injury without cord contusion on conventional MRI sequences (n=13)
Group 3. cord contusion on conventional MRI without hemorrhage (n=12)
Group 4. hemorrhagic cord contusion on conventional MRI (n=13)

A comparison of each cervical spine region of the patients with the normal controls was performed to assess the deviation of DTI parameters from normal controls. A one-sided t-test was employed to do the comparisons.

Results: Compared to volunteers, mean ADC values (Table 1) were significantly decreased between the upper, middle, and lower cervical cord sections for all patients with MR signal abnormalities of cord contusion (Groups 3 and 4). In patients with CT findings of acute traumatic injury but no MRI cord signal abnormality (Group 2), ADC was significantly decreased in the upper and middle cervical cord sections when compared to volunteers, with near significant decrease in the lower cervical spinal cord.

Compared to volunteers, mean FA values (Table 2) for all patient groups were significantly decreased in the middle and lower cervical cord.

Table 1. Comparison of mean ADC values for patient groups to mean ADC value for the control group.

	Mean ADC (x 10^{-3} mm^2/s)		
	Upper cervical cord	Middle cervical cord	Lower cervical cord
Control	8.2 ± 0.7	9.5 ± 1.0	9.4 ± 1.1
Group 1	7.5 ± 2.4 (p = 0.19)	9.2 ± 1.1 (p = 0.27)	8.5 ± 2.2 (p = 0.10)
Group 2	6.5 ± 2.2 **(p < 0.01)**	8.0 ± 1.9 **(p < 0.02)**	8.8 ± 0.9 (p = 0.068)
Group 3	6.2 ± 1.7 **(p < 0.001)**	7.1 ± 1.7 **(p < 0.001)**	7.3 ± 1.2 **(p < 0.001)**
Group 4	6.4 ± 1.2 **(p < 0.0001)**	7.0 ± 1.1 **(p < 0.0001)**	7.3 ± 1.2 **(p < 0.0001)**

Table 2. Comparison of mean FA values for patient groups to mean FA value for the control group.

	Mean FA		
	Upper cervical cord	Middle cervical cord	Lower cervical cord
Control	0.67 ± 0.09	0.71 ± 0.07	0.65 ± 0.08
Group 1	0.61 ± 0.09 **(p < 0.05)**	0.64 ± 0.08 **(p < 0.05)**	0.57 ± 0.10 **(p < 0.05)**
Group 2	0.74 ± 0.09 **(p < 0.05)**	0.63 ± 0.13 **(p < 0.05)**	0.52 ± 0.13 **(p < 0.05)**
Group 3	0.73 ± 0.14 (p = 0.14)	0.64 ± 0.17 **(p < 0.02)**	0.58 ± 0.08 **(p < 0.02)**
Group 4	0.69 ± 0.11 (p = 0.34)	0.62 ± 0.12 **(p < 0.02)**	0.55 ± 0.12 **(p < 0.02)**

Conclusions: In patients with blunt traumatic neck injury, change in the DT-MRI parameter of ADC is inversely proportional to the severity of cervical spinal cord injury. In patients with cervical spine fractures, statistically significant decrease in ADC is present even in the absence of cord contusion by conventional MRI sequences. The DT-MRI parameter of FA also shows statistically significant decrease in the middle and lower cervical spinal cord of all patient groups, even those lacking findings of cord contusion on conventional MRI sequences. These findings are in keeping with previous animal experiments.[3] Thus, ADC and FA are potential markers of both presence and relative severity of cervical spinal cord injury. ADC and FA may prove particularly useful in evaluation of trauma patients with clinical symptoms who lack conventional MRI findings of cord contusion. A prospective, longitudinal study of these parameters should be performed with correlation to clinical outcomes.

References:

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