ASIA scores correlate with DTI Metrics in Non-Hemorrhagic Traumatic C-Spine Injury

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Introduction
Conventional magnetic resonance imaging (MRI) is the best imaging modality to demonstrate ligamentous injury, hematoma, disk herniation, spinal cord edema and hemorrhage that occur following trauma[1]. Quantitative and qualitative image parameters like lesion length, maximum spinal cord compression, spinal cord swelling and, presence of hemorrhage within the cord has been reported to be useful in predicting neurological outcome[2]. There has been recent interest in evaluating spinal cord injury using diffusion tensor imaging (DTI)[3]. Recently, experimental DT-MRI derived measurement performed in the rat spinal cord during the hyperacute period following injury reported axial diffusion measurements were helpful to predict severity of injury and correlated well with histology[4]. The purpose of our retrospective study was to determine the correlation between American Spine Injury Association (ASIA) clinical injury motor score in patients with traumatic cervical cord injury and the various DT-MRI parameters.

Methods
Institutional review board approval was obtained and the informed consent requirement was waived for this HIPAA-compliant study. The study group was formed of 25 patients (21 men; 41.4 ± 17.5 years), consequently admitted over an 18-month period to our trauma center with cord contusions in the c-spine demonstrated by conventional MRI. The cord contusions were nonhemorrhagic (NHC) in 12 patients (2 women, 10 males) and hemorrhagic (HC) in 13 patients (2 women, 11 men). All patients were admitted following blunt trauma. The mechanism of injury included motor vehicle collision (n = 8), fall (n = 9), diving/surfing accident (n = 6), and assault (n = 2). The study group was retrospectively compared with 11 normal controls (age 31.5±10.7 years, 3 women, 8 male). Based on the CT and conventional MRI appearances there were 10 patients with flexion tear drop fractures, 8 patients with unilateral facetal subluxation, 2 patients with bilateral facet subluxation, 3 patients with acute disk herniation, 2 patients with spinal contusion without a fracture, and 1 patient with bilateral facetal perch. Both groups were imaged using standard conventional 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. DTI was 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 covering from the medullary cervical junction to the cervical-thoracic junction. 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.

Maps of MD and FA were generated with background noise suppressed using the DTI task card available on Siemens MR Workstations. The conventional images were viewed for evidence of signal abnormality to indicate the presence of a cord injury. The anatomical location of the cord injury and the presence of edema or hemorrhage were noted. ROIs were drawn by two radiologist (SC and KS) blinded to American Spinal Injury Association (ASIA) motor scores within the area of the spinal cord injury identified using conventional MRI, from which the DT-MRI parameters including MD, FA, the three eigenvalues λ_1, λ_2, and $\lambda_3$were calculated from which the axial diffusivity, $\lambda_{par} = \lambda_1$ and radial diffusivity $\lambda_{perp}=(\lambda_2+\lambda3)/2$ were computed. These parameters were compared with the corresponding location from the control subjects. To determine whether changes in DT-MRI parameters varied in severity with the two types of contusions, data from the patients with NHC and HC cord contusions were compared with those from the healthy controls. All comparisons were made using a one-sided two sample t-test. Significance was defined as $P < 0.05$.

Results
Compared to a similar location in the normal cord the FA was significantly reduced among both the HC and NHC patients as seen in Table 1. Although mean diffusivity decreased among both patients this did not reach statistical significance. The reduction in the FA was mainly due to a significant decrease in the axial diffusivity among the two patient populations. This was also accompanied by an increase in the radial diffusivity for both patient groups but only the NHC group reached significance. DTI parameters correlated strongly with the ASIA scores for the NHC group. A strong positive correlation with MD (R^2=0.81)), negative correlation with FA (R^2=0.67), positive correlation with λ_{par} (Figure 1,R^2=0.65) and positive correlation with λ_{perp} (R^2=0.77) was found for the NHC group with the ASIA scores. ASIA scores were very weakly correlated with the DTI parameters for the HC group.

Table 1	ASIA	FA	MD * 10^{-3} mm^2/s	λ_{par} * 10^{-3} mm^2/s	λ_{perp} * 10^{-3} mm^2/s
Normal Cord	100	0.67±0.06	0.90±0.07	1.73±0.11	0.49±0.09
Non-Hemorrhagic Injury (NHC)	60.1±28	**0.49±0.13****	0.83±0.15	**1.32±0.22****	**0.61±0.16***
Hemorrhagic Injury (HC)	19.3±28	**0.49±0.11****	0.81±0.20	**1.25±0.27****	0.59±0.19
Total Injury (HC+NHC)	36±35.7	**0.49±0.11****	0.82±0.18	**1.28±0.24****	**0.60±0.17***

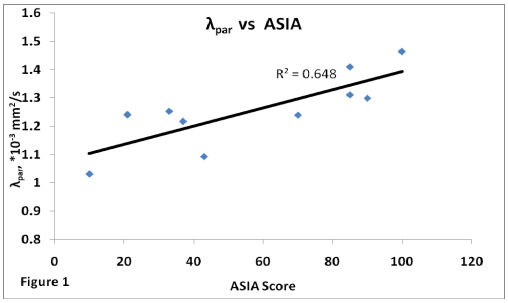

Figure 1

Conclusions
In patients with blunt traumatic neck injury, there are clear differences in the DTI parameters among the injured patients compared to the normal controls. Further, the fundamental DTI parameters, including ADC, FA, λpar and λperp appear to linearly scale with severity of injury as depicted by the ASIA score. However such a relationship was not seen among the HC group. The non-existence of a relationship between the HC group and the ASIA scores may be reflective of the microenvironment that presents other heterogeneous barriers to water diffusion in the HC group. In conclusion, the DTI parameters appear to capture the severity of c-spine injuries and correlate strongly with the ASIA scores. Further study is required to assess whether this holds on a large cohort of patients.

References:
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