Diffusion Tensor Imaging in the Evaluation of Traumatic Spinal Cord Injury

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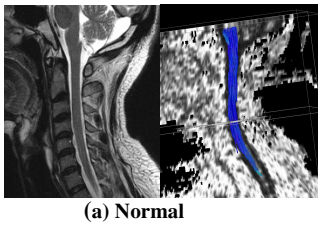
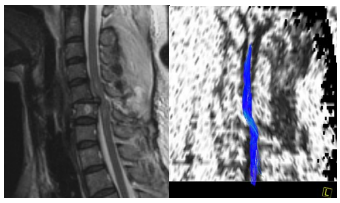
Introduction: Approximately 20,000 patients per year will suffer from paralyzing spinal cord injury in the United States alone.[1] Traumatic spinal cord injury may result in cellular swelling and degeneration and cause disruption to the myelin membranes. Diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) have been extensively used to study experimental spinal cord injury in animals with reasonable success. However no prior studies have reported DTI changes following human traumatic spinal cord injury (SCI). In this work we present the changes in DTI parameters following traumatic SCI and compare these changes with DTI parameters from normal control volunteers.

Methods: Data from fifteen patients (age, 44±17, 6 female), admitted to our trauma center following blunt force trauma with cervical spine injuries were imaged using MRI as part of the standard protocol were compared with normal controls (n=11, age 33±10, 3 female). Both groups were imaged using conventional and DTI-MRI. MRI was performed because of a neurological deficit on clinical examination localized to the cervical spine, neck pain or tenderness that was unexplained by admission cervical spine radiographs or computed tomography examination. The mechanism of injury included motor vehicle collision (n=6), motor cycle collision (n= 1), fall (n=4), assault (n=1), surfing (n=1) and diving accident (n=2). Six patients had hemorrhagic cord contusions, four had soft tissue injury and five had cord contusions. Diffusion tensor images were obtained in 6 non-collinear directions at an effective b-value of 1000 s/mm2 in the axial direction. All imaging was performed on a 1.5T Siemens Avanto scanner. Other imaging parameters were: FOV 20cm^2; matrix 128x128; slice thickness 2mm with no gap; 5 averages; and a TE/TR of 73/8000ms. A total of 72 axial images were acquired to cover from top of the brain to the skull base. Sagittal T2-weighted images were also obtained to get anatomical reference.
Data Analysis: FA and ADC maps were generated with background noise suppressed, using DTI task card provided by MGH (courtesy Dr. Sorenson, Dr. Benner). The spine was divided into thee regions. The Upper region comprised the area between the medullary cervical junction to C2, the mid region included C3-C5, and the lower region was from C6-T1. ROI's were drawn in each of the three regions for both the normal controls and patients from which FA and ADC were measured. Whole spine FA and ADC measures were obtained by averaging the three ROI's per subject. To assess the regional variation of ADC and FA, comparisons were made between the three regions among the normal subjects. To assess the degree of deviation from the normal controls each of the regions of the patients were compared with those of the normal controls and these assessments were also made at the whole spine level. A one-sided t-test was employed to do the comparisons.



(a) Normal



(b) Quadriplegic patient

Figure 1: Example DTI images of a normal subject and a motor vehicle collision patient with unilateral facetal subluxation with fracture.

Results: The ADC values of the cord increased in the mid (ADC 0.97E-3mm^2/s; p<0.004) and lower sections (ADC 0.973E-3mm^2/s;p<0.004) of the cord compared to the upper section (ADC 0.83E-3 mm^2/s) among the normal controls. There was no significant difference in the ADC between the mid and lower sections. No significant differences in the FA were found between the upper (FA 0.64) and the mid cord (FA 0.69) but there was significant difference between the upper FA and the lower FA (FA 0.62, p<0.03). Whole spine ADC values were significantly reduced in the patients (ADC 0.62E-3 mm^2/s, p<0.0001) compared to the normal controls (ADC 0.92E-3 mm^2/s) while only near significance was obtained for FA (normal FA 0.65; patients FA 0.62; p=0.067). ADC was also significantly reduced when comparing the individual region of the patients with that of the normal controls. When comparing the DTI values at the injury site among patients with the corresponding location in the normal controls, both the ADC (p<0.03) and FA (p<0.004) were significantly reduced. Patients presenting with hemorrhagic lesions (n=6) showed a marked and significant reduction in ADC (ADC 0.677E-3mm^2/s) and FA (FA 0.58) values of the whole spine. Figure 1 shows an example of a quadriplegic patient on whom the ADC and the FA was reduced at the site of the injury.

Conclusions: DTI images of the spinal cord using standard single shot EPI techniques provided good quality images. Our data from the normal controls indicates that the ADC and FA values increase along the spinal column with the upper region having the least value. Our data shows a decrease in both the ADC and FA which indicates intracellular selling and possible myelin sheath degeneration which is consistent with other animal injury experiments.[2,3] To our knowledge this is the first report on the use of DTI on patients presenting with traumatic spinal cord injury. While there appears to be a potential for the role of DTI in spinal cord injury patients, further controlled studies are needed to understand the sequelea of such injury.

References:

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