Voxel-Based Morphometry using Diffusion Tensor Imaging to determine the brain regions affected following mild and severe Traumatic Brain Injury

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INTRODUCTION: Traumatic brain injury (TBI) is the primary cause of death and disability in young population under 45 years of age, among which a significant portion suffer diffuse axonal injury (DAI). Both CT and conventional MRI are known to underestimate the extent of DAI injury. Diffusion tensor imaging (DTI) has recently shown some promise in the evaluation of the TBI patient[1,2]. Here a voxel based DTI analysis was carried out to compare two groups of patients (mild, severe) with normal subjects. The sensitivity of DTI parameters (ADC, FA) in differentiating severe and mild condition was studied along with the regional extent of the injury using voxel based morphometry.

METHODS: Imaging: Eleven TBI patient, six in mild condition (GCS: 13 – 15; ages 35±19) and five in severe condition (GCS: 3 – 8; ages 40±23) and 6 healthy adult volunteers (ages 39±11) were imaged with conventional MRI and DTI. Diffusion tensor images were obtained in 6 non-colinear directions at an effective b-value of 1000 s/mm^2. All imaging was performed on a 1.5T Siemens Avanto scanner. Other imaging parameters were: FOV 23cm^2; matrix 128x128; slice thickness 2mm with no gap; 5 averages; and a TE/TR of 73/7000ms. A total of 72 axial images were acquired to cover from top of the brain to the skull base. 3D high resolution volumetric images were also acquired for structural information (TR/TE/flip 21ms/4.6ms/30º).

Data Analysis: FA and ADC maps and diffusion weighted images (DWIs), with background noise suppressed, were generated using DTI task card provided by MGH. The DWIs were used as reference for brain extraction and registration to the Talairach space through the high resolution volumetric scan. The same brain mask and transformation were then applied to FA and ADC maps. DTI maps from the two groups of patients, mild and severe, were compared to DTI maps from volunteers separately. All image analysis were carried out using FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Z statistic images were thresholded using clusters determined by Z>2.5 and a (corrected) cluster significance threshold of P=0.01.

RESULTS: The top row of figure 1a shows the Z-score maps of ADC for severely injured patients compared to normal controls. The bottom row shows the mildly injured patients compared to normal controls. Similar maps for FA are shown in figure 1b. Among severely injured patients, a significant increase in the ADC and a decrease in the FA are seen in several areas of the brain. The extent of injury among the mildly injured patients was significantly less compared to the severely injured. ADC changes were seen in most regions of the white matter among the severely injured whereas the FA maps indicated fewer areas of reduced anisotropy. FA shows significant reduction in the splenium, genu, internal and external capsule and brain stem. For all the regions that FA showed a significant decrease there was a corresponding increase in the ADC values. In the mild patients an increase in the ADC was found mostly in the frontal lobe with no involvement of the deep cortical structures.

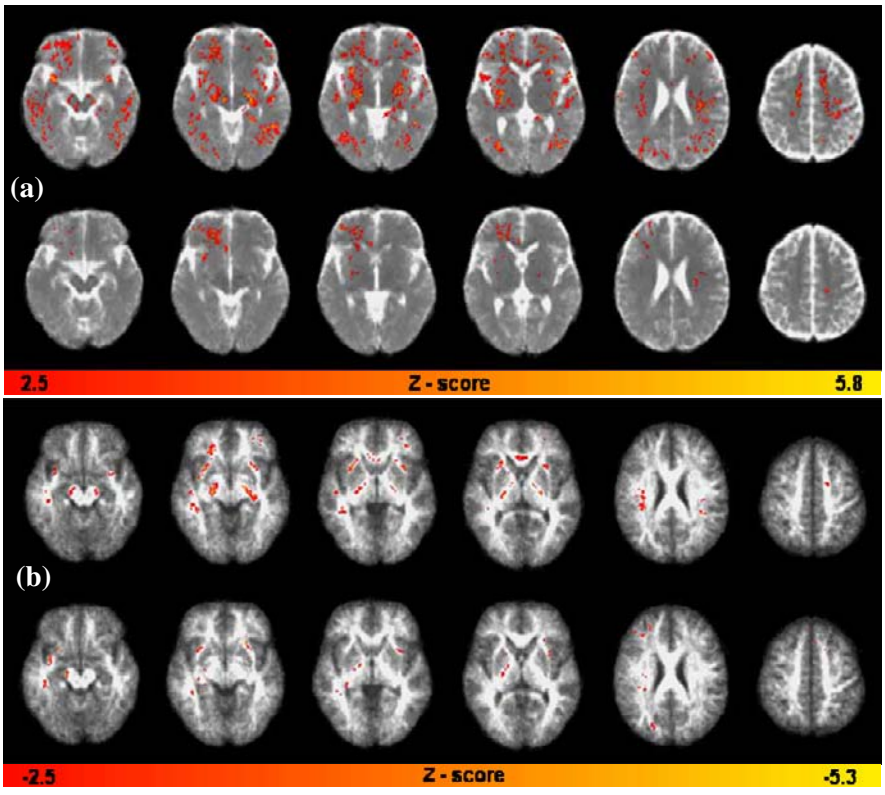

Figure 1. Z-score maps for ADC (a) and FA (b) values for severely injured patients (upper row) and mildly injured (lower row) patients.

CONCLUSION: The extent of changes in the ADC values explains the sensitivity as seen from our previously published results where we see whole brain ADC values to increase among traumatic brain injury patients[3]. Our data here suggests that while ADC may be a more sensitive marker for the extent of injury, FA may be more specific in determining the areas that are more severely injured. The pattern of injuries seen here seem to indicate that the more mild injuries start at the periphery of the brain and as the severity of the injury increases the deeper brain structures are involved.

Reference:

1. Huisman TAGM, et al. AJNR 2004; 25:370-376.
2. Konstantinos A, et al. AJNR 2002; 23:794-802.
3. Shanmuganathan K, et al. AJNR 2004; 25:539-544.