Mapping traumatic axonal injury using diffusion tensor imaging: correlations with functional outcome

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Introduction: Traumatic brain injury (TBI) is a major cause of morbidity and mortality. The extent and severity of TBI is greatly underestimated by CT and conventional MR sequences, and these appearances often correlate poorly with functional outcome. Diffusion tensor imaging (DTI) may offer insights into the extent and distribution of traumatic axonal injury (TAI) post TBI. The Glasgow Outcome Score (GOS) is the most widely used outcome measure post TBI. This analysis aimed to investigate how diffusivity parameters change in patients at least 6 months post injury with outcomes ranging from the vegetative state (VS) and minimally conscious state (MCS) spectrum (GOS 2) through to good recovery (GOS 5).

Methods: 61 patients underwent MR imaging at a minimum of six months post injury using a 3 Tesla Siemens Magnetom Total Imaging Matrix (TIM) Trio system. Informed consent or assent from next-of-kin was obtained in all cases. Ethical approval was obtained from the Local Research Ethics Committee. 32 age matched controls underwent an identical imaging protocol which included a 3D T1 weighted structural sequence (MPRAGE) and diffusion tensor imaging. The DTI parameters were as follows; 12 non-collinear directions; 6 b values (0 to 1590 s/mm^2); image matrix 96 x 96, 63 axial slices, image resolution 2mm isotropic; TR – 9800ms; TE – 98ms. A central white matter region of interest was made by segmenting Colin27[2], a high resolution, high signal-to-noise template in MNI125 space, using FMRIB's Automated Segmentation Tool (FAST).[3] The peripheral white matter was removed using Analyze 7.0[1]. FA, ADC and eigenvalue maps were created using FDT in FSL.[4] The diffusion weighted data were normalised using the vtkCISG normalised mutual information algorithm using a two step approach.[5] The b=0 image was subsequently coregistered to the subject's own MPRAGE. The transformation matrix normalising the MPRAGE was then applied to the b=0 image. All coregistered images were visually inspected to ensure the ROIs corresponded to the region specified. Mean FA ADC and eigenvalues for the different ROIs were calculated. The Jonckheere-Terpstra (J-T) Test, a nonparametric test for trend, was used to analyse the data. A qualitative mapping of white matter loss was undertaken using "Global" streamline tractography.[6]

Results: ADC, axial (λ1) and radial diffusivity (λ2+λ3/2) all showed a significant trend for increasing values with worse clinical outcomes (Fig.1). We also observed a concordant significant trend for lower FA with worse outcome. These trends were confirmed by visual inspection of global tractography images (Fig.2)

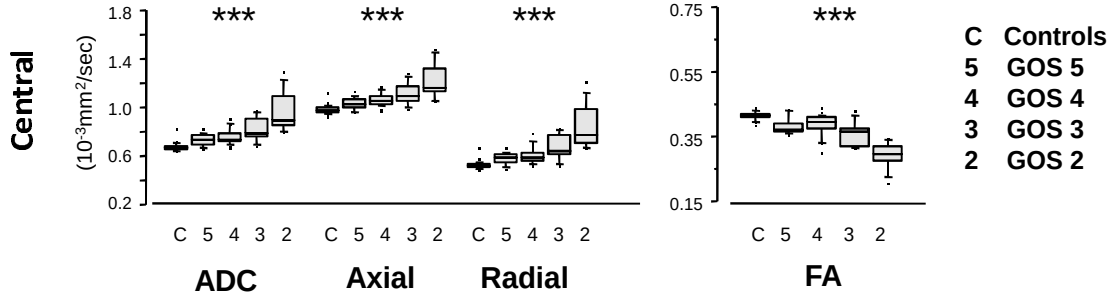

Figure 1: Fractional anisotropy values for the ROIs studied. The central lines in the boxes denote the median values, the upper and lower edges the 75th and 25th percentiles, the error bars the 90th and 10th percentiles and the closed circles the data outside these percentiles. *** $p < 0.001$ (J-T Test).

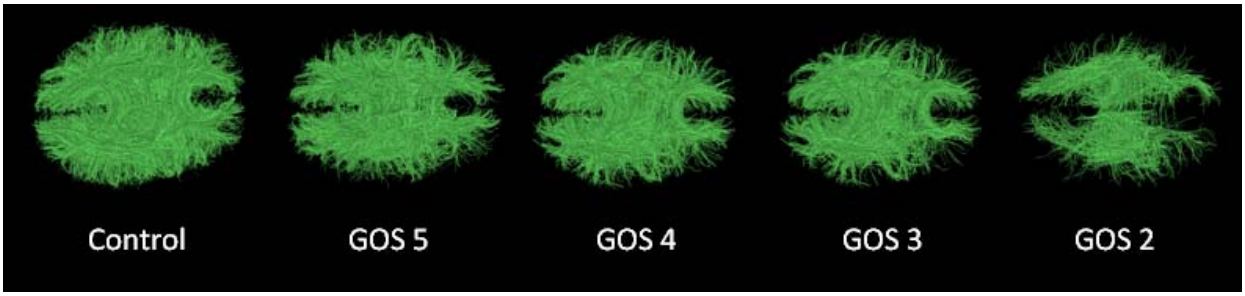

Figure 2: "Global" streamline tractography[6] with representative examples from the control, and different outcome groups. It can clearly be seen that the paths able to be successfully tracted are less in the patients with worse clinical outcomes. For ease of visualization, tracts with lengths less than 3cm are not shown.

Discussion: There was evidence of trends in DTI parameters in the central white matter with corresponding to the clinical severity of disease outcome in patients post TBI. The ability to detect the overall disease burden into groups may be important in allowing insights into disease progression and the pathophysiology of neurocognitive outcome.

References:

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