Automated Detection of Traumatic White Matter Injury Using Voxel-based Morphometry of Diffusion Tensor Images: A 3T Study With Parallel Imaging

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Introduction: Traumatic brain injury (TBI) is a leading cause of mortality and morbidity in young people (age ≤ 45). Diffuse axonal injury (DAI) occurs in about half of all instances of severe head trauma. Conventional MRI and CT are useful in the detection of petechial hemorrhages and edema in acute TBI and gliosis in chronic TBI. However, comparison with pathology shows that the conventional neuroimaging evaluation of TBI underestimates the full extent of white matter injury, especially in cases of DAI. This report presents automated detection of white matter injury in individual trauma patients by comparison of 3T diffusion tensor images (DTI) to a database of normal volunteers using voxel-based morphometry.

Materials & Methods: Eleven patients with head trauma, ranging from mild to severe, and 15 adult volunteers were imaged with conventional MRI and DTI performed on a 3T GE scanner with an eight-channel EXCITE head coil. Conventional MRI sequences included FLAIR, gradient echo T2*-weighted, and high-resolution 3D FSPGR T1-weighted and 3D FSE T2-weighted imaging. Whole-brain DTI was acquired in 55 independent diffusion-encoding directions at b=1000 s/mm^2 and 1.8-mm isotropic spatial resolution using an interleaved axial single-shot spin-echo echoplanar pulse sequence (TR=14s, TE=63ms, NEX=1) with parallel imaging employing the Array Spatial Sensitivity Encoding Technique (ASSET) with an acceleration factor of 2. Fractional anisotropy (FA) images, with the background noise suppressed and the skull stripped, were spatially transformed and registered to a standardized FA template using non-linear methods available in Statistical Parametric Mapping (SPM) **[1]**. The normal database was constructed from spatially transformed FA maps of the 15 normal volunteer DTI scans that registered within two standard deviations of the residual squared difference from the FA template. Spatially transformed FA maps from individual patients were then compared with this normal FA database using automated voxel-by-voxel comparison. Z-score maps were generated.

Results: Acute FA reduction within the inferior frontal fasciculi was detected in three patients with inferior frontal contusions imaged in the first week after injury (example **Figure 1,** *left*). The reduction in FA improved on one-month follow-up imaging (**Figure 1,** *right*) and correlated with the patients' cognitive improvement. FA maps from one patient with diffuse axonal injury at six-month follow-up demonstrated a diffuse decrease in FA throughout the white matter (Z-scores << -3), including normal-appearing areas on conventional 3T MRI (**Figure** 2). One patient with bilateral inferior frontal contusions scanned at one-year follow-up had persistently reduced FA in the bilateral inferior frontal white matter tracts, even though no corresponding white matter abnormality was evident on conventional 3T MRI.

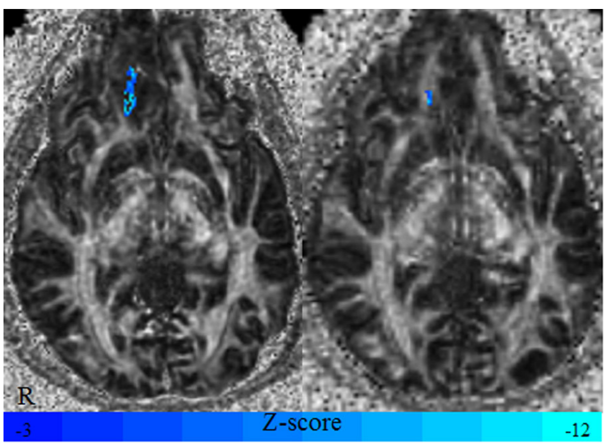

Figure 1

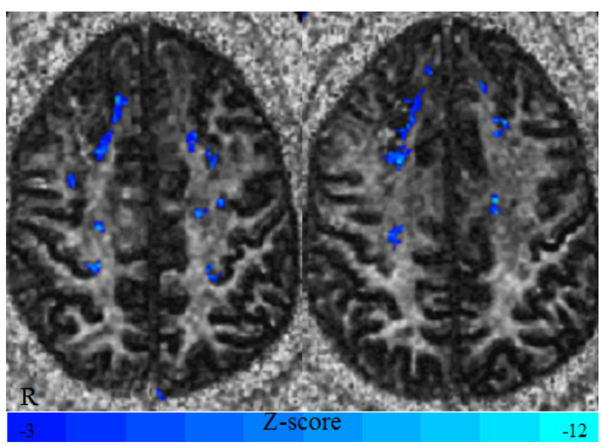

Figure 2

Conclusion: Voxel-based analysis of DTI provided automated detection and localization of traumatic white matter injury, thereby enabling correlation with specific functional and cognitive deficits. The use of parallel imaging with an 8-channel head coil mitigated artifacts near the skull base that would otherwise have precluded the use of high-field DTI to assess traumatic injury in the inferior frontal and temporal lobes.

Reference: [1] Ashburner J and Friston KJ. Nonlinear Spatial Normalization using Basis Functions. Human Brain Mapping 1999; 7(4): 254-266.

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