Assessment of Brain Apparent Magnetic Susceptibility of Patients with Mild Traumatic Brain Injury

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Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability in young people at the most productive time of their lives (1). Each year an estimated 1.5 million people in the United States alone sustain nonfatal TBI (2). Approximately 80% of these injuries are classified as mild TBI (3). Unfortunately, the diagnosis of mild TBI is challenging, as these patients often have no focal abnormalities on routine imaging studies such as CT and MRI (4). Quantitative susceptibility mapping (QSM) is emerging as a novel technique that can provide unique information about the underlying tissue's apparent magnetic susceptibility. It is therefore valuable for quantification of specific biomarkers including iron, calcium and gadolinium (5,6). Our hypothesis is that the novel contrast generated by QSM could provide unique information to better understand TBI. The goal of this work was to characterize brain susceptibility in mild TBI patients from a military population using QSM.

Methods

32 military mild TBI patients (34.6 ±7.3 years, 5 female, 90% blast) and 16 controls (28.9 ±7.7 years, 5 female) were scanned on a 3T GE 750 with a 32-channel phased array head coil. Patients were scanned 976 ± 561 days after injury. Structural images were acquired with a 3D BRAVO sequence: TR/TE = 6.7/2.5 ms, FA = 12º, Resolution = 0.5 × 0.5 × 0.6 cm^3, ARC = 2. Multi-echo images were acquired using a 3D flow-compensated multi-echo gradient-echo sequence with TR = 45 ms, 5 echoes, TE_0 = 13ms, echo-spacing = 6ms, FA = 20° and asset-factor = 2. Images were acquired with a 512 × 256 matrix, 24 × 24 cm^2 FOV, and 88 slices at 1.5 mm thickness.

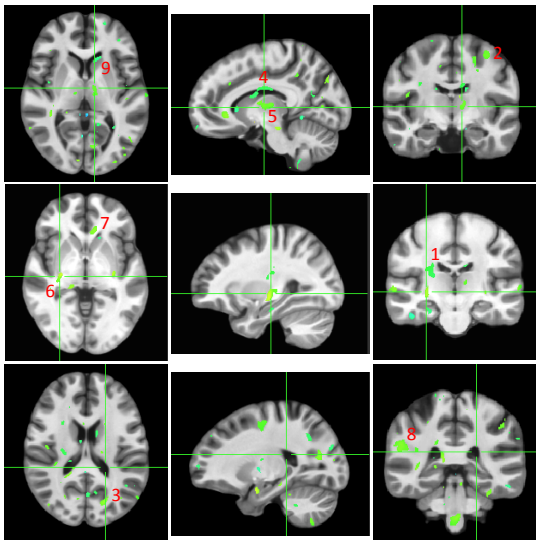

Figure 1. Scattered clusters showing significant altered apparent magnetic susceptibility between mild TBI patients and healthy controls (p<0.01 after cluster size correction). Clusters are numbered by their size.

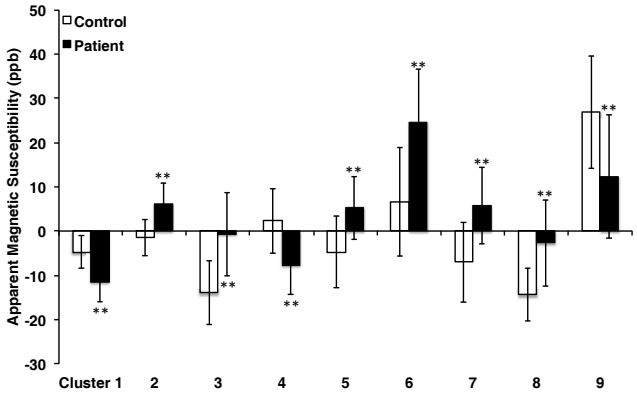

Figure 2. Apparent susceptibilities at the nine clusters from the controls (white bar) and TBI patients (black bar).** p< 0.01.

QSM images were calculated from the multi-echo complex imaging data, using the morphology-enabled dipole inversion approach (5-6), which is implemented in the MEDI software (Dept. of Biomedical Engineering, Cornell University, NY). QSM images were aligned to the structural images using the *3dAllineate* function from the AFNI software package. The structural images were subsequently warped to a population-based template using ANTS. A voxel-by-voxel univariate statistical test in the form of a group comparison (two-sample t-test) between mild TBI patients and normal controls was performed using AFNI's*3dttest++* function.

Results

Voxel-wise analysis of QSM images demonstrated nine scattered clusters of altered susceptibility (p<0.01 after cluster size correction) in the mild TBI patient group compared to controls. Figure 1 illustrates the group analysis results with clusters numbered according to their size (1 being the largest). The apparent susceptibilities of the nine clusters are illustrated in Figure 2. The cluster region 1 showing decreased apparent magnetic susceptibility in the patient group demonstrated a correlation with time after injury (R = 0.50, p < 0.01). In addition susceptibilities in cluster regions 6, 7 and 9 also demonstrated significant correlations with scores of Short Form of Health and Posttraumatic Stress Disorder Check List Civilian Version as shown in Table 1.

Conclusion and Discussion

QSM has been applied to help the evaluation of mild TBI patients. Voxel-wise analysis revealed scattered clusters of altered susceptibility in the mild TBI patient group compared to controls. Because QSM is particular sensitive to iron deposition and demyelination (7), the susceptibility changes seen in mild TBI patients may be indicators of alterations in iron and/or myelin content and could be an indicator for damage to the brain.

Table 1

		Cluster 6	Cluster 7	Cluster 9
Short Form of Health Survey (SF-36)	Emotional well being			R = 0.65
	General health			R = 0.64
Posttraumatic Stress Disorder Check List-Civilian Version (PCLC)	Total score	R = 0.62		R = 0.63
	Re-experiencing	R = 0.60		
	Arousal/autonomic activation		R = 0.76	R = 0.72

Reference:

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