Traumatic Brain Injury: 3 Tesla Magnetic Resonance Spectroscopic Imaging and Cognitive Function

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Introduction

Previous studies show that non-invasive magnetic resonance spectroscopy (MRS) can detect altered concentrations of specific brain markers of neuronal injury (N-acetylaspartate; NAA), inflammation (choline; Cho), and glia (myo-inositol; mIns) following traumatic brain injury (TBI) (Holshouser 1997, Friedman 1998). Moreover, these markers can predict cognitive recovery (Friedman 1999). However, most previous MRS studies measured small volumes of radiologically normal-appearing tissue and focused on dominant peaks in the spectrum. Our aim was to determine whether the increased signal-to-noise and spectral dispersion of 3 Tesla spectroscopy and larger sampling of spectroscopic imaging combined spectral line-fitting using linear combinations of metabolite basis spectra could detect perturbations in other metabolites present in the brain proton spectrum. Secondly, we sought to determine whether these metabolites were associated with overall cognitive function.

Methods

Patients with traumatic brain injury (n=18) and age-, education-, and sex-matched uninjured controls (n=18) were recruited. Injury severity was quantified using the Glasgow Coma Score in the first 24 hours post-injury. Injured subjects were scanned as soon as they were stable for transportation to our outpatient imaging facility. Neuropsychological testing was performed within a day of MR studies.

Each subject was studied at 3 Tesla (Siemens Allegra) using two-dimensional magnetic resonance spectroscopic imaging (SI). A STEAM sequence was used to excite a rectangular voxel of mixed gray and white matter superior to the lateral ventricles (TE=20ms, TR=1500ms, 16 by 16 phase encoding steps, FOV=23cm, slice thickness=15mm). The slice was angled parallel to the inferior margins of the genu and splenium as visualized on the mid-sagittal slice. Vendor-provided routines were used to optimize magnetic field homogeneity, pulse power, and water-suppression. Datasets were zero-filled to a 32 by 32 spatial matrix and metabolite concentrations calculated using LCModel (Provencher 1993). A single grand average for each metabolite/subject was calculated from all voxels.

Overall cognitive functioning levels were quantified using a battery of neuropsychological tests of attention, language, memory, executive, and motor skills and a mean z-score calculated as described previously (Friedman 1998).

Results

Initial injury severity ranged from 3-15 with a mean of 9.2. The average interval from injury to SI was 33±25 days. The patient group had less education (13.9 ± 1.94 vs. 12.7 ± 1.43 yr, p=0.03) and performed worse on neuropsychological testing than the controls (Total z-score: -0.95 ± 1.05 vs. -0.07 ± 0.55, p=0.002). This effect was largely due to memory and motor function. NAA, Cre, GABA, and Glu were lower and GPC (glycerophosphocholine) was elevated (Table). Statistically significant correlations between metabolites and overall neuropsychological function are also shown.

	NAA	Cre	GABA	GPC	Glu
TBI (n=18)	12.3 ± 1.9	12.1 ± 1.2	2.0 ± 0.3	2.8 ± 0.4	12.2 ± 1.4
Uninjured (n=18)	13.8 ± 1.4	12.8 ± 0.9	2.2 ± 0.2	2.5 ± 0.2	13.7 ± 1.0
p-value	0.01	0.04	0.004	0.008	0.001
Significant correlations with neuropsychological z-score (r-value; n=16)	0.55	ns	ns	ns	0.48

Discussion

Magnetic resonance spectroscopy is a powerful technique to quantify numerous brain chemicals and improving techniques permit widespread sampling throughout the brain. Our data are consistent with the metabolic depression (decreased NAA), membrane breakdown (elevated GPC), and altered excitatory state (decreased GABA and Glu) seen following TBI. The correlation of NAA and glutamate with overall cognitive functioning levels suggest that these might be markers of outcome. The data reported do not take into account the anatomic patterns of injury that might contribute to specific patterns of cognitive and behavioral impairment associated with TBI. However, they indicate that, on average, there is widespread injury throughout the brain. The data do demonstrate that improved acquisition and analysis methods are sensitive to various forms of injury. These data were acquired in an automated manner using vendor-supplied software demonstrating the generalizability of these methods to clinical practice.

References

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