3D Echo-Planar Spectroscopic Imaging based Metabolic Imaging and Assessment of Whole Brain Temperature in Brain Injuries

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Target Audience: For researchers in the area of Imaging and Spectroscopic Biomarkers for Traumatic Brain Injury

Purpose: Traumatic brain injury (TBI) can cause simple to complex injury to the brain with a broad spectrum of symptoms and disabilities. TBI is generally classified as mild or severe depending on the severity of the damage. The impact of the TBI can be devastating leading to long-term complications or death. An increase in brain temperature was observed in TBI[1] subjects due to neurogenic fever, and elevated brain temperature is linked to poor prognosis. Axonal injuries and lobar injuries increase the risk of neurogenic fever development following severe TBI[2]. A temperature range of 35-36^{O}C seems to be the optimal temperature to treat patients with mild and severe traumatic brain injury[3]. The noninvasive measurement of brain temperature with magnetic resonance spectroscopy (MRS) have been developed [4, 5] and is considered as the most accurate method of measuring region specific temperature distribution in the brain. Single or multislice acquisition based proton MR spectroscopic imaging has limited information for diagnosis in clinical settings. A 3D MRSI with interleaved water acquisition, larger spatial coverage is highly desirable for assessing changes in cerebral metabolism and temperature; however, conventional 3D MRSI techniques require long acquisition times and also require separate water acquisition for accuracy, resulting in limited clinical translation. 3D Echo-planar spectroscopic imaging (EPSI) permits rapid acquisition of MRS data from the entire brain[6]. Using the chemical shift separation between the water and NAA at each voxel of the brain, we have computed the whole brain temperature. In this study, we propose 3D EPSI based computation of the whole brain metabolite maps and temperature changes in mild TBI and control subjects.

Materials and Methods: Three patients (mean age – 55yrs) and two controls (mean age – 55yrs) were included in this pilot study. All the patients were admitted to hospital just after injury. The Glasgow Coma Scale (GCS) at the time of admission was 14-15 (mild TBI). The MRI data were acquired within 72 hours of study. Prior to MR scans, the injury was confirmed by CT scans as part of routine clinical examination. Informed consent was obtained from all subjects. MRI and MRSI data were acquired at 3T (Siemens Tim Trio) using 32 channel phased array coil. A spin echo based 3D EPSI sequence was used to acquire the MRSI data with TE/TR1/TR2/TI/FA/FOV/ Voxel Size =70 ms/1710 ms/591 ms/198 ms/73º/ 280×280×180 mm^3/5.6×5.6×10 mm^3. Bandwidth of water suppression was 70 Hz. Metabolite and water spectral signals were acquired in a single TR in an interleaved fashion. The total acquisition time was 26 minutes.T1-weighted high-resolution images were obtained using a 3D MPRAGE sequence with TR/TE/flip angle/slice thickness/#slice/FOV/matrix size/#average = 2200 ms/1.69 ms/20º/1 mm/160/256 mm × 176 mm/192 × 132/1; without inter-slice spacing and the total acquisition time was ~4 minutes. EPSI sequence was tested and validated on a brain phantom, and the temperature calibration was performed prior to calculation of the brain temperature[7]. Post processing included re-gridding of the K-space data from non-Cartesian to Cartesian co-ordinates, followed by 4D Fourier transformation, for quantitation of metabolites and creation of NAA, Cr, and Cho metabolite maps[6]. Phase correction and eddy current compensation was performed using the unsuppressed water during pre-processing stage in MIDAS[6]. The relation between NAA–Water chemical shift difference in ppm and temperature in ^{O}C of the brain metabolites[7] derived using the brain phantom was used to compute the temperature of brain.

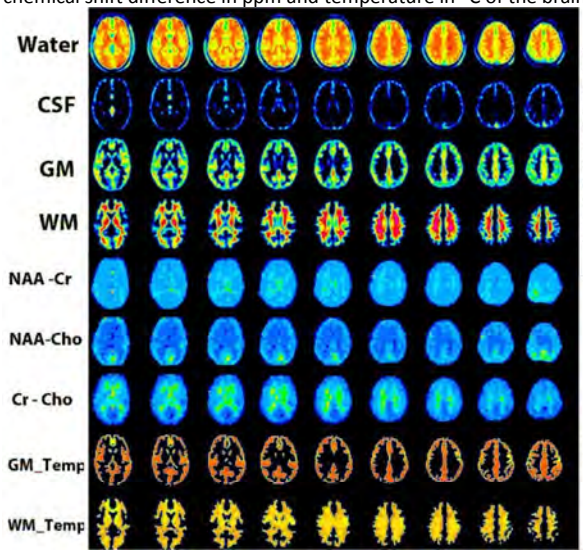

Figure 1. Sample maps of water, CSF, GM, WM, Metabolite ratios NAA-Cr, NAA-Cho, Cr-Cho & Temperature maps in GM and WM

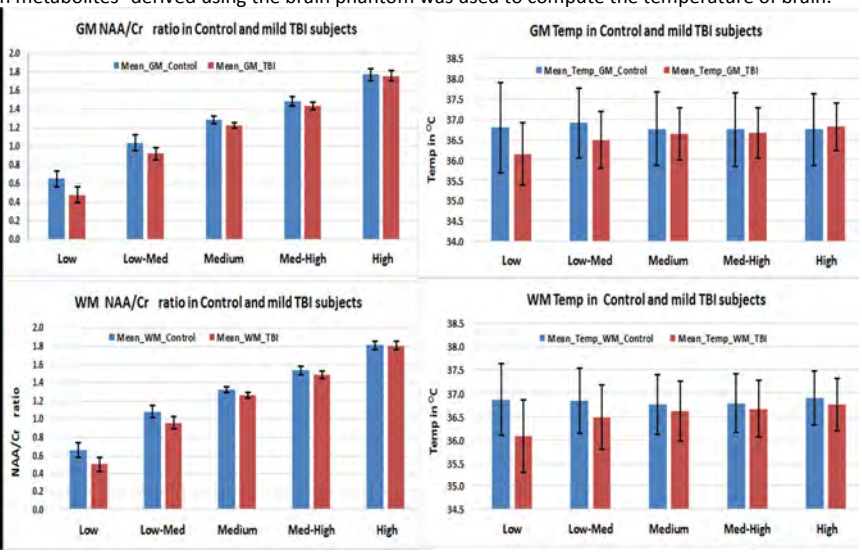

Figure 2. GM and WM NAA/Cr (left panel) and temperature in the corresponding regions (right panel) for healthy control and mild TBI subjects

Results: The 3D EPSI was implemented on a Siemens 3T Tim Trio scanner. The temperatures of the brain at different locations were computed using the chemical shifts between NAA and water. The brain regions were classified based on the NAA/Cr ratio as Low (> 0 & <= 0.775), Low-Med (> 0.775 & <= 1.18), Medium (> 1.18 & <= 1.385), Med-High (> 1.385 & <=1.65) and High (> 1.65) for both Controls (N=2) and mild TBI (N=4) subjects. The mean temperature and their standard deviations were calculated in the respective regions. The different metabolite maps, CSF, GM, and WM maps, and temperature in GM and WM are shown in Fig. 1 with institutional units. The NAA/Cr ratios in GM and WM for Controls and mild TBI subjects and their corresponding temperature values are shown in Fig. 2.

Conclusions: 3D EPSI with interleaved water acquisition was utilized to derive the temperature maps using the NAA – Water chemical shifts for each voxel. . Using the CSF, GM and WM maps the temperature maps were corrected for the different regions. The temperature in control subjects was ~36.5 for all the NAA/Cr regions, whereas the temperature was lower for the Low, Low-Med regions in mild TBI subjects. The ratio of NAA/Cr was also lower than the control subjects in the Low and Low-Med bands.

References: [1] Childs C et al. Neurocrit Care. 2006; 5(1):10-4. [2] H J Thompson et al. J Neurol Neurosurg Psychiatry 2003; 74: 614–619. [3] Tokutomi T et al. Neurosurgery 2003 Jan; 52(1):102-11. [4] Cady et al. Mag Reson Med 1995; 33: 862-67 [5] Corbett R, et al. J Neurochem 1995;64:1224-30. [6] Andrew A. Maudsley et al. Magnetic Resonance in Medicine. 2001; 46(6):1072–78. [7] Bhanu Prakash KN et al. ISMRM 2014.