Short Echo-Time MRSI of Human Brain at 7 Tesla with Improved Shimming and Fat-Suppression

I. Saha[1,2], J. Moore[1,3], S. Sengupta[1,4], S. Pradhan[1,3], J. M. Joers[5,6], and J. C. Gore[1,2]

[1]Vanderbilt University Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [2]Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States, [3]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN, United States, [4]Department of Biomedical Engineering, Vanderbilt University, Nashville, TN, United States, [5]Department of Radiology, Children's Hospital of Wisconsin, Milwaukee, WI, United States, [6]The Medical College of Wisconsin, Milwaukee, WI, United States

Introduction: Proton MR spectroscopic imaging (MRSI) at 7 T offers potential for gains in the SNR, increased chemical shift, and higher spectral resolution for mapping of a number of brain metabolites [1]. However, MRSI at 7 T is also challenged because of the short T_2 relaxation times of metabolites, B_0 and B_1 inhomogeneities, and the need for higher bandwidth pulses [1,2]. Here we present our ongoing work on developing 2-D/single slice MRSI methodology at 7 T using image-based shimming and a short echo time STEAM sequence. We also report our effort on developing a method for better suppressing the skull lipid signal to achieve high quality MR spectroscopic images from interesting areas at the periphery of the brain.

Methods: Experiments were performed using a human 7 T Philips Achieva whole-body MR system with a 16-channel NOVA head coil. SENSE accelerated 3-D inversion prepared T_1 images in sagittal planes were obtained using a TFE sequence, and the isotropic images then reformatted in coronal and transverse orientations for improved MRSI matrix placement. Global second order least squares field-map based shimming [3] was performed using an in-house Matlab shimming tool. Low resolution field-maps for five 2 mm slices aligned with and totaling in thickness to the MRSI slice were acquired with a repeated gradient echo sequence (TR/TE = 20/4.4 ms; ΔTE = 1 ms). The ROI, specified on the scanner surrounding the required MRSI matrix, was exported to the shim tool and combined with a brain extraction algorithm to obtain the final shim ROI. Resulting shim values obtained from this operation were used during MRSI. For 2-D MRSI experiments, a STEAM sequence with high bandwidth FM RF pulses was implemented to address slice profile and chemical shift displacement artifacts. During MRSI, the matrix was placed along the midline of brain (FOV = 120 mm x 120 mm; VOI = 100 mm x 100 mm; voxel size = 10 mm x 10 mm; slice thickness = 10 mm). The STEAM sequence was employed with with echo time of 15 ms; mixing time of 32 ms; and repetition time of 3.5 s. Additional RF power calibration, outer volume suppression and water suppression using a MOIST scheme were performed using standard routines in the Philips software.

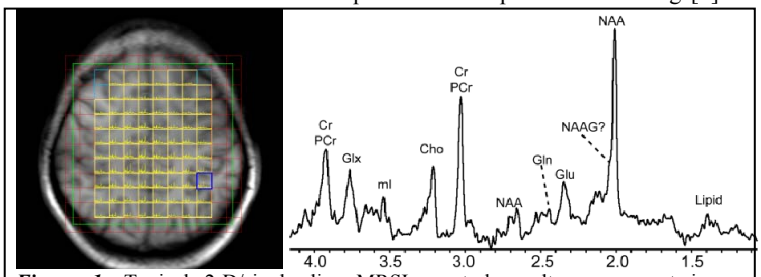

Figure 1: Typical 2-D/single-slice MRSI spectral result on a scout image demonstrating good quality spectra; a representative spectrum from a single 1 mL MRSI voxel (blue voxel) acquired with 4 transients is presented.

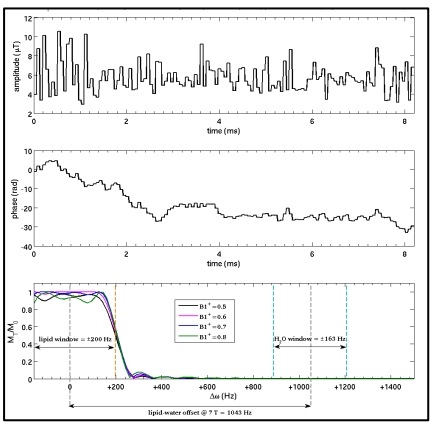

Figure 2: Amplitude (top) and phase (middle) modulation waveforms for an 8 ms B_1 insensitive pulse designed to produce a 90° excitation within ±200 Hz window centered on the lipid resonance of ^{1}H. Resulting transverse magnetization response (bottom) reveals the pulse to be fairly insensitive to B_1^+ variations while having a minimal effect on adjacent resonances.

Results and Discussion: We observed an improvement in the B_0 field inhomogeneity by applying field-map based 2nd order global shimming instead of projection based pencil-beam volume shimming during spectroscopy. Field-map based shimming aided in achieving higher quality spectra – e.g., we observed ~15% reduction in the FWHM of NAA by switching from a pencil-beam shimming method. Our preliminary MRSI results at 7 T (Figure 1) show promises of quantifying the distributions of metabolites like NAAG, Glu, Gln, myo-Inositol in addition to the more commonly studied metabolites NAA, Creatine and Choline. However, we have observed spectral deterioration near the skull due to infiltration of skull-lipid signals. In addition to prominent lipid signals in voxels closest to the skull, the use of SENSE-accelerated MRSI acquisitions results in lipid signals folding-over ('SENSE-aliasing') into deeper regions of the brain (e.g., Figure 3(a)). We have explored improved lipid suppression strategies for SENSE-MRSI at 7 T, including using composite pulse-trains [4]. We have implemented B_1 insensitive composite pulse-trains such that a 90° B_1-insensitive excitation is produced at the lipid resonance. The appropriate RF attributes for our composite pulses are shown in Figure 2. We inserted our SENSE-accelerated 2D STEAM MRSI sequence with this pulse accompanied with appropriate crusher gradients to suppress the lipid signal. Figure 3 shows preliminary result of successful implementation of these pulses *in vivo*. A representative MRSI spectrum obtained with our composite lipid-suppression pulses at 7 T (Figure 3(b)) demonstrates promises to overcome the SENSE-aliasing artifact in the regions near the brain midline. We observed that the quality of lipid signal suppression is over all consistent in the MRSI matrix including the voxels near the scalp. Additionally, we are developing our data processing protocol to quantify metabolites using LCModel and to generate metabolite distributions maps.

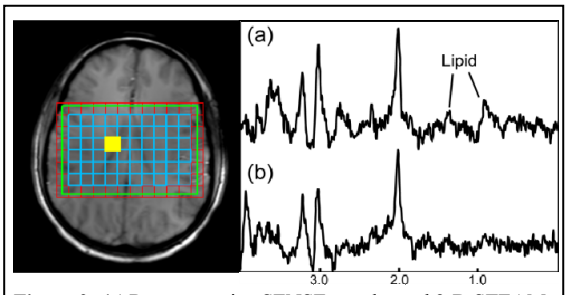

Figure 3: (a) Representative SENSE-accelerated 2-D STEAM MRSI spectrum at 7 T obtained (from the "yellow" voxel in the scout image) without our fat-suppression pulse-trains; and ***(b)*** with our composite pulses for lipid-suppression.

References: [1] Henning *et al*., *NMR Biomed.* 22, 683 (2009); [2] Tkac *et al.*, *Magn. Reson. Med.* 46, 451 (2001); [3] Schneider *et al*., *Magn. Reson Med*. 18, 335 (1991); [4] Moore *et al., J. Magn. Reson*. 205, 50 (2010). **Acknowledgements:** NIH (BRP) grant 5 R01 EB000461.