High Spatial Resolution short TE Proton-Echo-Planar-Spectroscopic-Imaging (PEPSI) in Human Brain at 7 Tesla using B1-Compensation and Adiabatic Refocusing

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Introduction

We have shown linear increases in SNR between 1.5 and 7T for Proton Echo Planar Spectroscopic Imaging (PEPSI) at short TE [1]. However, non-uniform spatial sensitivity, increased chemical shift displacement errors, lipid contamination due to B_1-inhomogeneity, and increased RF power deposition are major challenges for metabolite imaging at ultra-high field (7T). In this study at 7T we combine PEPSI with paired adiabatic refocusing pulses and B_1-compensated outer volume suppression (OVS) to enable short TE (20 ms) metabolite mapping. Localized tuning of the OVS RF pulses was implemented based on B_1-mapping. We demonstrate feasibility of high spatial resolution (0.25 cc voxel size) metabolite mapping in central and peripheral regions of the human brain in clinically feasible measurement time using a 16-channel line array headcoil.

Methods

- MR system: 90-cm-bore magnet operating at 7T (Magnex Scientific, Abingdon, UK), driven by a Siemens Syngo console (Siemens Medical Solutions, Erlangen, Germany). Headcoil: sixteen-channel transmission line array headcoil [2] driven by a combination of eight 1kW RF amplifiers (CPC, Brentwood, NY, USA) and one 8 kW RF amplifier (Siemens Medical Solutions, Erlangen, Germany), of which the power was split with equal amplitude and fixed phase increments with an eight-way power splitter (Werlatone, Inc., Brewster, NY, USA).
- PEPSI pulse sequence: 90° slice-selective Shinnar-Le-Roux optimized excitation and refocusing of the same slice with a pair of second order hyperbolic secant adiabatic full passage pulses (time-bandwidth product of 26). The RF headcoil efficiency allowed an amplitude of γB_1 = 1150 Hz and a duration of 5 ms of the adiabatic pulse, enabling an echo time of 20 ms.
- Outer volume saturation: based on a B_1-map, the mean flip angle of a manually drawn region of interest (=saturation slab) in the lipid layer around the skull was compared to the expected flip angle at that region. The deviation of actual flip angle from intended flip angle in the B_1-map was used as an increasing or decreasing correction factor for the voltage of the corresponding system-calculated RF pulse saturating that slab.
- Data acquisition parameters: supra-ventricular slice location, WET water suppression, TE 20 ms, TR 2.5 s, voxel size 0.25 cc, 6 averages, scan time 16 min, 8 individually B_1-adjusted outer volume saturation slabs, based on a B_1 map computed from two gradient echo scans acquired with different flip angles (60° and 120°), to minimize the effects of B_1-inhomogeneity.
- Data processing: Quantification using LCModel with a simulated basis set, and a 1-average unsuppressed PEPSI water reference file (scan time 2 min. 40 sec). Correction for T_1-saturation was applied using literature values [1]. Fit quality was assessed using Cramer-Rao lower bounds.

Results

The B_1-map displayed a more than 2-fold B_1-transmit-variation across the slice (**Fig.1**). The maxima in the B_1-map corresponded to regions with reduced water suppression efficiency as evidenced in the integrated water-suppressed scan (**Fig.1**), mainly consisting of residual water and lipid signals. Manually tuning the outer volume suppression pulses was effective in reducing residual lipid signals to levels below the intensity of NAA in most parts of the slice. The spectroscopic images (**Fig.2**) display relatively uniform metabolite concentrations throughout the slice. Signal intensity variations were overcome with the unsuppressed water reference file. Spectral quality in central gray matter is illustrated in **Figure 2f**. Concentration values for Ino (11.5 +/- 2.9 mmol), Cho (3.1 +/- 1.2 mmol), Cr (10.7 +/- 2.6 mmol), Glu (10.7 +/- 5.2 mmol) and NAA (11.9 +/- 4.3 mmol) averaged across the slice were consistent with previous studies [3]. Cramer-Rao lower bounds were less than 20 % for Ino, Cr and NAA, less than 30 % for Cho and less than 50% for Glu.

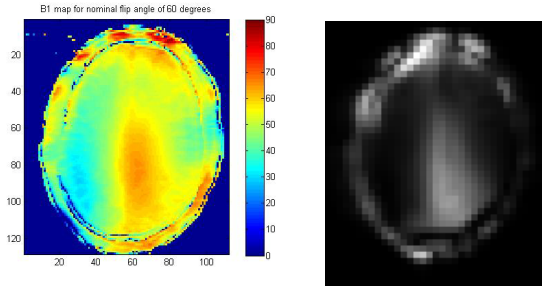

Fig. 1: B_1-map at 7 T and map of integrated water-suppressed data shows residual lipids and water.

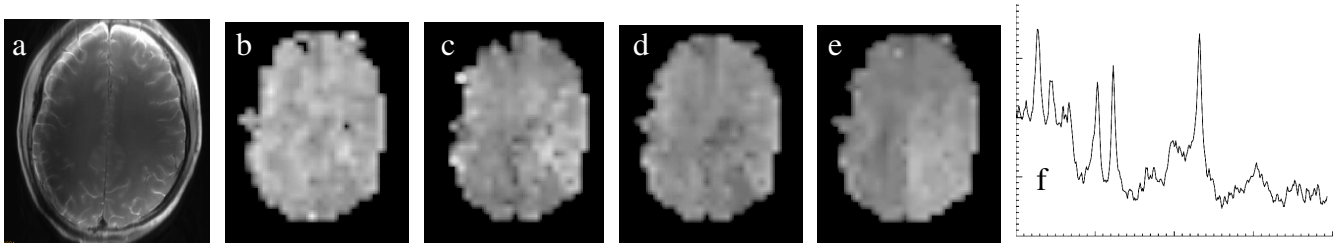

Fig. 2: Turbo-spin-echo image (a) of the PEPSI slice selection. Metabolite images of Ino (b), Cho (c), Cr (d) and NAA (e) measured in 16 min with 0.25 cc voxel size. A representative spectrum (f) from central gray matter shows the spectral quality and signal-to-noise of one voxel from the dataset.

Discussion

This PEPSI methodology with adiabatic refocusing pulses and tuned outer volume suppression pulses provides uniform spatial sensitivity into lateral gray matter at short echo times while maintaining SAR values below FDA guidelines. We are also investigating the feasibility of PEPSI without refocusing RF pulses using delayed acquisition of the FID signal to minimize SAR and reduce sensitivity to B_1-nonuniformity. B_1-shimming [5] of each of the OVS pulses to further optimize OVS performance is under development.

References

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