Adapting volumetric 1H echo-planar spectroscopic imaging of the human brain from 3 to 7 Tesla

Karim Snoussi[1,2], Joseph S. Gillen[1,2], Michael Schär[1,2], Richard A.E. Edden[1,2], Andrew A. Maudsley[3], and Peter B. Barker[1,2]

[1]*Russel H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medidine, Baltimore, Maryland, United States,* [2]*Kennedy Krieger Institute, Johns Hopkins University, Baltimore, Maryland, United States,* [3]*Miller School of Medicine, University of Miami, Miami, Florida, United States*

Target audience: Research and clinical spectroscopists concerned with spatial metabolite quantitation in the human brain.

Purpose: While 7T single-voxel (SV) MRS has been proven to offer improved SNR and lower uncertainty estimates compared to 3T (1), adoption of MR spectroscopic imaging (MRSI) methods at 7T has been somewhat slower. Various approaches to MR spectroscopic imaging at 7T have been previously developed (*e.g.* see (2) and references therein). However, few of them have been demonstrated to perform MRSI with extended 3D volumetric coverage. The aim of this work was to adapt a volumetric proton echo-planar spectroscopic imaging (EPSI) sequence routinely used at 3T for 7T.

Methods: All experiments were performed on a Philips Achieva 7T scanner. The 7T scanner was equipped with a dual-transmit setup and a 32-channel receive coil. A sagittal 3D MPRAGE scan, 0.8 mm isotropic resolution, was used for setting up the EPSI scan. The EPSI sequence was closely based on that developed at 3T by Maudsley *et al*. (3) and consisted of an inversion-pulse followed by 4 CHESS pulses, for lipid and water suppression respectively, and then an inferior saturation band followed by a slice-selective spin-echo with EPSI readout. Phase-encoding was performed in 2 directions to give full 3D coverage. An interleaved, small flip angle (20°) minimum TE gradient-echo EPSI readout was also used to record the brain water signal. The 80 mm slab excitation was prescribed in an oblique coronal orientation approximately perpendicular to the long axis of the temporal lobe (Figure 1A). Scan parameters include TR/TE 1710/35 ms, acquisition matrix 50x50x18, FOV 280x280x180 mm^3, nominal voxel size 5.6x5.6x10 mm^3 ≈ 0.3 ml. The inversion time TI for fat suppression was 250 ms, the water suppression bandwidth 200 Hz, and the spectral bandwidth for EPSI readout 2466 Hz, i.e. 8.3 ppm at 7T. Sequence SAR was < 46% of the FDA limit for head imaging. Prior to acquisition, localized power optimization and shimming up to 3rd order performed using a field-map based shimming algorithm[2] (Philips 'shimtool'). The EPSI scan time was 25 min. All spectra were processed using the 'MIDAS' software package (4). The MIDAS package was used to read the raw data, regrid and Fourier transform the multichannel data, perform optimal channel combination, and register the EPSI data to the anatomical MPRAGE images.

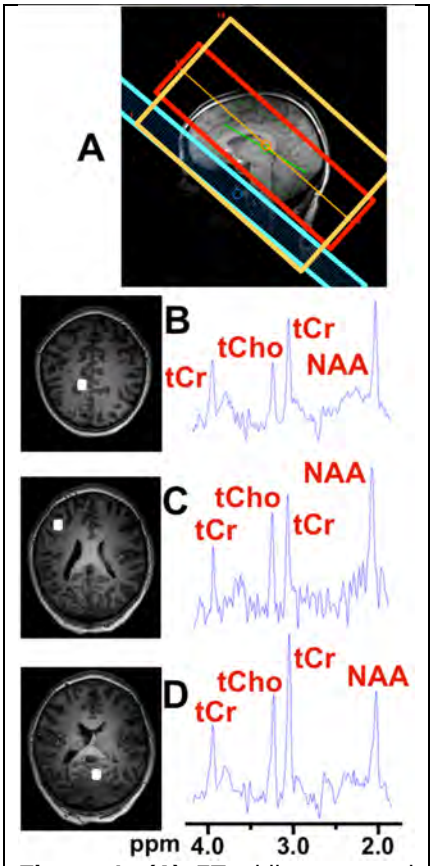

Figure 1. (A) 7T oblique-coronal setup for the 3D EPSI scan. The red box is the slab excitation, orange the EPSI field of view, and blue indicates the inferior saturation band (green box unused). **(B,C,D)** 3D EPSI in a normal volunteer. Selected spectra from the 3D EPSI data set (TR/TE: 1710/35 ms; nominal voxel volume: 0.3 ml).

Results: Examples of selected EPSI spectra at 7T in a normal volunteer (age 35 years, female) are shown in Figure 1B,C,D. Well resolved peaks from NAA 2.01 ppm, tCr 3.03 ppm, tCho 3.19 ppm and tCr 3.92 ppm are seen with good SNR from the nominal 0.3 ml voxels. Field inhomogeneity was less than 20 Hz over the whole volume of the EPSI slab. The main differences between the 'standard' 3T EPSI implementation and that at 7T include: longer TI for optimized fat suppression (due to longer lipid T_1 at 7T), increased water suppression bandwidth, higher spectral bandwidth for EPSI readout (higher sampling rate and readout gradient strength), and combined processing of odd and even readout lobes.

Discussion: The volumetric short TE 7T EPSI sequence developed here provides extended brain coverage, an interleaved water reference for quantitation, 3rd order shimming, minimal chemical shift displacement artifact, and low SAR. Compared to a recent FID-based approach to spectroscopic imaging at 7T (5), the spin-echo based sequence provides spectra largely free from 1st order phase gradients, and has less macromolecule signal contamination. One of the challenges of 7T spectroscopic imaging is the non-uniformity of the B_1 transmit field due to wavelength/dielectric effects at high frequency, which leads to 'shading' across the field of view of the EPSI acquisition.

Future work will address this issue.

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