Metabolic Imaging with 3D Echo Planar Spectroscopic Imaging at 7 Tesla

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INTRODUCTION: Proton Magnetic Resonance Spectroscopic imaging (^{1}H MRSI) permits detection and quantification of altered metabolite levels in pathological conditions and also to understand regional distribution of major metabolites in the brain. 3D MRSI is essential for mapping the metabolite distribution for the whole brain to study neurodegeneration in rodents. A region specific metabolic change is important to characterize the pathology and treatment. Whole brain mapping of metabolites such as N-acetylaspartate (NAA), a biomarker for neuronal integrity; total Choline (tCho), a marker of membrane metabolism and malignancy index in cancer; total Creatine (tCr) including (Phosphocreatine PCr + Creatine Cr) reflects energy status, are required to assess the *in vivo* pathological conditions. 3D Echo Planar Spectroscopic Imaging (EPSI) is one of the promising fast spectroscopic imaging techniques to map the regional metabolite concentrations within clinically feasible time. Whole brain distributions of NAA, tCr, and tCho and its ratios can be measured using 3D long echo time EPSI.

MATERIALS AND METHODS: 3D EPSI sequence was implemented on a 7T Bruker Clinscan using Siemens IDEA VB15. Spectroscopic data was collected using spin echo (SE) based EPSI sequence, with interleaved water reference acquisition similar to the earlier work [1]. EPSI sequence was modified to acquire signal with a voxel resolution of 2 mm^3, in-plane phase encoding (50 × 50), 5 slices (2 mm thick) and TR/TE/TA = 4000 ms/70 ms/16 min. The metabolite excitation pulses for SE EPSI sequence had the Ernst angle of 84º, followed by 180º for re-focusing. The water excitation pulse had an Ernst angle of 20º. TR = 4000 ms was used for both water and metabolite acquisition. The trapezoidal readout gradient lobes consisted of up and down ramp sampling (duration 20µs respectively) and plateau duration of 140 µs. 3D T_1 weighted MPRAGE or T_2 weighted turbo spin echo data was acquired to register the spectroscopic data for spatial reference of anatomical regions. EPSI sequence was tested and validated on a brain phantom containing 12 metabolites[2]. *K*-space raw data was collected during the acquisition and post processed with MIDAS software[3]. Post processing included re-gridding of the *K*-space data from non-Cartesian to Cartesian co-ordinates, followed by a 4D Fourier transformation, quantitation of metabolites and creation of NAA, Cr, and Cho metabolite maps[3]. Metabolite and water spectral signals were acquired in a single TR in an interleaved fashion. Phase correction and eddy current compensation was performed using the unsuppressed water data during pre-processing stage in MIDAS.

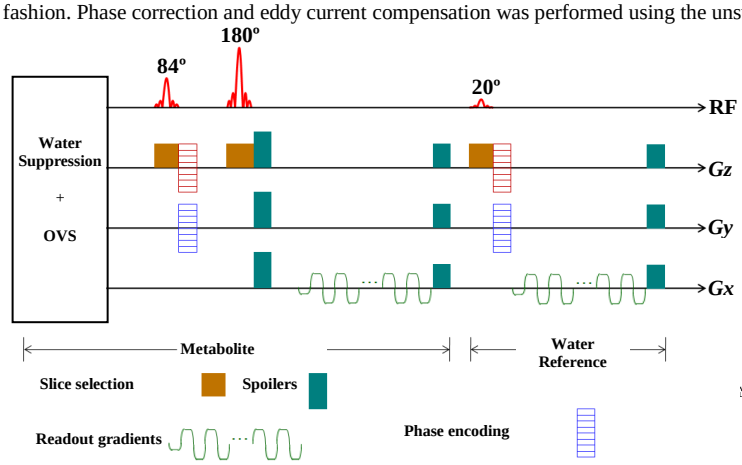

Figure 1. EPSI Sequence with interleaved water acquisition.

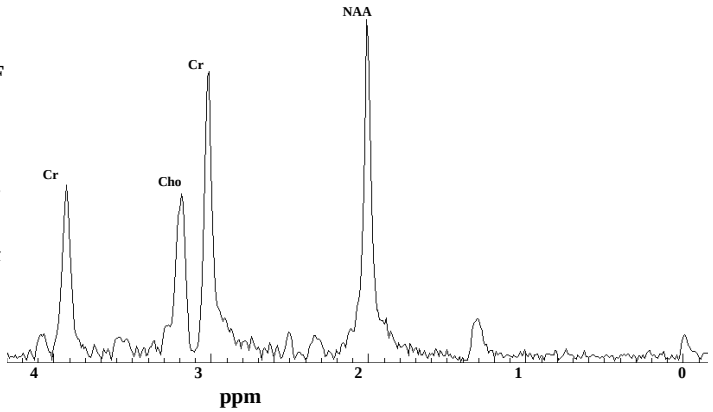

Figure 2. Spectrum from a 2 mm^3 single voxel from a brain phantom.

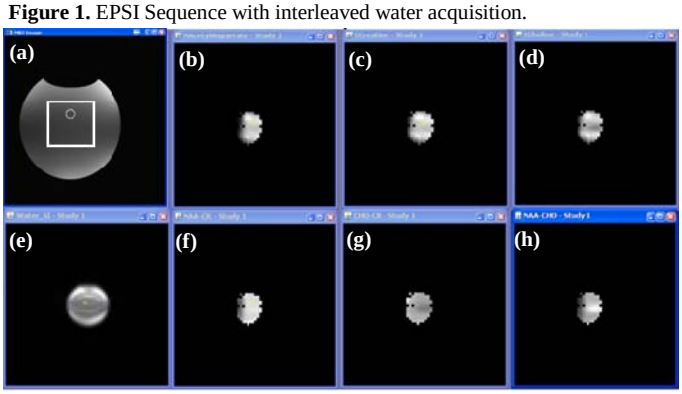

Figure 3. Metabolic maps obtained after processing in MIDAS. From left to right - Top row **(a)** T_1 weighted image **(b)** NAA **(c)** Cr and **(d)** Cho and in bottom row **(e)** Water **(f)** NAA/Cr **(g)** Cho /Cr and **(h)** NAA/Cho.

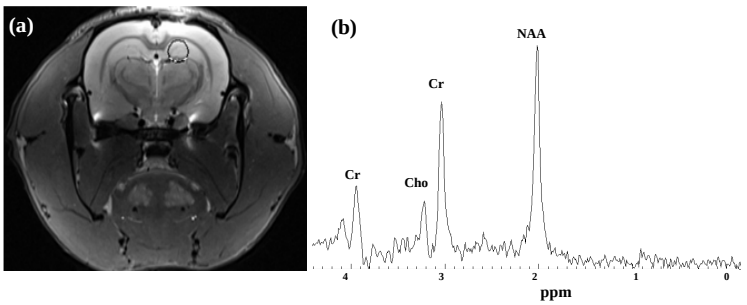

Figure 4. (a) T_2 weighted turbo spin echo image of the rat brain **(b)** *In vivo* MR spectrum acquired using EPSI sequence from the rat's hippocampus at TE = 70 ms.

RESULTS and DISCUSSION: Figure 1, shows the EPSI sequence with interleaved water acquisition. Figure 2, shows the spectrum of the brain metabolite phantom for a single voxel at TE = 70 ms. Figure 3 shows the reconstructed metabolite maps of NAA, Cr, Cho and their ratios using MIDAS[3]. The EPSI spectrum of NAA, Cr, and Cho acquired from a voxel of 2 mm^3 in the rat hippocampus is shown in Figure 4.

CONCLUSIONS: We have implemented and validated a 3D EPSI sequence on a 7T Bruker Clinscan MRI/MRS scanner and demonstrated in a brain phantom and *in vivo* on a rat brain. Regional metabolite distributions of NAA, Creatine & Choline and its ratios were computed using MIDAS Software. The feasibility of mapping whole brain NAA, Cr and Cho concentrations is demonstrated from the rat brain. The 3D EPSI sequence significantly reduces the acquisition time when compared to 3D multi-voxel chemical shift imaging sequences. This technology can be used for whole brain metabolic imaging in animal models with human diseases such as cancer, epilepsy, traumatic brain injury.

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References: [1] Ebel, *et al*. Magnetic Resonance in Medicine 53:465–469, 2005 [2] Govindaraju V, *et al.* NMR Biomed 13:129-153, 2000 [3]. Maudsley, *et al*. NMR Biomed.; 19: 492–503, 2006.