A new approach to short-TE full-sensitivity MRSI of human brain at 7T

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Introduction Magnetic resonance spectroscopy at 7T human scanners provides high signal-to-noise ratio and increased spectral dispersion, which allows the measurement of a large number of metabolites [1]. Spectroscopic imaging enables to obtain metabolic information from multiple voxels simultaneously and to create metabolic maps of the neurochemical profile [2,3]. In this study, a short-TE MRSI sequence (TE=12ms) based on a semi-adiabatic spin-echo (Fig.1) was implemented, which affords full-sensitivity, minimizes signal loss due to T_2 relaxation and J-evolution, reduces the chemical shift displacement, and has no baseline distortions compared to FID based methods. Metabolic maps of relative concentrations are reported for nine metabolites.

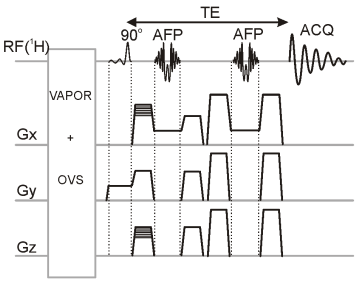

Figure 1.Sequence diagram for semi-adiabatic spin-echo MRSI.

Methods All experiments were performed on three healthy volunteers at a 7T/68cm MR scanner (Siemens Medical Solutions, Erlangen, Germany) with a home-built ^{1}H quadrature surface coil (12cm diameter). 3D T_1-weighted images were acquired using MP2RAGE [4] (TE/TR=3.37/5000ms, TI1/TI2=700/2200ms, slice thickness=1mm, FOV=176×256mm^2, matrix size=176×256) were used to place the VOI and overlay with metabolic maps. B_0 field inhomogeneity was optimized using first- and second-order shimming with FASTMAP, which results in water linewidth of 14-15 Hz. 2D ^{1}H MRSI sequence was based on a semi-adiabatic spin-echo sequence, where a slice selective asymmetric 90° pulse and two broadband adiabatic pulses (refocusing pulse, HS4, R=28, BW=7.4kHz, T_{pulse}=3.5ms, $\gamma B_1/2\pi$=1.6kHz) were implemented to achieve a column selection and the third dimension localization was completed by outer volume suppression [1] and phase encoding. VAPOR was applied with OVS prior to the localization. Measurement parameters are TE/TR=12/5800ms, FOV=120×120mm^2, VOI=60×60mm^2, slice thickness=10mm, matrix=16×16, NEX=1, elliptical k-space sampling, total acquisition time = 15 min. Metabolite concentrations were quantified using LCModel [5] and metabolites maps were created by a home-written routine in Matlab.

Results and Discussion In each voxel, spectra demonstrate high quality with high SNR (41 ± 8, mean ± sd, all 8×8 voxels), no baseline distortion and very minor lipid contamination (Fig.2a middle). The spin-echo based MRSI reduces the baseline distortions compared to those based on FID and gains double the sensitivity compared to STEAM based methods. The use of broadband refocusing pulse minimizes the chemical shift displacement, while the TE of 12ms is still fairly short and preserves the signal loss due to T_2, whereas J-evolution is strongly reduced by the use of adiabatic pulses. In the representative spectra from GM and WM containing voxels, higher glutamate and NAAG were observed in GM and WM, respectively (Fig.2a right). At least 10 metabolites, i.e., Cr+PCr, GPC+PCho(tCho), NAA, NAAG, Ins, Glu, Gln, GSH, GABA and PE were reliably quantified in most voxels within VOI using LCModel with CRLB < 30%. Metabolites maps of relative concentrations to total creatine (tCr) were reported (Fig.2b). The Glu/tCr and Glx/tCr show higher concentrations in the region of GM compared to WM, which is consistent with the other study [3]. NAAG/tCr was higher in WM, which was also observed in the MRS study of Pouwels [6].

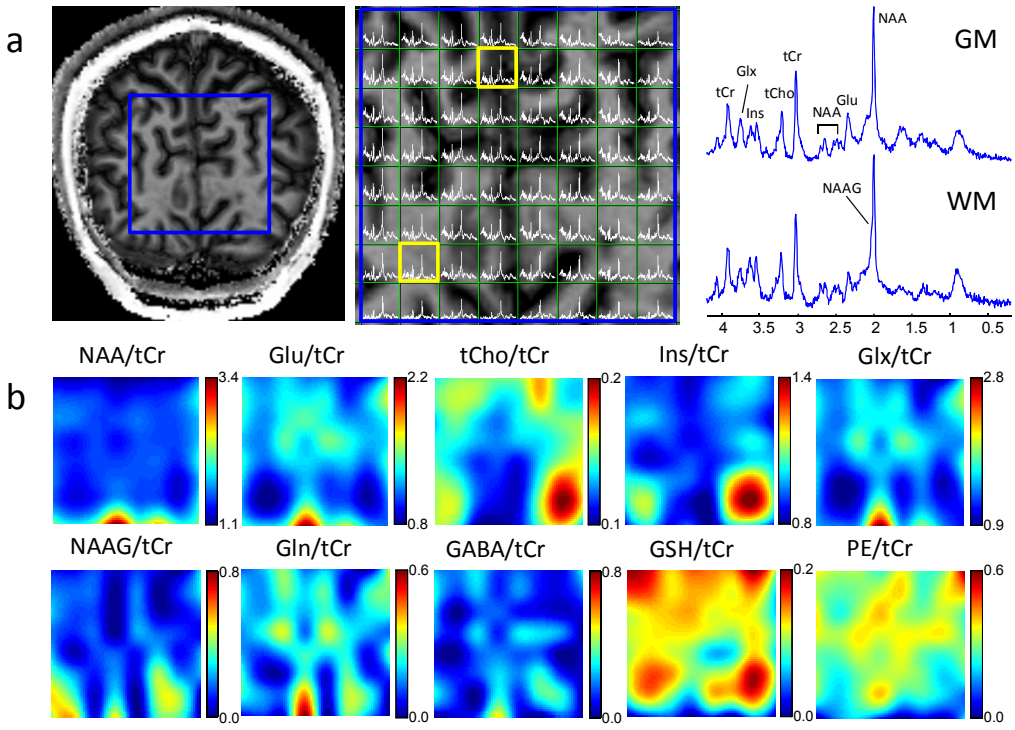

Figure 2. a) Left : coronal view of selected VOI (blue square, mostly covers occipital lobe) for spectroscopic imaging; Middle : enlarged spectra maps in VOI; Right : representative spectra from voxel containing GM and WM , respectively (yellow boxes in the middle image, 7.5×7.5×10mm^3, no apodization is applied). b) Maps of relative concentrations using tCr (TE/TR=12/5800, FOV=120×120mm^2, VOI=60×60mm^2, slice thickness=10mm, matrix=16×16, NEX=1).

In conclusion, the short-TE semi-adiabatic spin-echo based MRSI at 7T is feasible to measure high quality spectra from multiple voxels in human brain simultaneously, with full signal intensity, no baseline distortion, minimal chemical shift displacement and signal loss due to T_2 and J-modulation. Thus it allows regional maps of nine metabolites. The high SNR achieved in this study can allow the further improvement of spatial resolution.

References [1] Mekle R et al., Magn Reson Med. 2009. [2] Mlynarik V et al., Magn Reson Med. 2008. [3] Henning A et al., NMR in Biomed. 2009. [4] Marques JP et al., Neuroimage. 2010. [5] Provencher SW, Magn Reson Med 1993. [6] Pouwels P J W et al. NMR in Biomed. 1997.

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