Phase Rotation with Asymmetric RF Pulses in Localized Stimulated Echo Spectroscopy (PRAISES) : A 2.5-ms TE Sequence for Clinical Spectroscopy

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Introduction: In localized ^{1}H neurospectroscopy, very short echo time (VTE) sequences maximize spectral information, improve quantitation accuracy, and increase the sensitivity and utility of chemical profiling (1,2) by reducing T_2-weighting and phase dispersion effects, and by preserving the stoichiometric relationships in the brain tissue. Most VTE sequences depend on high-amplitude, short-duration gradients that are not easily adapted for clinical scans due to FDA limitation on dB/dt. In this work, we present the *p*hase *r*otation with *a*symmetric RF pulses *i*n localized *s*timulated *e*cho *s*pectroscopy (*PRAISES*) technique as a clinically friendly VTE sequence. On a 1.5-T MRI system, PRAISES offers a TE as low as 2.5-ms by combining RF coherence selection and gradient coherence selection techniques in a phase rotation (PR) STEAM sequence. Here, we present development work on the PRAISES technique.

Methods and Materials: The 2.6-ms duration sinc RF pulses in a 6-ms TE PR-STEAM sequence (3) were replaced by asymmetric RF pulses of equivalent duration. Employing the minimum-phase RF pulse design technique of Pauly et al (4), an Interactive Data Language ((IDL), Research Systems Inc.) program was written to generate an asymmetric RF pulse (asymmetry factor of 0.184) with an identical magnitude profile, theoretically, as the sinc pulse. To obtain the shortest possible TE, the asymmetric RF pulses were incorporated into the PR-STEAM sequence as described by Tkác et al (2), with the direction of the 1st and 3rd pulses reversed relative to the 2nd RF pulse. All slice-selective refocusing gradients were played out during the second TE/2 interval to keep the TE to a minimum. The peak slew rate in the resulting sequence was only 58 mT•m^{-1}•ms^{-1} for a 10x10x10mm^3 voxel. For the phase rotation paradigm, combining the phase increments from the three RF pulses yielded a phase rotation for the stimulated echo $\Delta\Phi_{STE}$ of 0º and for the 3rd FID a phase rotation $\Delta\Phi_{FID}$ of 157.5º, resulting in a 2.5-ms TE PRAISES sequence. The sequence was tested on a Magnetom Sonata whole-body 1.5-T MRI system (Siemens Medical Systems, Erlangen, Germany) on three healthy adults (N=3). The data was collected from an anterior-frontal brain region to increase the potential for out-of-volume contamination (Fig 1). The system body coil was used for excitation and a receive-only circularly polarized head coil for reception. The water signal was suppressed by a three-pulse WET preparation (5). Spectral parameters were: 2. 5-kHz spectral width, TE/TM/TR=2.5/10/5000 ms, 2048 complex points, VOI ~ 6-cm^3, and NEX=112. Using an in-house program written in IDL, the data was 2D-FFT, the appropriate line selected, 1D-IFFT, phase corrected using the water reference technique of Klose (6), truncated to 1024 data points using a reverse Chapman-Richard function (to provide a smoother transition to zero than rectangular truncation), and zero-filled to 8K. The data were processed in jMRUI. Modeling with Hankel singular value decomposition and subtracting the resulting fits removed the residual water signal. Spectra were apodized with a 3.5-Hz Gaussian line shape for viewing. No attempt was made to quantify the spectra, as currently no prior-knowledge basis sets exist for this echo time at this field strength.

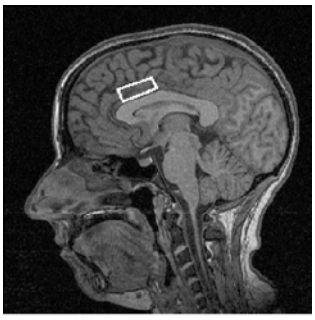

Figure 1. Sagittal slice showing voxel position in anterior cingulate gyrus.

Results and Discussion: In spite of the absence of TE crusher gradients, the signal from the stimulated echo and the residual signal from the 3rd sliced selective RF pulse - the lipid and water peaks - are well separated by the phase rotation technique (Fig 2a). The lipid signal from the scalp, generated by the 3rd slice-selective pulse (axial slice), although one hundred times greater than the lipid signal in the voxel, does not appear to contaminate the localized voxel (Figs 2b & 2c). Consistent with our previous study using a 6-ms TE PR-STEAM sequence (3), the Glx complex centered at 2.34-ppm is greatly increased, while prominent peaks from other metabolites appear to increase only slightly (Fig 2c). Visually, the primary differences between spectra from this 2.5-ms TE PRAISES and a 6-ms TE PR-STEAM are: 1) macromolecule/lipid peaks at 0.9-ppm and at 1.40-ppm more than double in intensity; 2) better defined peaks around the Glx complex; and 3) the consistent appearance of a small resonance downfield from NAA (Fig 3, see arrow), possibly NAAG. These preliminary tests of PRAISES, as well as our previous 6-ms TE PR-STEAM study, strongly suggest that accurate quantification of glutamate and glutamine at 1.5-T with ^{1}H-MRS is not possible at echo times above 10-ms without correcting for the TE-dependent effects of T_2-attenuation and phase dispersive effects of j-coupling. Future studies will focus on measuring the localization efficiency, quantification accuracy, and precision of the PRAISES technique.

Reference:

1. Pfeuffer et al, J. Magn Reson 1999, **141**:104. 2. Tkác et al, Magn Reson Med 1999, **41**:649. 3. Knight-Scott et al, Magn Reson Imaging 2005, **23**:871. 4. Pauly et al, IEEE trans Med Imag 1991, **10**:53. 5. Ogg et al, J Magn Reson 1994, **B104**:1. 6. Klose U, Magn Reson Med, 1990, **14**:26.

Figure 2. Typical results from 2.5-ms TE PRAISES spectra. (a) 112 spectral lines after 2D-FFT. (b) top – STE spectrum, bottom – FID spectrum. (c) Localized spectrum after phase correction and water removal.