RF phase rotation in STEAM: obtaining echo times below 10 ms on a 1.5T whole-body MR system

J. Knight-Scott[1], D. D. Shanbhag[1], S. A. Dunham[1]

[1]Biomedical Engineering, University of Virginia, Charlottesville, VA, United States

Abstract

An RF phase rotation scheme was implemented for a spectroscopic stimulated echo localization experiment (STEAM) on a 1.5-T whole-body MR system. The phase rotations allowed removal of the spoiling gradients that are applied during the echo time (TE) periods to suppress signals from unwanted coherence pathways. The removal of the TE spoilers allowed reduction of the minimum TE to 5.2-ms. Spectral improvements included not only increased spectral conspicuity, but also large signal intensity increases for the glutamate + glutamine and macromolecules resonances.

Introduction

Short echo times in ^{1}H MR brain spectroscopy improve information content and reduce spectral distortions from strongly coupled resonances. Short echo times are critical for the detection of metabolites such as glucose (Glc), glutamate + glutamine (Glx), and the broad resonances from macromolecules. Although there are several techniques for achieving short echo times below 20-ms, very few of these techniques are translatable to the clinical 1.5-2.0 T MR systems. Here we show how RF phase rotation can be combined with gradient spoiling in STEAM to access echo times below 10-ms on a clinical strength, whole-body MR system.

Method

Background: Spoiler gradients are applied during the mixing time (TM) and the TE/2 intervals of the STEAM sequence to select only the coherence pathway leading to the stimulated echo (STE). The TM spoilers suppress the signals from all coherences except the STE and the FID from the 3rd RF pulse, while the function of the TE spoilers is to suppress the FID signal. However, the application of TE spoilers significantly increases the minimum TE. This increase can be avoided by employing phase rotation to separate these two signals rather than gradient spoiling to suppress the FID. Since only two signals are considered for separation, phase rotation of either the 1st or 2nd RF pulse will modulate the STE while leaving the FID unaffected.

Experiments: A phase rotation STEAM sequence was implemented on a whole-body 1.5-T MR system by removing the TE spoiler gradients and rotating the first RF pulse in 157.5º increments (Fig 1). Each slice-select RF/gradient combination had a ramp time 0.4 ms and RF pulse lengths of either 2.6-ms or 2.2-ms. The amplitude of each TM spoiler gradient was 23-mT/m. The completed sequence yielded a minimum TE of 6-ms for the 2.6-ms RF pulses and a TE of 5.2-ms for the 2.2-ms RF pulses. The localization effectiveness of the sequence was validated in test phantoms and healthy adults.

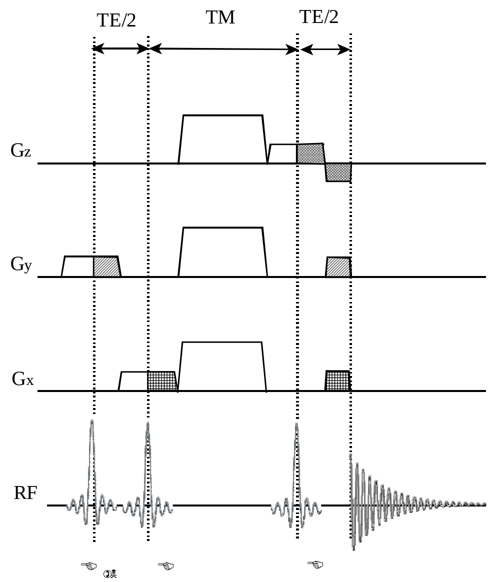

Figure 1. Phase rotation scheme for STEAM sequence. All spoiler gradients in the TE/2 intervals were removed to reduce the minimum available TE.

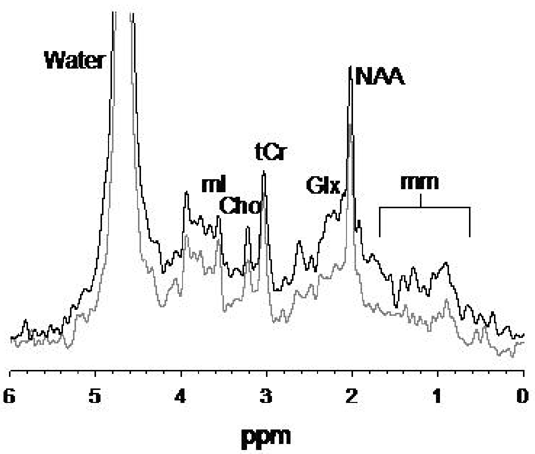

Figure 2. ^{1}H MR spectra from the posterior cingulate of a healthy young volunteer (6 cm^3, TR/TM=5s/10ms, 112 excitations, 2500 Hz spectral width): upper trace, 6 ms TE; lower trace, 20 ms TE. The spectra are identically scaled to allow for their direct comparison. The glutamate + glutamine (Glx) and the macromolecules (mm) resonances show the largest gains with increases of 50 to 100%.

Results and Discussion

Both the phantom data (not shown) and the human data (Figure 2) show improved spectral conspicuity and increased intensity for the short TE phase rotation data, compared to spectra acquired with a standard 20-ms TE sequence. In the phantoms, no additional out-of-volume contamination was detected with the phase rotation sequences. Our minimum RF pulse length was 2.2-ms; however, shorter echo times can be obtained by further reducing the RF pulse lengths or reducing the gradient ramp time. On MR systems that excite with local RF coils, lower power requirements will allow shorter RF pulses and subsequently even shorter TEs than demonstrated here. Current high-field animal systems can particularly benefit from a STEAM phase rotation sequence. Because these systems typically have slice-selective RF pulse lengths of 1-ms or less, echo times as short as 2-ms are easily accommodated with a phase rotation scheme. Phase rotation in STEAM will make sub-10 ms TEs routinely available on most clinical MR systems.

Reference

J. Hennig. The application of phase rotation for localized *in vivo* spectroscopy with short echo times. J. Magn. Reson. **96**: 40-49 (1992).