Short TE Whole Brain MRSI with High-Bandwidth Adiabatic SLR Refocusing and Echo Planar Readout

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INTRODUCTION: Fast volumetric MR spectroscopic imaging using efficient spatial and spectral encoding has been developed to detect alteration in tissue metabolism within a feasible clinical scan time. [1,2] At high fields, a short TE acquisition is desired to study a large number of metabolites and minimize signal loss due to T2 relaxation and J-coupling. However, double spin-echo based localization schemes with conventional RF pulses suffer from long TE and large chemical shift localization error due to pulse width and bandwidth limitations. With conventional RF pulses, metabolite signal loss is exacerbated from B1 inhomogeneity. In addition to the signal loss, the B1 inhomogeneity introduces inaccuracy to the metabolite quantification, especially when water is used as the reference. In this work, we present a short TE spin-echo using minimum phase excitation and adiabatic refocusing RF pulses with broad bandwidth and short pulse widths. This localization scheme was incorporated into a fast volumetric MRSI sequence with an echo planar readout, with the data automatically processed using the MIDAS package.[3]

METHODS: A pair of identical adiabatic Shinar-LeRoux (SLR) 180° pulses [4] were used to achieve high-bandwidth B1-insensitive refocusing. Adiabatic SLR pulses achieve more uniform RF energy distribution for the same pulse duration and bandwidth when compared to conventional hyperbolic secant (HS) adiabatic pulses. Therefore, they are good alternatives to achieve high bandwidth refocusing, while minimizing echo time and adhering to peak RF limitations. A pair of pulses was required in order to refocus the quadratic phase accrued across the slice. The final pulse we used had a 5 ms duration, 4.32 kHz BW and a 17 µT peak B1, which was a reasonable compromise between duration, bandwidth, slice profile, and peak RF. Pulse waveforms are shown in Figure 1 and the corresponding frequency profile is shown in Figure 2.

To further shorten the echo time, a minimum phase RF pulse with 5.12 ms pulse width and 3 KHz bandwidth was used for excitation. The minimum phase excitation pulse and the pair of adiabatic SLR refocusing pulses were incorporated into a spin-echo volumetric MRSI sequence [1] and implemented on a GE 3T MR scanner as shown in Figure 3. The sequence used inversion recovery for lipid suppression, CHESS water suppression, a 140 mm slab excitation, and echo-planar readout plus 2-dimensional phase encoding, for a final sampling resolution of 50x50x18 points. The sequence also included an interleaved water MRSI acquisition with identical spatial and spectral parameters. MRI and MRSI data were automatically processed using the MIDAS package to map choline creatine and N-acetylaspartate (NAA). [3]

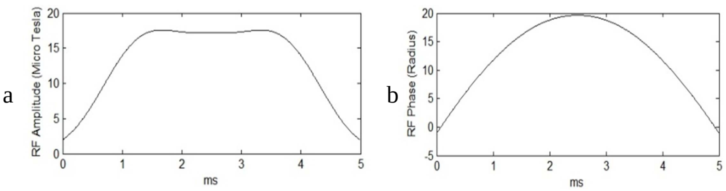

Fig. 1 Magnitude (a) and phase (b) of the adiabatic SLR refocusing pulses.

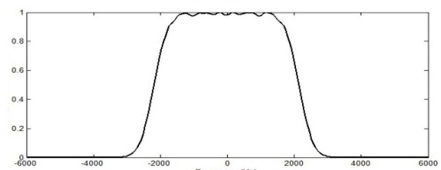

Fig 2. Frequency profile of the adiabatic SLR refocusing pulse.

RESULTS: Multiple phantom and in vivo datasets were acquired using the proposed sequence. High quality spectra were obtained throughout the phantom. Shown in Figure 4 were representative spectra acquired from a healthy 28 year old male subject with TR/TE/TI = 1710/20/198ms, 28cm FOV and 25 minute acquisition. The NAA image was also generated using the MIDAS package and shown in Figure 5. With a voxel size of 0.56x0.56x1cm, average SNRs of Cho/Cre/NAA were measured at 24/28/41.

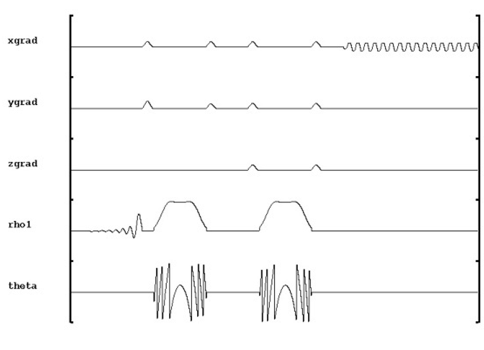

Fig. 3 Sequence diagram of the MRSI with EPI readout and min-phase excitation and adiabatic SLR refocusing .

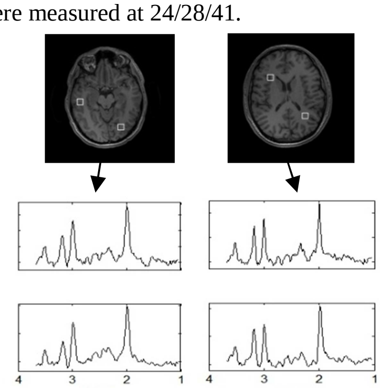

Figure 4.Spectra from representative voxels.

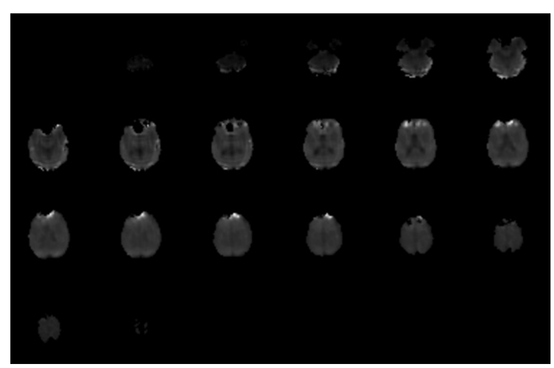

Fig 5. NAA images from each slice in the slab.

CONCLUSIONS: We have successfully developed a short TE whole brain MRSI sequence using adiabatic refocusing RF pulses with high bandwidth and short duration. As demonstrated in the in vivo study, spectra with high SNR were obtained throughout the brain. The high SNR allowed further reduction of scan time with parallel imaging. This demonstrates the feasibility of high resolution short TE whole brain MRSI with adiabatic refocusing within clinically acceptable scan time.

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