CT-PRESS Based Spiral Spectroscopic Imaging with Robust Water and Lipid Suppression using Multiple Dualband Frequency-Selective RF Pulses

M. Gu[1], D. M. Spielman[1], N. M. Zahr[2], A. Pfefferbaum[2], E. V. Sullivan[2,3], and D. Mayer[1,2]
[1]Radiology, Stanford University, Stanford, California, United States, [2]Neuroscience Program, SRI International, Menlo Park, California, United States, [3]Psychiatry & Behavioral Sciences, Stanford University

Introduction

Using effective homonuclear decoupling, constant-time point-resolved spectroscopy, CT-PRESS [1,2], has been proposed for the detection of coupled resonances such as glutamate (Glu) and myo-insitol (mI). As a 2D spectroscopy technique, it requires long minimum scan times for multivoxel applications, prohibiting wide spread use in clinical settings. To shorten the minimum scan time, CT-PRESS has been combined with fast spiral spatial encoding [3]. To avoid lipid contamination, however, the method usually employs either the excitation of a restricted brain region using PRESS volume pre-selection, losing metabolite signals from subcortical regions, or applies inversion recovery [4], resulting in reduced SNR. Recently, a robust suppression scheme using multiple dualband frequency-selective RF pulses has been proposed to suppress both water and lipids and thus provide whole-brain coverage without metabolite signal loss [5]. Here, we combine this suppression technique with the CT-PRESS based spiral spectroscopic imaging sequence for improved detection of metabolites of Cho, Cre, mI, Glu, Gln and NAA with whole-brain coverage.

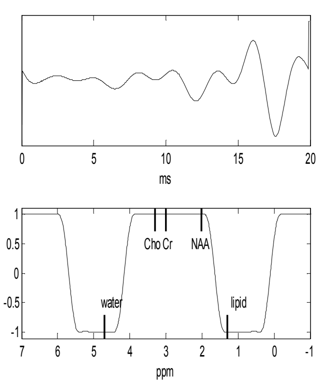
Methods

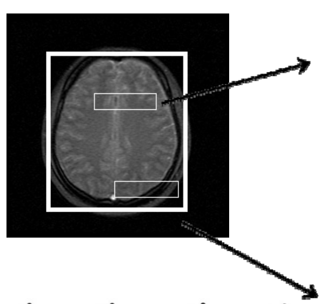
The water and lipid suppression scheme consists of four dualband frequency-selective RF pulses with optimized flip angles. Each RF pulse has minimum phase with apulse duration of 20 ms to ensure sharp transition bands of 50 Hz. The minimum-phase RF pulse and its dualband inversion profile are shown in Figure 1. The four dualband frequency-selective RF pulses are separated by 30ms and their flip angles are shown in Figure 2. The flip angles were found by minimizing the maximum absolute value of residue longitudinal magnetization with representative water and lipid T1s (1.5s for water and 170ms, 260ms, and 280 ms for lipids) at the time of excitation under the condition of ±20% B1 inhomogeneity [5].

The CT-PRESS sequence was optimized for the detection of the Glu C4 resonance at 2.35ppm at 3T [2]. The last refocusing RF pulse in the PRESS module was shifted by 129 steps with the step size of $\Delta t1/2$=0.8ms, resulting in a spectral bandwidth in F1 of 625 Hz. The constant time, tc, was set at 139ms to achieve maximum SNR for resolving the Glu C4 resonance. The data acquisition started right after the last refocusing RF pulse to increase the SNR. The spatial encoding was achieved using repeated spiral gradients with a spectral bandwidth in F2 of 1190Hz. The spiral k-space data were gridded onto a Cartesian grid. 2D Fourier transform was performed for reconstruction after apodization in both t1 and t2 dimensions with a t1-dependent linear phase compensation for shifted acquisition. The 1D-diagonal spectrum was generated by integrating the 2D magnitude spectrum along F2 within a ±13Hz interval.

Results

To test the effectiveness of the method, a brain CT-PRESS based spiral spectroscopic imaging sequence with standard CHESS water suppression was compared with dualband water and lipid suppression. Studies were performed on a healthy human subject after high-order shimming with the following characteristics: TR=2000 ms, FOV=24cm, 4 spiral interleaves, 1.5x1.5x2cm voxel size, single slice and 17:20 minute acquisition time. Figures 3 and 4 show grid plots of spectra with multiple dualband frequency-selective water-and-lipid suppression from representative voxels both inside and on the edge of the brain. The PRESS box was selected to encompass the all brain tissue within the slice while partially eliminating some subcutaneous lipids. The measured residual water using multiple dualband frequency-selective RF pulses is on the order of half of that using the CHESS water suppression. The effectiveness of the lipid suppression is clearly demonstrated on the spectra with the measured suppression on the order of 20.





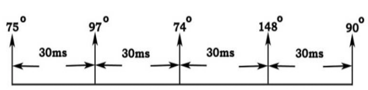


Fig. 1 Dualband minimum phase RF inversion pulse and its profile.

Fig 2. Scheme of multiple flip angle dualband frequency-selective RF pulses.

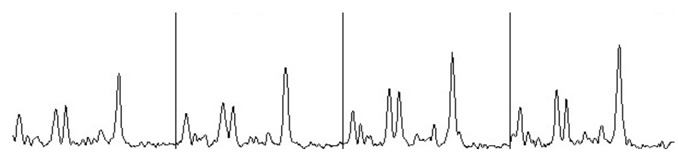


Fig 3. Grid plot of spectra from representative voxels inside brain using multiple dualband frequency-selective RF pulses.

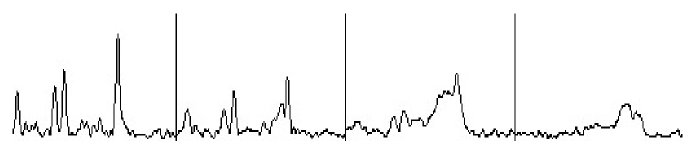


Fig 4. Grid plot of spectra from representative voxels inside brain using multiple dualband frequency-selective RF pulses.

Conclusion

We have combined a robust water and lipid suppression scheme using dualband frequency-selective RF pulses with CT-PRESS based spiral spectroscopic imaging at 3T. The effectiveness of the multiple dualband RF pulses was demonstrated in an in vivo human study within an acquisition time suitable for clinical study. Results demonstrate effective water and lipid suppression and undisturbed metabolite spectra.

Acknowledgements

Lucas foundation, GE Health Care, NIH RR09784, MH080913, AA005965, AA013521-INIA, AA017347 and AA017168.

Reference

[1] W. Dreher, et al, MRI, 17(1), 141-150, 1999
[2] D. Mayer, MRM, 54(2), 439-442, 2005
[3] D. Mayer, et al, MRM, 55(5), 974-978, 2006
[4] A. Ebel, et al, MRM, 49, 903-908, 2003
[5] M. Gu., et al., MRM 61(2), 462-466, 2009