Robust lipid suppression using multiple frequency-selective pulses for brain spectroscopic imaging at 3T

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Introduction

Brain spectroscopic imaging has been increasingly used in diagnosis and treatment assessment in recently years. In spectroscopic imaging, strong lipid signal, if not suppressed, contaminates much smaller metabolite signals, making it impossible to interpret and quantify the spectra. To suppress lipid signals, many methods have been proposed and implemented. The most common approach for reducing lipid signals is the use of volume preselection via PRESS [1]. This technique only excites restricted areas inside the brain. To achieve whole brain coverage, at 1.5T, the inversion recovery technique is normally used, which causes 30-40% metabolite signal loss [2]. At 3T, a frequency selective inversion recovery technique has been implemented to suppress lipids without causing any metabolite signal loss [3]. However, lipid signals are not fully suppressed as lipids have several different T1s. In addition, the suppression ratio will be further reduced in the presence of B1 inhomogeneities. To address these issues, a robust lipid suppression technique has been proposed and implemented for brain spectroscopic imaging at 3T.

Methods

The chemical shift between lipids and the closest metabolite (NAA) is 0.7 ppm. At 3T, these two spins are separated by 89 Hz. To flip lipid spins without disturbing the metabolites, 20 ms long minimum phase RF pulses with a sharp transition band of 50 Hz and a flip band of 500 Hz, were designed using the Shinnar-Le Roux algorithm [3,4]. To account for B1 inhomogeneity and different T1s of lipid spins, four such pulses, 10ms apart, with different flip angles were used before the 90 degree excitation. The four different flip angles were found by minimizing the maximum absolute value of residue longitudinal lipid magnetization at the time of excitation for three different T1s, 170/260/280 ms, and ±10 percent B1 inhomogeneity. To test the lipid suppression effect and compare it with single frequency selective inversion recovery method [3], a CSI imaging sequence was implemented with the following characteristics: spectral-spatial spin echo pulse for metabolite and lipid excitation and water suppression, TR/TI/TE=2000/170/144 ms, spiral readout gradients, single slice, 2.5 cc voxels and 2 minute acquisition time. [5]

Results

The simulated absolute values of residual lipid magnetization at different T1s with ±10% B1 inhomogeneity are plotted in figure 1 and absolute values of residual lipid Mz at targeted T1s are plotted in figure 2. It is clearly shown that multiple flip pulses achieved much better lipid suppression at targeted T1s and were robust under B1 inhomogeniety. The four flip angles found using the optimization algorithm are 110/74/67/162 degrees and the scheme of the sequence is shown in figure 3. Figure 4 shows spectra from two voxels with and without lipid inversion obtained from an in vivo study. The two representative voxels are chosen such that one is in the subcutaneous fat on the back of the head and the other is within the brain close to the back of the head. The spectra from the voxel in the subcutaneous fat clearly show that the lipid signal is suppressed with single inversion pulse and it is further suppressed with multiple flip angle pulses. The measured suppression is on the order of 10 for single inversion pulse and higher than 20 for multiple flip angle pulses. The spectra from the voxel in the brain show that the artifact in the spectrum that is due to lipid signal leakage is significantly reduced, and metabolite spectra are not disturbed in both suppression methods.

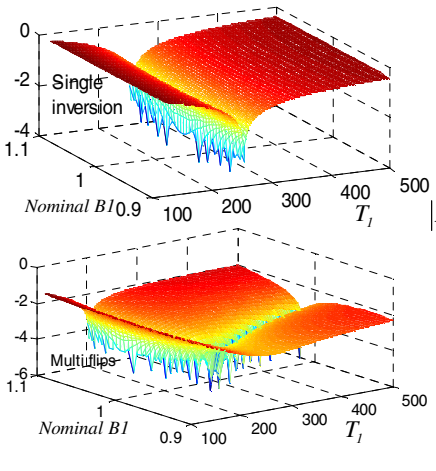

Figure 1. Simulated plots of absolute value of Residule lipid Mz at T1s from 100-500ms under 10% B1 variation. Values are in log scale.

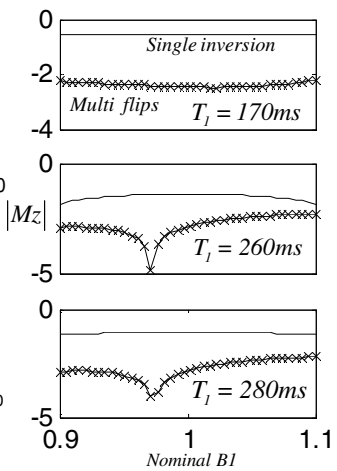

Figure 2. Simulated absolute values of residual lipids at targeted T1s. $|Mz|$ values are in log scale.

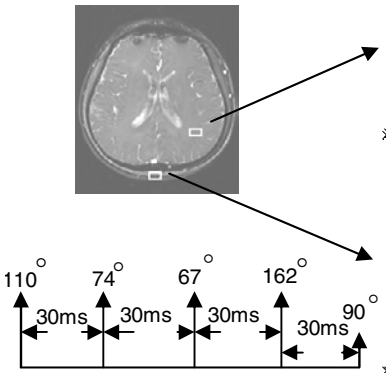

Figure 3. Scheme of multiple flip angle frequency selective pulses for lipid suppression.

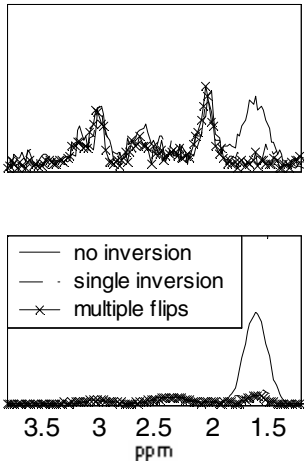

Figure 3. In vivo spectra of representative voxels, 2.5cc, 2 minute acquisition.

Conclusion

We have designed and implemented a robust method to suppress lipids using frequency selective pulses for a spiral CSI scan at 3T. The effectiveness of this multiple pulse method is demonstrated on an in vivo scan. It showed improved suppression compare to single frequency selective inversion recovery and undisturbed metabolite spectra.

Acknowledgements

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Reference

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