Detection of short T2 component in brain by SWIFT

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Introduction

Tissue components such as lipids in cell membranes and cell organelles are likely to have very short transverse relaxation times, T_2, due to their semisolid like structure. In several pathological conditions the cell membrane composition is altered, e.g. in white matter in multiple sclerosis. Nowadays, these changes are detected indirectly through the water signal since detection of signal from very short T_2 species is practically impossible with conventional MRI methods. Imaging sequences especially for short T_2 detection have been proposed, e.g. ultra short echo time (UTE) techniques [1]. Typical TEs of UTE are in the range of 50-200 µs [2], but even shorter TE's, or acquisition delays, can be reached with SWIFT (Sweep Imaging with Fourier Transformation) [3]. SWIFT is an imaging technique based on virtually simultaneous excitation and detection with gapped frequency-swept pulses. Few microsecond (3-12 µs) acquisition delays can be reached with SWIFT, limited only by T/R switch hardware and coil ringdown since no gradient or spin echo is formed. The problem with SWIFT and other similar methods is that virtually the whole spectrum of signals with different T_2's is detected, leaving the short T_2 components masked by the long T_2 components. The purpose of this study was to explore two simple long T_2 suppression methods in combination with SWIFT acquisition in order to obtain MRI images with signal originating predominantly from the short T_2 protons.

Materials and Methods

Two different long T_2 suppression schemes were used. The first suppression scheme is based on the idea that short T_2 components do not follow narrow bandwidth [4], i.e. long pulses, since their relaxation rate exceeds the excitation rate. The preparation consisted of an adiabatic inversion followed by a delay. Ideally, a saturation pulse would be applied before every acquisition, but this is not feasible since >100000 radial spokes must be collected for high resolution SWIFT images. Inversion instead of saturation was used, which will keep the z-magnetization of the long T_2 components on average close to zero due to T_1 recovery. The purpose of the delay was to better place the acquisition around the zero crossing for further improving the suppression. Two pulse lengths (T_p = 80, 100 ms, HS4, R=10) were used, and the delay was set to 0.1 s. The inversion pulse was given every 20 acquisitions. Root mean square transverse magnetization of a single 20 acquisition period was calculated through Bloch equation simulations in steady state for different T_2's.

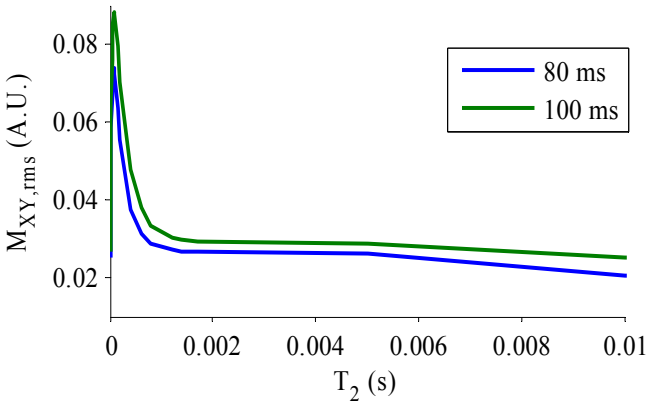

Figure 1. Simulated transverse magnetization with 80 ms and 100 ms HS4 pulses according to suppression scheme 1.

The second suppression scheme was based on a subtraction of a normal SWIFT and a short T_2 suppressed magnitude image. Short T_2 suppression was carried out with two consecutive adiabatic inversion pulses (HS4, R = 20, T_p = 20 ms) placed around the water peak. The inversion pulses were given every 16 acquisitions. Two different offsets of the band centers were used for comparison (±800, 950 Hz).

Imaging was conducted with a 9.4 T vertical magnet interfaced with a Varian DirectDrive console using a 10 mm quadrature transceiver volume coil. For all imaging, SWIFT acquisition parameters were: a flip angle of 5°, TR = 5.1 ms, an acquisition delay of 7 µs, 128000 spokes, sw = 62.5 kHz, FOV = 2.7x2.7x2.7 cm^3. Final image resolution was 256^3. A mouse brain was perfused in 4% PFA and then washed in saline. For imaging, the brain was immersed in Fomblin (Solvay Solexis) inside an NMR tube.

Results and Discussion

Figure 1 shows the simulation results of the first suppression scheme. Although not demonstrated here, Bloch equation simulations of scheme 2 also showed suppression of on-resonance short T_2 components, which is an advantage for the subtraction. Figure 2 shows representative images using the two suppression schemes; b) and c) confirm the simulations results in Figure 1. Both methods highlight the white matter as expected, although the S/N ratio of scheme 2 is considerably better. The images shown are likely to be a mixture of signal from short T_2 myelin water and the macromolecular pool, although based on the simulation results, at least conventional myelin water T_2's (~10-50 ms [5]) should be suppressed. Also, scheme 2 is bound to have a contribution of magnetization transfer contrast and therefore the contrast is a combination of direct and indirect detection of short T_2 species.

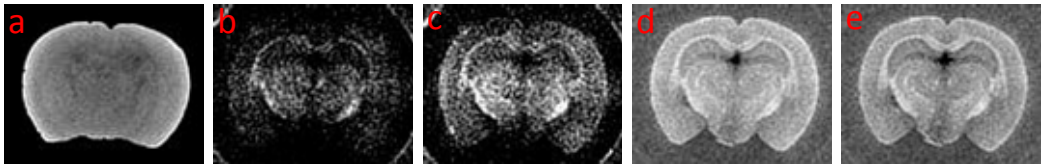

Figure 2. a) Normal SWIFT image. b,c) Long T_2 suppressed SWIFT image obtained with scheme 1 using (b) 80 ms and 100 ms HS4 inversion pulses. d,e) Long T_2 suppressed SWIFT difference image obtained with scheme 2 using d) ±800 Hz and e) ±950 Hz offsets.

Conclusion

The results give promise to the possibility to highlight the short T_2 components in the brain with SWIFT using different long T_2 suppression methods. Future work will be directed towards improving the long T_2 suppression, controlling the magnetization transfer effects and validating direct detection of the macromolecular pool. The ability to image purely short T_2 components could open new possibilities for studying brain pathologies.

References

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