Effect of Dipolar Coupling on the T1ρ MRI Signal in the Mouse Brain

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Introduction

The anisotropic arrangement of white matter fiber tracts in the brain restricts the motion of water (1) and may result in a residual dipolar interaction. The existence of this dipolar interaction has been detected in the rat brain by multiple-quantum filtered methods (2). This interaction also affects the $T_{1\rho}$ (spin-lattice relaxation time in the rotating frame) relaxation time and can be observed via spin-lock MR methods (3). We present a new pulse sequence that can perform localized $T_{1\rho}$ spectroscopy with minute increments in spin-lock time (TSL) and combined with outer-volume suppression (OVS) MRI. Further, we demonstrate the existence of residual dipolar oscillations (REDIOS) in spin-locked spectra from water protons in a mouse head *in vivo* and isolate the component from the brain by the OVS technique.

Materials and Methods

A new pulse sequence was developed to allow $T_{1\rho}$ spectroscopy measurements pre-encoded with OVS pulses indicated by the dotted parentheses (**Figure 1**). The OVS pulse and gradients are repeated 4 times to destroy magnetization outside a rectangular region of interest. The π/2 pulse selectively excites a band of spins that are "spin-locked" in the transverse plane by the application of the SL pulse that is 90° phase-shifted from the phase of the first π/2 pulse. MR imaging was performed, with and without OVS, by turning off the SL pulse and inserting phase encode and read gradients. Once a region of interest was selected in this manner, the phase-encode and read gradients were turned off and the SL pulse was turned back on to perform $T_{1\rho}$ spectroscopy. The pulse sequence was implemented on a 4.7T horizontal-bore MRI scanner controlled via a Varian console. A live 6-month old wild-type mouse was placed inside a 3cm-diameter quadrature birdcage coil. A nose cone was affixed to the animal with surgical tape to allow isoflurane inhalation anesthesia to be performed during MRI. The imaging parameters were: FOV=2cmx2cm, a single axial slice with thickness=2mm was acquired with TE/TR=2/500ms to determine spectroscopic locations. Following which, $T_{1\rho}$ spectroscopy was performed by varying TSL between 50μs to 900ms in 48 steps.

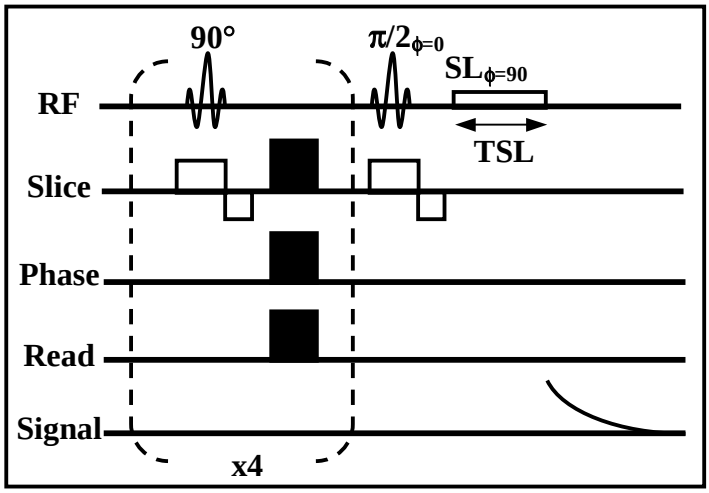
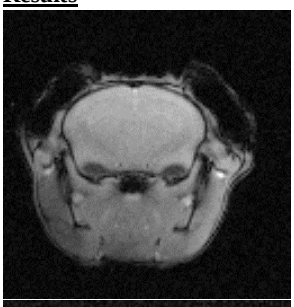
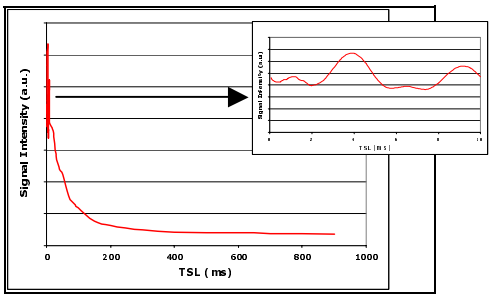
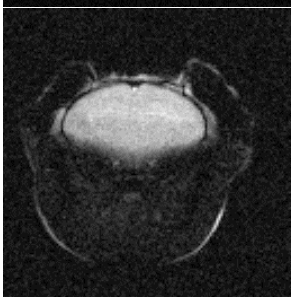


Figure 1: The pulse sequence used in the experiments to perform outer-volume suppression and $T_{1\rho}$ spectroscopy.

Results







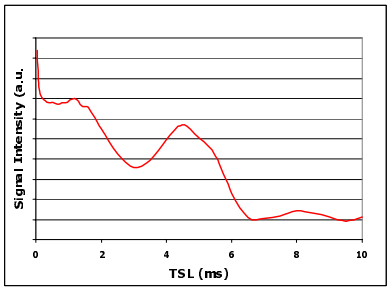


Figure 2: Typical MR image and evolution of $T_{1\rho}$-prepared magnetization from the same region as a function of spin-lock time (TSL). Data was obtained without OVS and therefore reflects signal from the entire slice including brain and muscle tissue. The inset graph is a magnified version of the first 10ms of evolution of the magnetization and demonstrates the presence of REDIOS. Data from the same experiments but using distilled water did not show any REDIOS thereby confirming that the oscillations observed in the mouse head's spectra are due to the residual dipolar interaction.

Figure 3: The same slice is examined again with OVS pulses turned on. The MR image clearly shows the effect of signal suppression from surrounding tissues leaving only signal contribution from the brain. The REDIOS observed in this case was markedly different from that in Figure 2. However, multiple frequency components are still observed in the spectra. Methods to isolate the frequency components are under development.

Conclusion

We have demonstrated the existence of a REDIOS in the mouse brain *in vivo* indicating the presence of dipolar order in water in brain tissue. In addition, we developed and implemented a spectroscopic method to measure REDIOS in a spatially localized manner. Additional studies are currently underway to spatially map REDIOS distribution in mouse models of neurodegeneration.

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