A New Pulse Sequence for Rapid Spin-locked MR Imaging

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Introduction

The spin-lattice relaxation time in the rotating frame, $T_{1\rho}$ (T_1-rho) has been employed to study a variety of tissues *in vivo* (1, 2). However, dynamic MRI studies to measure flow and oxygen metabolism (3, 4) require fast imaging strategies that are able to acquire $T_{1\rho}$-weighted images in sub-second time regimes. In this work, we present a method for rapid $T_{1\rho}$-weighted imaging and show the application of this technique for measuring $T_{1\rho}$ in the human brain.

Materials and Methods

In the new pulse sequence (**Figure 1**), a non-selective $\pi/2$ pulse excites spins that are then spin-locked in the transverse plane by the application of two phase-alternating ($\pm 90°$ phase-shifted from the phase of the first $\pi/2$ pulse) SL pulses. The duration of the SL pulses is denoted as TSL. The second non-selective $\pi/2$ pulse will restore the spin-locked magnetization to the longitudinal axis. A strong "crusher" gradient (indicated as a filled square block) is applied to destroy any residual transverse magnetization. The "$T_{1\rho}$-prepared" magnetization at the end of the crusher gradient is described by the equation:

$$M(TSL) = M_0 e^{\frac{-TSL}{T_{1\rho}}} \qquad [1]$$

where M_0 is the thermal equilibrium magnetization.

For rapid imaging, we employed a echo-planar imaging readout (5). Images of a 30 year-old healthy male volunteer were obtained on a Siemens Sonata 1.5T clinical scanner. The imaging parameters were: FOV=24cmx24cm, slice thickness=5mm, TE/TR=23ms/1s. The TSL time was varied from 5-30ms in 4 steps and the images were fit to Eq. [1] on a pixel-by-pixel basis to generate $T_{1\rho}$ maps.

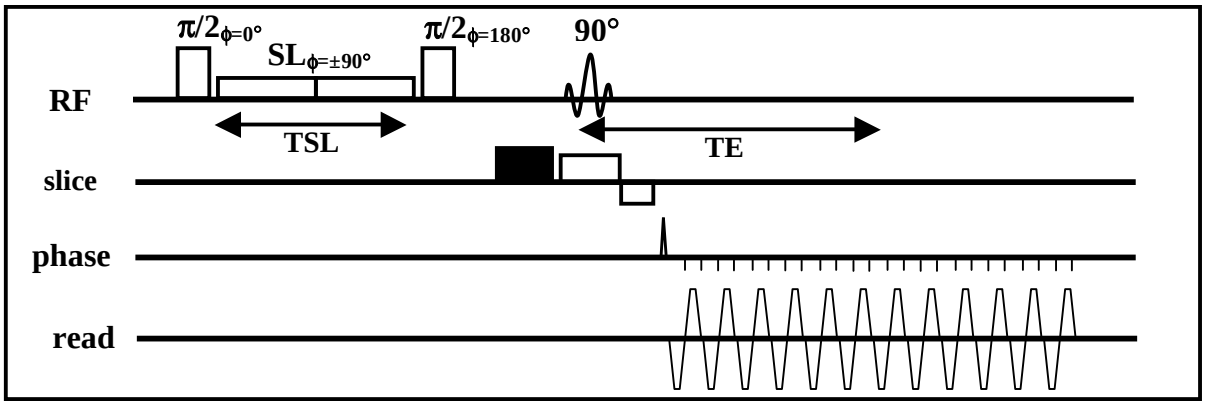
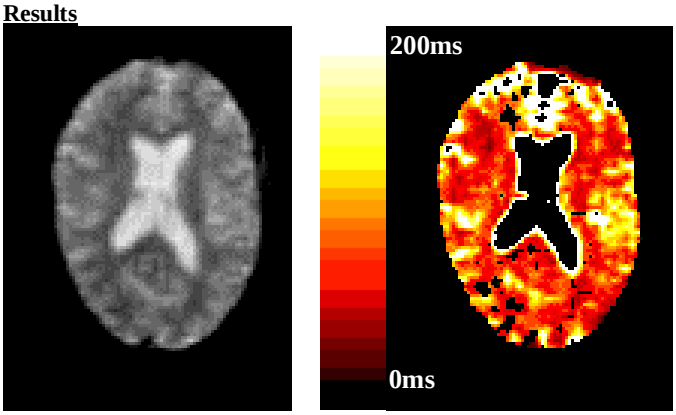


Figure 1: The pulse sequence for rapid $T_{1\rho}$-weighted MRI.

Results



A B

Figure 2: A $T_{1\rho}$-weighted MR image (**A**) shows similar contrast in the brain as a T_2*-weighted MR image. The $T_{1\rho}$ map (**B**) of the same slice determined by fitting four different $T_{1\rho}$ images as a function of TSL time shows $T_{1\rho}$ values of brain tissues are typically 80-90ms in white and gray matter and greater than T_2* of these tissues. $T_{1\rho}$ of CSF in the ventricles and salci is on the order several hundred ms and pixels whose $T_{1\rho}$ values did not converge during fitting were masked out to better visualize the $T_{1\rho}$ of surrounding tissue. The $T_{1\rho}$ relaxation time constant is dependent on the amplitude of the spin-lock field, γB_1, and is affected by molecular processes that occur with a correlation time τ_c. Therefore the amplitude of the SL pulse can also be varied (within SAR limits) to generate different levels of contrast in the brain.

Conclusion

We have demonstrated the feasibility of a novel imaging pulse sequence to perform rapid $T_{1\rho}$-weighted MRI. Each image was obtained in 1 second and then used to generate a $T_{1\rho}$ relaxation time map. The analysis of the pulse sequence under different conditions such as minimizing echo time, B_1 inhomogeneity etc. and its application to *in vivo* imaging is underway.

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