$T_{2\rho}$-weighted Spin-lock MRI

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Introduction

The transverse relaxation time in the rotating frame, $T_{2\rho}$, describes the direct saturation of the longitudinal magnetization by an rf pulse. In the presence of an on-resonance rf pulse of duration τ, the longitudinal magnetization M exponentially decays according to Equation 1. $T_{2\rho}$ can be approximated as the reciprocal average of T_1 and T_2 (Equation 2) [1]. In the few publications concerning $T_{2\rho}$ in the literature [2-4], there has not yet been a direct application of the $T_{2\rho}$ parameter as a mechanism of generating in vivo contrast. The purpose of this work is to investigate the use of $T_{2\rho}$ to provide a novel means of T_2-type contrast that includes both T_2 and T_1 information.

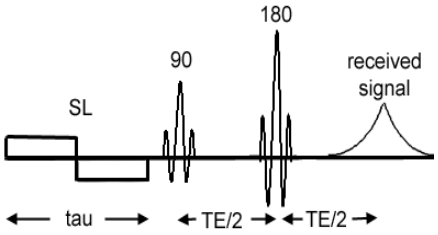

Figure 1 Spin-echo-based $T_{2\rho}$-weighted pulse sequence diagram. For simplicity, only the rf channel is shown. A self-compensating on-resonant spin-lock pulse (SL) of duration τ is applied prior to spin-echo readout.

$T_{2\rho}$-weighted Pulse Sequence

$$M(\tau) = M_0 e^{-\tau/T_{2\rho}} \quad \textbf{Eq. 1}$$

$$\frac{1}{T_{2\rho}} \sim \frac{1}{2}\left(\frac{1}{T_1}+\frac{1}{T_2}\right) \quad \textbf{Eq. 2}$$

A $T_{2\rho}$-weighted pulse sequence (Figure 1) is very similar to a magnetization transfer (MT) sequence. A long duration, on-resonance "spin-lock" rf pulse is applied to longitudinal magnetization prior to excitation and readout. The rf pulse is split into two "self-compensating" halves of opposite phase to mitigate the effects of rf inhomogeneity [5]. In an MT-type sequence, the frequency of the rf pulse is set off-resonance from the water peak on the order of 1000 Hz, whereas in the $T_{2\rho}$ sequence the rf pulse is on-resonance and generally of shorter duration.

Methods

A $T_{2\rho}$-weighted pulse sequence based on a spin-echo readout was written for use on a clinical Siemens 1.5T Symphony scanner. MR data of an in vivo healthy human brain were acquired using the $T_{2\rho}$-weighted sequence with the standard head coil. A series of $T_{2\rho}$-weighted images was acquired using spin-lock pulse durations of 15 to 75 ms with spin-lock pulse amplitude of 500 Hz (γB_1) and imaging parameters of FOV = 20 cm x 20 cm, matrix = 256 x 128, and TR/TE = 1500/15 ms. Each image in the $T_{2\rho}$-weighted series was a single 5 mm thick axial slice inferior to the corpus callosum. In addition, a T_2-weighted image series was acquired using five TE times evenly spaced from 15 to 75 ms at the identical slice position using the same imaging parameters without a spin-lock pulse. T_2 and $T_{2\rho}$ maps were created by fitting each pixel from both image series as a function of relaxation time using linear regression.

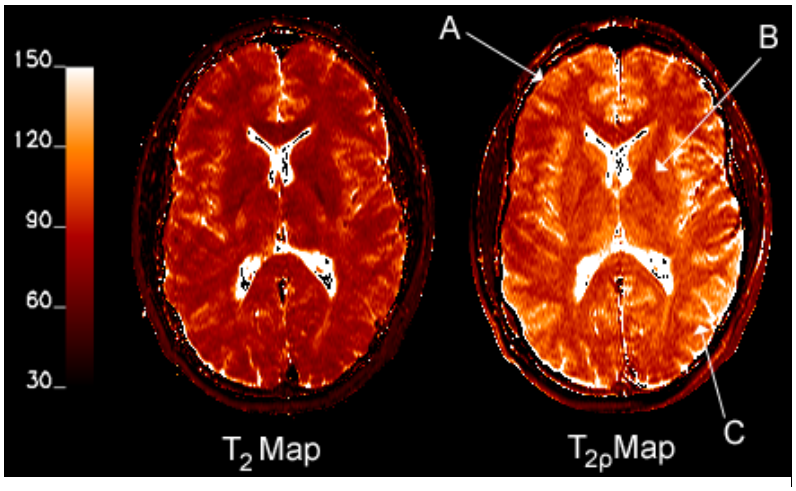

Figure 2 T_2 and $T_{2\rho}$ maps of an axial slice of a healthy human brain. The color scale on the left represents relaxation numbers for both maps in units of milliseconds. Several structures are more evident in the $T_{2\rho}$ map than the T_2 map including cortical gray matter (A), the internal capsule (B), and sulci (C).

Results and Discussion

$T_{2\rho}$ was higher than T_2 everywhere in the brain (Figure 2) as expected according to Equation 2. This increased dynamic range of the relaxation parameter allows the $T_{2\rho}$ mechanism to be used as a novel means of affecting contrast. The $T_{2\rho}$ map differentiates structures such as the internal capsule that have similar T_2 values as the surrounding tissue but a more disparate $T_{2\rho}$. In a standard T_2-weighted image with long TR, T_1-weighting is minimal. However, a $T_{2\rho}$-weighted image provides T_2-like contrast with ancillary information about T_1. In a single scan, the additional influence of T_1 can be used to characterize pathologies that may present similar T_2's but different T_1's. The inherently slower decay rate of $T_{2\rho}$ can be used to improve contrast-to-noise ratio (CNR) between structures. Figure 3 compares CNR between gray and white matter for simulated T_2- and $T_{2\rho}$-weighted data at both 1.5 T (T_1/T_2 = 600/80 ms and 900/100 ms for gray and white matter, respectively [6]) and 4.0T (T_1/T_2 = 1040/50 ms and 1720/60, respectively [7]). The CNR of the $T_{2\rho}$-weighted data is greater than that of the T_2-weighted data, especially at the higher field, for all realistic (TE > 0) relaxation times.

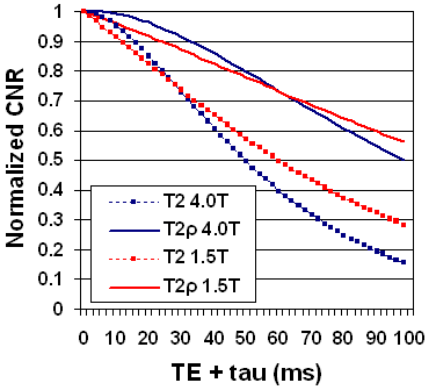

Figure 3 CNR comparison of simulated T_2- and $T_{2\rho}$-weighted data as a function of total relaxation time (TE + τ).

References: **1.** Solomon. *Phys Rev Lett.* 1959; 2:301-2. **2.** De Luca, et al. *J Magn Reson.* 1999; 139: 126-31. **3.** Kessemeier, Rhim. *Phys Rev B.* 1972; 5(3):761-8. **4.** Moran, Hamilton. *Magn Reson Imaging.* 1995; 13: 837-46. **5.** Charagundla, et al. *J Magn Reson.* 2003; 162:113-21. **6**. Haacke, et al. Magnetic Resonance Imaging. 1999 p. 457. Wiley; New York. **7**. Jezzard, et al. Radiology. 1996 Jun; 199:773-9.