A Method for Reduced SAR $T_{1\rho}$-weighted MRI

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Introduction

$T_{1\rho}$-weighting can be added to a pulse sequence by including a pre-encoded spin-lock pulse cluster consisting of a pair of nonselective 90º pulses separated by a low power "spin-lock" pulse of duration TSL. As the spin-lock amplitude (B_1) decreases, the $T_{1\rho}$ relaxation phenomenon becomes less efficient and therefore the value of $T_{1\rho}$ decreases [1]. The US FDA has established guidelines to regulate the specific absorption rate (SAR) of rf energy in an MRI experiment [2]. The spin-lock pulse cluster in a $T_{1\rho}$-weighted sequence significantly increases SAR thereby hindering application of the technique for routine clinical use. In order to maintain SAR within FDA guidelines, TR must be significantly lengthened which impinges on patient comfort, accentuates possible motion artifacts, and reduces the ability to manipulate T_1-weighted image contrast. The purpose of this work is to develop a reduced SAR version of the spin-lock sequence.

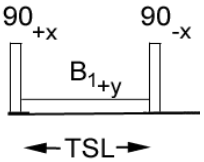

Figure 1 $T_{1\rho}$-weighting spin-lock pulse cluster.

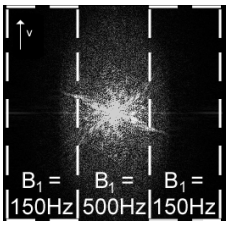

Figure 2

Methods

The reduced SAR spin-lock sequence employed the principle of partial k-space acquisition by applying a full amplitude (γB_1 = 500 Hz) spin-lock pulse for only the phase-encode lines in the central portion of k-space where most of the signal energy exists (Figure 2). For the remainder of high frequency k-space, a low amplitude spin-lock pulse (150 Hz) was applied. In this way, the majority of the signal energy maintains full $T_{1\rho}$ contrast while SAR is significantly reduced. The full and low amplitude phase-encode lines are interspersed chronologically in order to evenly spread SAR over time. The reduced SAR spin-lock sequence was implemented on a Varian INOVA 4.7T research scanner. A single axial 2 mm-thick slice of a healthy in vivo mouse brain was acquired using the following parameters: FOV = 2 cm x 2 cm, acquisition matrix = 128 x 128, and TE/TR = 13/1000 ms. Six $T_{1\rho}$-weighted images were acquired at TSL = 10, 20, 30, 40, 60, and 80 ms. The six-image series was repeated for 100%, 50%, 25%, and 12.5% of k-space receiving a full amplitude spin-lock pulse. $T_{1\rho}$ was measured from each image series by fitting the image data as a function of TSL using linear regression. The average $T_{1\rho}$ for each data set was measured as the mean of the $T_{1\rho}$ values within manually drawn regions-of-interest on the cortical and hippocampal regions. The relative change in $T_{1\rho}$ for each image set was calculated with respect to $T_{1\rho}$ data from the 100% full amplitude spin-lock data. SAR was calculated according to a model developed by Collins et al. [3].

Results and Discussion

The reduced SAR sequence produced $T_{1\rho}$ maps (Figure 3) that were very similar to the full spin-lock map. Average $T_{1\rho}$ values in regions of the brain (Figure 4) produced minimal change in $T_{1\rho}$ on the order of a few percent (Figure 5). The Collins model predicted a substantial reduction in SAR (Figure 6). This work illustrates the feasibility of using the reduced SAR $T_{1\rho}$-weighted sequence to produce full-contrast $T_{1\rho}$-weighted images while minimizing SAR. With appropriate imaging parameters, the reduced SAR sequence can be used to safely acquire $T_{1\rho}$-weighted images on humans with short TR and even at high fields ($B_0 \geq 3T$). This approach is quite general and can be exploited to reduce SAR in any pulse sequence that involves long duration rf pulses such as spin-decoupling sequences.

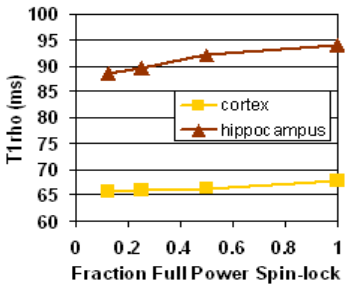

Figure 4 Mean $T_{1\rho}$ in two regions of the brain.

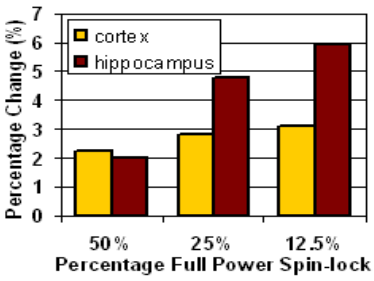

Figure 5 Change in $T_{1\rho}$ with respect to full spin-lock data.

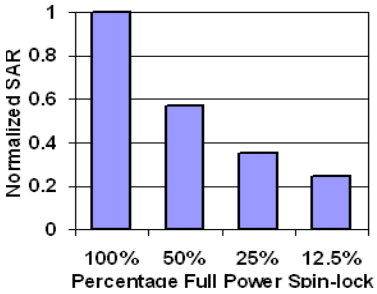

Figure 6 Modeled SAR data normalized w.r.t. 100% power.

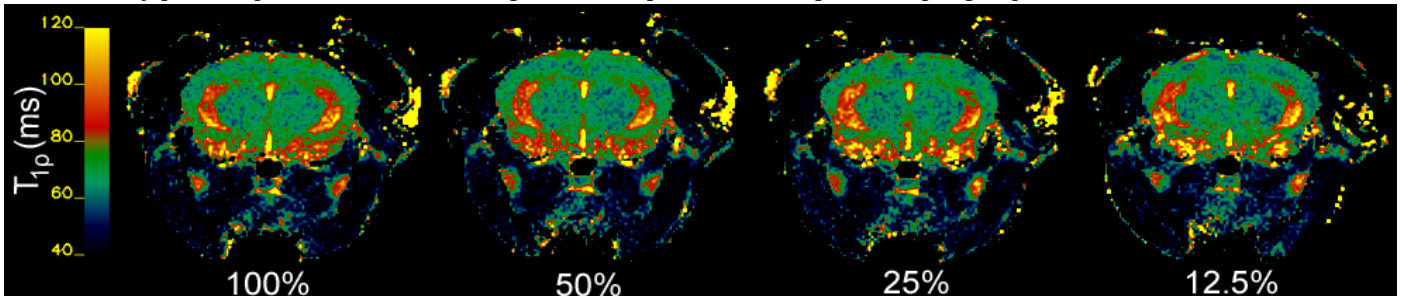

Figure 3 $T_{1\rho}$ maps of an in vivo mouse brain for 100%, 50%, 25%, and 12.5% of central k-space receiving full spin-lock pulse amplitude.

References **1**. Regatte, et al. J Magn Reson Imaging. 2003;17:114-21. **2**. US Food & Drug Admin. Nov. 1998. **3**. Collins, et al. Magn Reson Med. 1998;40:847-56.