$T_{1\rho}$ MRI of the Human Brain Using a Spin-locked SSFP Pulse Sequence

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Objective

To assess the feasibility of a new $T_{1\rho}$ MRI pulse sequence (SLIPS) to generate images with improved contrast in human brain.

Background

An alternate contrast mechanism to standard T_1- or T_2-weighted MR imaging is $T_{1\rho}$, or "T-1-rho", the spin lattice relaxation time constant in the rotating frame, which determines the decay of the transverse magnetization in the presence of a "spin-lock" radio-frequency field. In biological tissues, $T_{1\rho}$ is dependent on the macromolecular composition and provides contrast unlike conventional T_1/T_2-based methods. $T_{1\rho}$ has been shown to provide functional contrast derived from changes in CBV that is additive to the BOLD effect (1). $T_{1\rho}$ measurements were also performed on the human brain using a single-slice fast spin-echo method (2), where the values were greater than T_2 in the same locations. Spin-locking reduces contributions from susceptibility and diffusion to signal loss resulting in a greater dynamic range, which translates to greater sensitivity in biological tissues than T_2. There is now a need for a multi-slice imaging sequence for time-efficient whole-brain $T_{1\rho}$ measurements. In this work, we describe a new pulse sequence based on a balanced steady-state free precession (SSFP) pulse sequence (3, 4).

Pulse Sequence Design

In the new sequence, called Spin-Locked Imaging with Precession in the Steady State (SLIPS), a $T_{1\rho}$-preparatory pulse cluster is sandwiched between a 3D balanced steady-state free precession pulse sequence. In the preparatory pulse cluster, a hard $\pi/2$ pulse is applied with zero phase (ϕ=0°). This is followed by two phase-alternating spin-lock (SL) pulses of total duration TSL. The $T_{1\rho}$-prepared magnetization is returned to the z-axis by another hard $\pi/2$ pulse (ϕ=180°) and any residual transverse magnetization is destroyed by the application of a crusher gradient.

Materials and Methods

The Institutional Review Board of our institute approved all experiments. MR imaging was performed on 2 healthy volunteers (mean age: 25±4) on a Siemens 1.5T Sonata clinical scanner with the vendor-supplied head coil. Axial images were obtained with and without $T_{1\rho}$ preparatory block. Imaging parameters were: TE/TR=2.5/4.9ms, slice thickness=4mm, FOV=22cm, matrix=256 x 256, for a total imaging time of 5 minutes for 32 slices. The amplitude of the spin-lock pulse (γB_1) was 400Hz and TSL time was varied five times to obtain data sets for fitting $T_{1\rho}$ maps. A single user manually selected regions of interest in gray and white matter and recorded average signal intensities from SLIPS and conventional SSFP images.

Results and Discussion

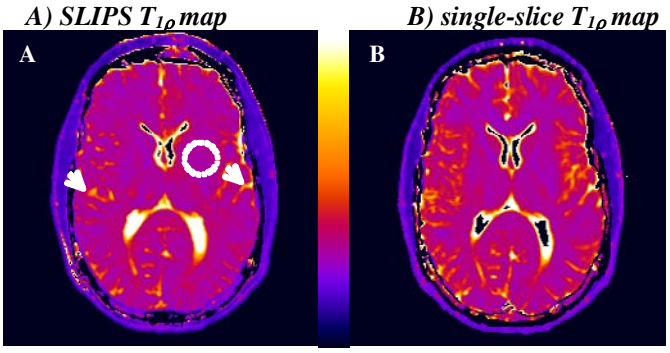

Figure 1: Comparison of a SLIPS $T_{1\rho}$ map (A) with the "gold-standard" 2D single-slice $T_{1\rho}$ map (B) of the same slice. The color bar ranges from 0ms (black) to 250ms (white). In the 2D sequence, each slice required an imaging time of 4 minutes, but with SLIPS, an entire 3D volume of 32 slices can be obtained in just 5 minutes. Some regions (indicated by arrows in image A) containing CSF appear to have a lower $T_{1\rho}$ in the SLIPS map, an effect of fluid-suppression due to a short TR of the 3D sequence. However, in the region of parenchyma (indicated by the dotted circle), $T_{1\rho}$ was insignificantly different between the 3D SLIPS (73.3±2.5ms) and the 2D single-slice (74.1±2.7ms) maps.

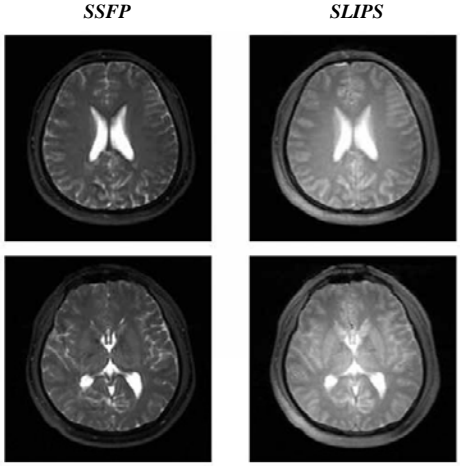

Figure 2: Two representative images show improved contrast between gray and white matter obtained with the standard balanced SSFP and SLIPS sequences, respectively. The contrast to noise ratio between gray and white matter in SLIPS images was greater (23%) than that in the SSFP images (3%).

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