T1ρ Imaging of Articular Cartilage using a CPMG Pulse Train for Spin Locking

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Introduction: A promising technique for evaluating cartilage is $T_{1\rho}$ imaging, or relaxation of spins under the influence of a radio-frequency field [1-2]. In typical $T_{1\rho}$ imaging, magnetization is tipped into the transverse plane and "spin-locked" by a constant radiofrequency (RF) field. However, CPMG pulse trains with rapid refocusing also result in spin locking [3], but have yet to be used for generating $T_{1\rho}$ contrast. The purpose of this work was to explore using CPMG pulse trains to generate $T_{1\rho}$ contrast.

Methods: Five healthy volunteers (ages 24-43) were imaged in the axial plane at 1.5T on a GE Signa TwinSpeed MRI scanner (GE Healthcare, Milwaukee, WI) using a T/R quadrature knee coil. The local institutional review board approved all imaging studies.

Our CPMG spin-locking sequence consists of a 90x pulse followed by a train of 180y pulses. The refocusing interval (Tr) between the 180y pulses is varied to yield an effective spin-locking frequency in Hz, given by 1/(2Tr) [3]. CPMG $T_{1\rho}$ measurements were made with locking frequencies of 100, 200, and 333 Hz. A minimum Tr of 1.5 ms limited our maximum spin-lock frequency.

Measurements of $T_{1\rho}$ were also made with a continuous RF spin locking pulse at the same anatomic locations with frequencies of 100, 200, 333, 500, and 700 Hz. The maximum spin-lock frequency in the continuous RF sequence was limited by RF power deposition limits. An MLEV pulse train was also acquitted at 333 Hz to compare with CPMG. Finally, T_2 relaxation time at the same location was measured using an MLEV sequence with a Tr of 6 ms (effective locking frequency of 83 Hz) [4].

The CPMG $T_{1\rho}$, continuous RF $T_{1\rho}$, MLEV $T_{1\rho}$, and MLEV T_2 had identical imaging parameters: TR of 2000 ms, 14 spiral arms, 4096 points, and bandwidth $\pm$125 kHz. In-plane resolution was 0.7 mm with a 16 cm FOV, 4 mm slice thickness. A single slice through the patella cartilage was acquired in 5 minutes with two signal averages. The $T_{1\rho}$ sequences acquired 5 spin lock times (TSL) of 3, 15, 28, 50, and 100 ms. The MLEV T_2 sequence acquired 5 echoes at approximately 3, 13, 28, 53, and 98 ms. Average relaxation times for each subject were measured using a 3 mm ROI at 5 identical locations in the cartilage of the medial patella facet. Relaxation measurements and maps were created using Osirix software. Results were compared using a student's paired t-test.

Results: There was no significant difference between continuous RF and CPMG $T_{1\rho}$ measurements at 100, 200, and 333 Hz (Figure 1; $p > 0.4$). The MLEV and CPMG spin lock methods showed no difference in $T_{1\rho}$ values at 333 Hz ($p > 0.4$), indicating good B1 and B0 homogeneity. Across the range of spin lock frequencies, $T_{1\rho}$ values significantly increased with spin lock frequency (Figure 2). Measured $T_{1\rho}$ relaxation times significantly increased from 100 Hz to 333 Hz ($p < .05$), from 333 Hz to 500 Hz ($p < .03$), and from 500 Hz to 700 Hz ($p < .01$). Spin locking at 200 Hz showed a significant increase compared with T_2 ($p < .04$).

Conclusion: CPMG-based $T_{1\rho}$ measurements provide an alternative method to produce $T_{1\rho}$ contrast that may be less sensitive to B0 inhomogeneity and phase errors than continuous RF methods. Both $T_{1\rho}$ methods produced relaxation time values that increased with spin lock frequency and were higher than T_2. The optimal spin locking frequency for $T_{1\rho}$ imaging may be higher than achievable with RF power deposition limits at 1.5T. Our study showed that a CPMG-based technique produced similar $T_{1\rho}$ measurements in healthy articular cartilage when compared with continuous RF methods.

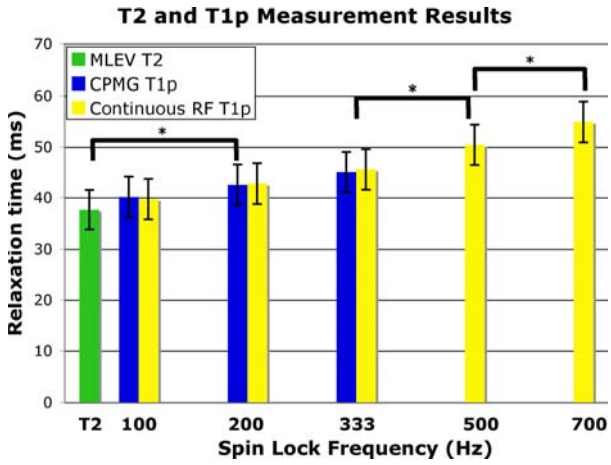

Figure 1: Comparison of the CPMG $T_{1\rho}$, continuous RF $T_{1\rho}$ and T_2 Measurements as a function of spin lock frequency (Hz).

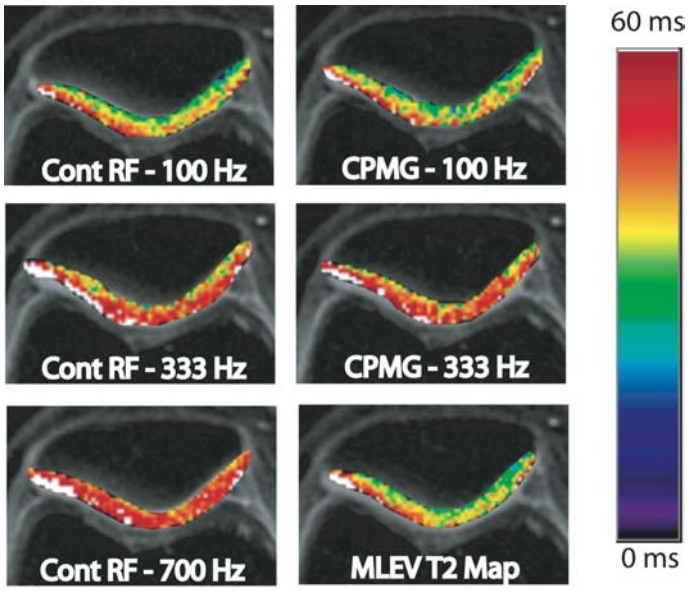

Figure 2: Color maps of the CPMG $T_{1\rho}$, continuous RF $T_{1\rho}$ and T_2 measurements as a function of spin lock frequency (Hz) in a healthy volunteer.

References

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