Introduction: A promising technique for evaluating cartilage is T1ρ imaging, or relaxation of spins under the influence of a radio-frequency field [1-2]. In typical T1ρ 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 T1ρ contrast. The purpose of this work was to explore using CPMG pulse trains to generate T1ρ 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 90° pulse followed by a train of 180° pulses. The refocusing interval (Tr) between the 180° pulses is varied to yield an effective spin-locking frequency in Hz, given by 1/(2Tr) [3]. CPMG T1ρ 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 T1ρ 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 acquired at 333 Hz to compare with CPMG. Finally, T2 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 T1ρ, continuous RF T1ρ, MLEV T1ρ, and MLEV T2 had identical imaging parameters: TR of 2000 ms, 14 spiral arms, 4096 points, and bandwidth ±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 T1ρ sequences acquired 5 spin lock times (TSL) of 3, 15, 28, 50, and 100 ms. The MLEV T2 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 T1ρ measurements at 100, 200, and 333 Hz (Figure 1; p > 0.4). The MLEV and CPMG spin lock methods showed no difference in T1ρ values at 333 Hz (p > 0.4), indicating good B1 and B0 homogeneity. Across the range of spin lock frequencies, T1ρ values significantly increased with spin lock frequency (Figure 2). Measured T1ρ 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 T2 (p < .04).

Conclusion: CPMG-based T1ρ measurements provide an alternative method to produce T1ρ contrast that may be less sensitive to B0 inhomogeneity and phase errors than continuous RF methods. Both T1ρ methods produced relaxation time values that increased with spin lock frequency and were higher than T2. The optimal spin locking frequency for T1ρ imaging may be higher than achievable with RF power deposition limits at 1.5T. Our study showed that a CPMG-based technique produced similar T1ρ measurements in healthy articular cartilage when compared with continuous RF methods.

References

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