Rapid Measurement of Cartilage T_1 and T_2 Relaxation Times at 3.0T with Spiral MRI

G. Gold[1], B. Hargreaves[2], E. Han[3], J. Pauly[2], G. Wright[4], C. Beaulieu[1], J. Brittain[3]

[1]Dept. of Radiology, Stanford University, Stanford, CA, United States, [2]Dept. of Electrical Engineering, Stanford University, Stanford, CA, United States, [3]Applied Science Laboratory West, GE Healthcare, Menlo Park, CA, United States, [4]Dept. of Medical Biophysics, University of Toronto, Toronto, Ontario, Canada

Introduction: Two promising techniques for evaluating cartilage physiology are T_2-mapping [1] and delayed gadolinium enhanced MRI of cartilage (dGEMRIC) [2]. T_2 relaxation times correlate with collagen content, and T_1 relaxation times in dGEMRIC correlate with proteoglycan content. Clinical application of these techniques has been difficult due to long scan times. MRI sequences that measure relaxation times using spiral imaging may allow faster physiologic evaluation of cartilage for widespread clinical use.

Methods: T_1 measurements were made using a spiral T_1 Look-Locker preparation sequence [3]. The spiral T_1 sequence had TR/TE 2200/6 ms, 10 degree flip angle, 12 spiral arms, 4096 points, bandwidth $\pm$125 kHz, and 8 samples along the T_1 recovery curve 200 ms apart. In-plane resolution was 0.7 mm with a 16 cm FOV, 3 mm slice thickness and 1 mm skip. 7 slices were acquired in 20 minutes with eight signal averages. This sequence was compared with fast spin-echo inversion recovery (FSE-IR) for T_1 measurements with TR/TE 2200/14 ms and a $\pm$62.5 kHz bandwidth. In-plane resolution was 0.7 mm with a 16 cm FOV, 3 mm slice thickness and 1 mm skip. Inversion times were 50, 100, 200, 500, 800, 1200, and 2100 ms, and 7 slices were acquired in 35 minutes.

T_2 was measured using a spiral T_2-preparation CPMG sequence [3, 4] with 4 echoes at 6, 24, 48, and 96 ms, 10 spiral arms, 4096 points, and a bandwidth of $\pm$125 kHz. Contrast preparation was repeated every 2200 ms. In-plane resolution was 0.8 mm, 16 cm FOV, 3 mm slice thickness, 1 mm skip, and a scan time of 6:40 for the entire knee. This sequence was compared to multi-echo spin-echo with TR/TE 3000/20, 40, 60, 80 ms, 0.7 mm in-plane resolution, 16 cm FOV, 3 mm slice thickness, 1 mm skip, bandwidth of $\pm$16 kHz, and a scan time of 11:10 for the entire knee.

Imaging was done on a GE 3.0T whole body scanner. We tested the accuracy and repeatability of the spiral techniques in a phantom of known relaxation times (Eurospin, Inc). In five healthy volunteers and one patient with osteoarthritis, we measured the T_1 and T_2 relaxation times of cartilage. We measured and compared cartilage SNR of the first echo for each sequence. Relaxation times were measured at comparable locations in the cartilage of the medial femoral condyle. T_1 and T_2 maps were created using Xcinema (Stanford University) and MRVision (MRVision Co).

Results: T_1 and T_2 measurements in the phantom with the spiral techniques were accurate to within the tolerance of the phantom ($\pm$3%) and highly repeatable. The SNR measurements from the first echo show cartilage SNR that is not statistically different for the spiral and conventional T_1 and T_2 measurement methods. The measured T_2 relaxation times between the spiral and spin-echo methods were not significantly different (Figure 1). T_1 relaxation times (Figure 1) were significantly longer using the Look-Locker spiral T_1 method compared with FSE-IR ($p < .05$), but similar to literature values of cartilage T_1 at 3.0T [3]. T_1 and T_2 maps from our healthy volunteers show a typical distribution of relaxation times (Figure 2). Our patient with early osteoarthritis showed areas of increased T_2 relaxation times and decreased T_1 relaxation times after gadolinium administration.

Conclusion: Measuring cartilage physiology using T_1 and T_2 relaxation times with conventional techniques has been difficult in the clinical environment. The spiral methods presented here are highly accurate and repeatable, lending themselves to clinical studies. Spiral MRI techniques for measuring relaxation times decreased imaging time, which may allow for assessment of cartilage physiology in routine knee examinations.

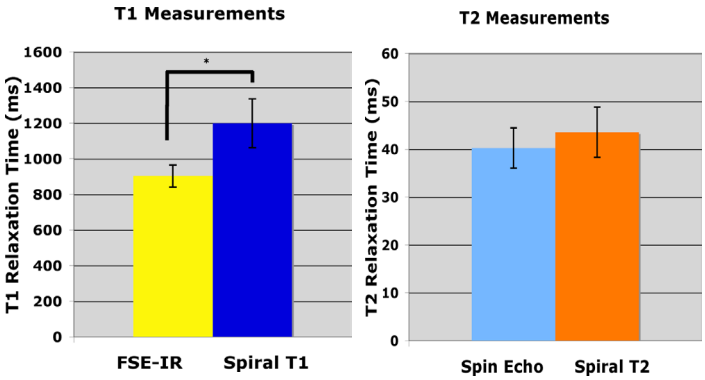

Figure 1: Comparison of the T_1 and T_2 measurements. The measured T_1 relaxation times are significantly longer for the Look-Locker spiral T_1 sequence than the FSE-IR method (*$p < .05$).

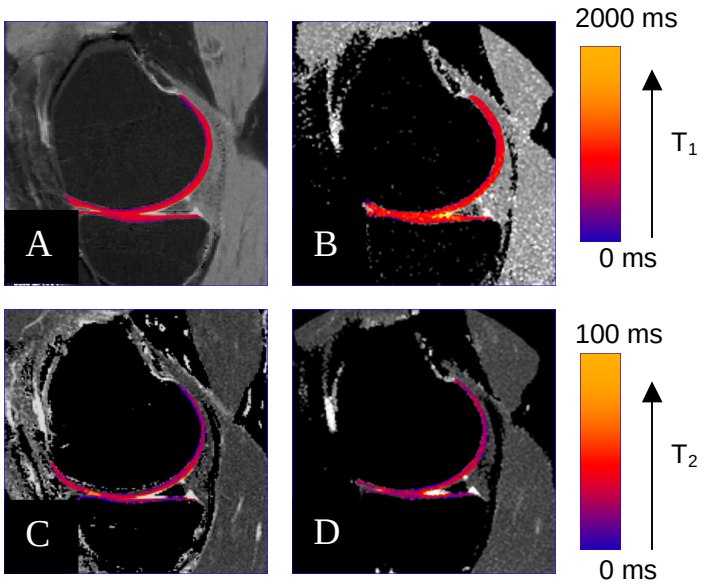

Figure 2: Images from a healthy volunteer. A) FSE-IR T_1 map. B) Spiral T_1 map with T_1 color scale (right). The measured T_1 relaxation times are longer using the spiral technique. C) Spin Echo T_2 map. D) Spiral T_2 map with T_2 color scale (right).

References

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