Investigation of Knee Cartilage with Rapid Combined 3-D T1 and T2 Mapping at 1.5 T

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Introduction:

In-vitro and in-vivo investigations of quantitative spin-lattice (T1), spin-lattice in the rotating frame (T1ρ) and spin-spin (T2) relaxation times of articular cartilage[1-4] have associated changes in these parameters with proteoglycan (PG) loss and disruption of the collagen framework, both associated with osteoarthritis. Unfortunately, despite the demonstrated utility of T1 and T2 mapping in the diagnosis of early osteoarthritis, quantitative relaxometry is not typically part of routine clinical evaluation. This can be attributed primarily to the absence of a rapid, high-resolution, fully three-dimensional (3-D) method for mapping both T1 and T2 in a clinically feasible time. The recently described DESPOT1 and DESPOT2 relaxometry methods[5], which derive T1 and T2 information from multiple SPGR and fully-balanced SSFP image volumes acquired with constant TR and varied flip angle (α), permit such high-resolution studies. The method has previously been demonstrated in full-brain T1 and T2 mapping[5]. In this study we demonstrate the clinical feasibility of the DESPOT methods for the study of T1 and T2 changes in articular cartilage.

Methods:

High-resolution (500µm x 500µm x 2mm resolution) sagittal-oriented, full knee (13cm x 13cm x 25cm field of view) T1 and T2 maps of 1 healthy male volunteer (normal alignment, pain-free) and 1 female volunteer with chronic anterior knee pain (slight genu valgum) were acquired using the DESPOT methods on a 1.5T clinical imager using a quadrature extremity coil. Ages of the volunteers were 22 and 23, respectively. Imaging parameters for both sequences were: DESPOT1: TR/TE=9.4/1.9ms, $\alpha = 4°$ and 14°, bandwidth=±15.63kHz and acquisition time for both flip angle volumes (T_{acq}) = 10:14, DESPOT2: TR/TE=6.4/3.2ms, $\alpha = 15°$ and 70°, bandwidth=±41.7kHz and T_{acq} = 7:00. In order to improve SNR, 3 DESPOT1 and 2 DESPOT2 datasets were acquired and averaged, yielding a total exam time of just over 45 minutes. Average T1 and T2 values were determined from regions of interest placed within the center of the medial and lateral femoral condyle and tibial plateau, the primary weight-bearing surfaces in the knee.

Results:

Figure 1 contains representative images from the T1 and T2 maps of both volunteers. Fig a and b correspond to the asymptomatic volunteer, c and d to symptomatic volunteer. All maps show good delineation of the cartilage surfaces from the surrounding bone, muscle and synovial fluid. Within the symptomatic volunteer, significantly less cartilage is seen and increased T2 values are present along the cartilage boundary. Average T1 and T2 values corresponding to the primary weight-bearing surfaces from both volunteers are shown in Fig. 2 with error bars indicating the standard deviation of the measurements. Slight differences in both T1 and T2 between the femoral and tibial cartilage is seen in both volunteers, with femoral cartilage having slightly higher values on average. Large T2 differences are seen between the asymptomatic and symptomatic T2 values, with the symptomatic data showing higher T2 values in the femoral cartilage and significantly decreases values in the tibial cartilage.
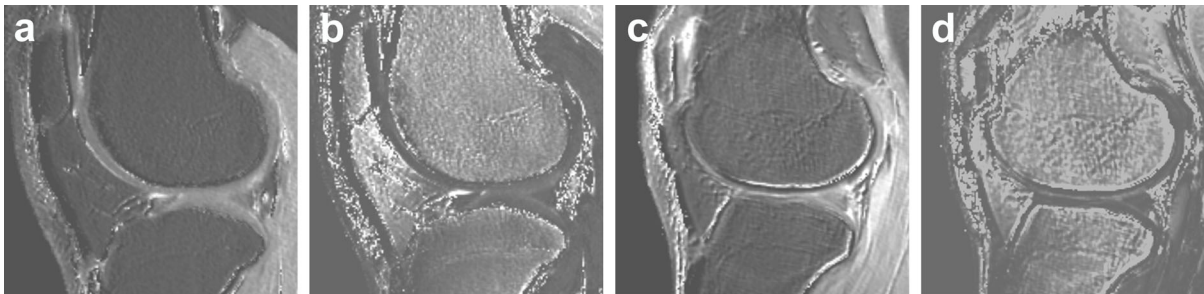

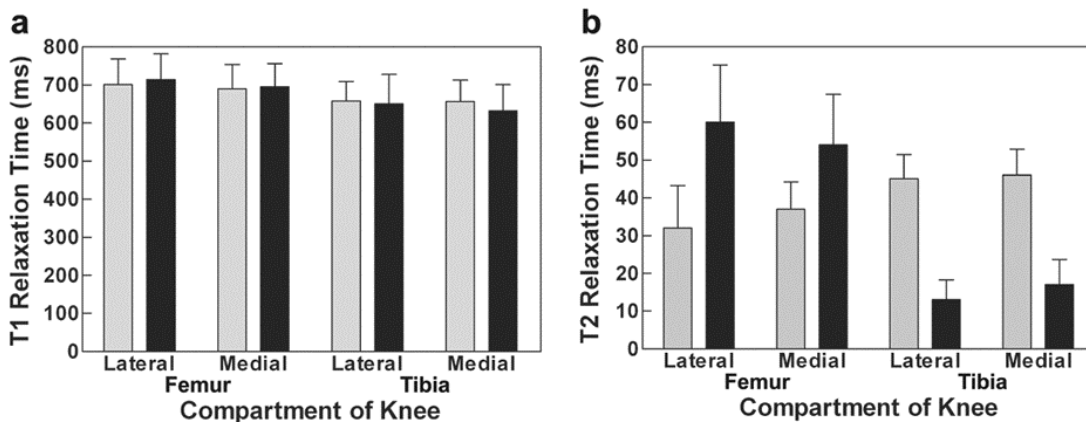**Figure 1:** T1 and T2 maps of an asymptomatic volunteer (a, b) and a symptomatic volunteer (c, d).

Figure 2: Average volunteer T1 (a) and T2 (b) values from the medial and lateral femoral condyle and tibial plateau for the asymptomatic (grey) and symptomatic (black) volunteers. Error bars indicate the standard deviation.

Discussion/Conclusions:

The lack of a rapid, precise and high-resolution T1 and T2 mapping method has hindered the clinical adoption of quantitative relaxometry in the study and diagnosis of cartilage degradation, osteoarthritis and degenerative joint diseases. In this study we have demonstrated the clinical feasibility of full-knee T1 and T2 mapping at high-resolution in less than 45 minutes on a clinical 1.5T scanner. Additionally, we have shown preliminary differences in T1 and T2 values between healthy and injured cartilage, though no conclusions can be made given the limited sample size of the study. The proposed DESPOT1 / DESPOT2 combination provides results with high precision and reproducibility, making the method ideal for high-resolution in-vivo investigations of knee cartilage at 1.5T.

References:

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