High-Resolution 3-D T1 Mapping at 1.5T and 3.0T using DESPOT1

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Introduction: Recently, the use of T1 relaxation time quantification in articular cartilage has received increased attention due to its value in estimating glycosaminoglycan content when used in combination with delayed gadolinium ($Gd\text{-}DTPA^{2-}$) enhanced imaging (dGEMRIC)[1]. A primary limitation to this promising approach, however, is the need for rapid, high-resolution, and volumetric T1 mapping. Presently, most dGEMRIC studies rely on conventional inversion prepared fast spin echo (FSE-IR) methods to quantify T1 and require up to 5 minutes of scanning per slice, making multi-slice imaging difficult or impractical. Here we present an alternative T1 quantification method which allows for high-resolution, fully three dimensional imaging of the knee in less than 16 minutes. We evaluated the implementation of DESPOT1 at both 1.5T and 3.0T for examining T1 quantification in normal patellar cartilage.

Methods: To rapidly measure T1 throughout the knee we made use of the variable nutation spoiled gradient recalled echo method known as DESPOT1[2,3]. Axially-oriented images of the patellar cartilage were acquired from 6 healthy and asymptomatic volunteers (3 males, 3 females, mean age = 24 years) at 1.5T and 3.0T (GE Signa scanners) with the following imaging parameters: 1.5T: FOV = 10cm x 10cm x 10cm, matrix = 256 x 256 x 128, TE/TR = 3.1ms/14.4ms, α = 4° and 13°, and BW = ±7.14kHz. 3.0T: FOV = 10cm x 10cm x 7.7cm, matrix = 400 x 400 x 128, TE/TR = 2.1ms/9.4ms, α = 4° and 16°, and BW = ±22.72kHz. These protocols resulted in voxel dimensions of 390µm x 390µm x 780µm (1.5T), and 250µm x 250µm x 600µm (3.0T); therefore, the voxel volume at 3.0T was approximately three times smaller than that at 1.5T. Data was acquired using two custom built dual element receive-only coil (shown in Figure 1) designed for targeted patellar imaging at 1.5T and 3.0T. Total imaging time for each volunteer was held constant between the two field strengths at approximately 16 minutes. Average T1 values were calculated for each volunteer using segmented cartilage from 20-26 contiguous slices and compared with literature values to determine the accuracy of the method.

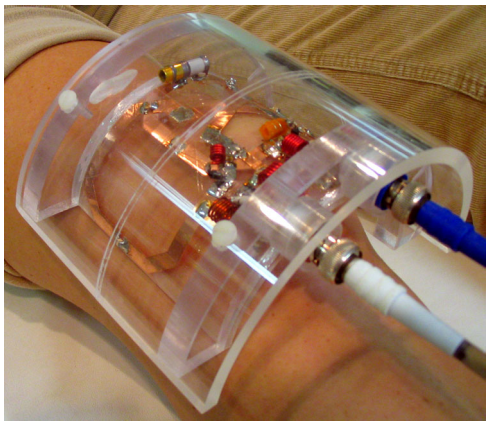

Figure 1: Custom built, dual element, receive-only patellar coil utilized at 3.0T. An identical coil design was used at 1.5T.

Results: Representative T1 maps of the patellar cartilage at 1.5T and 3.0T are shown in Figures 2 and 3. Average T1 values for the 6 volunteers at 1.5T and 3.0T were 742ms (±47ms) and 1011ms (±55ms), respectively, which agree well with previously reported values of 770ms[4] and 1240ms[5]. A general gradient in T1 values is noted through the cartilage, moving from the deep patellar cartilage to the articular surface. Within the 3.0T T1 maps, a slight fall-off in T1 is visible near the anterior aspect of the patella, which is likely due to incomplete decoupling of the coil, resulting in localized B1 inhomogeneities. Similar signal-to-noise ratios (SNR) were observed in cartilage at 3.0T, compared with the 1.5T data (14.4 and 15.4 respectively), and the slight difference may be attributed to the smaller voxel volume, increased bandwidth, and shorter TR used in the 3T acquisitions. Despite the marginally lower SNR relative to the 1.5T data, spatial resolution and hence tissue contrast within the tissue and trabecular bone is markedly improved, and overall T1 map quality at 3.0T is excellent within the cartilage region.

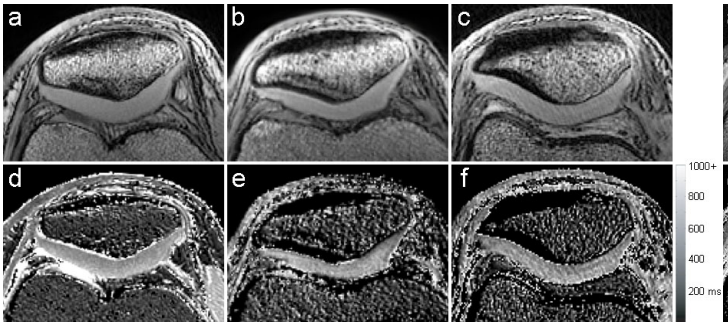

Figure 2: 390 µm in-plane resolution T1-weighted SPGR images (α =14°) of 3 healthy volunteers (a-c) and corresponding T1 maps (d-f) acquired at 1.5T.

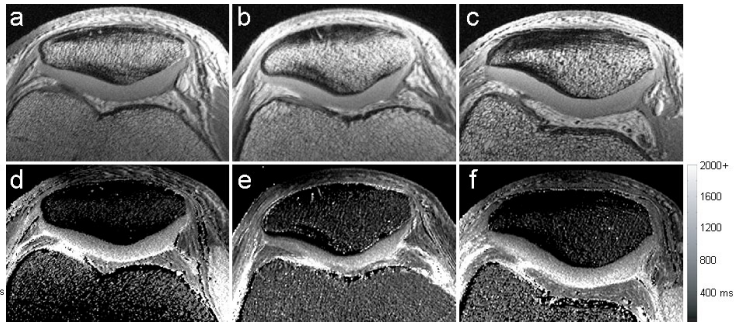

Figure 3: 250 µm in-plane resolution T1-weighted SPGR images (α = 16°) of the same volunteers as Figure 2 (a-c) and corresponding T1 maps (d-f) acquired at 3.0T

Discussion / Conclusions: The high-resolution voxel dimensions (390µm at 1.5T and 250µm at 3.0T) attained in this study has the potential to evaluate the complex morphology within articular cartilage. In addition to achieving a three-fold decrease in voxel volume at 3.0T, SNR was also maintained between the two field strengths. The T1 relaxation times noted 1.5T and 3.0T are comparable with values reported in literature. The presented method permits rapid determination of T1 throughout the patellar cartilage and knee at high-resolution in a clinically acceptable time of less than 16 minutes. Our results at 1.5T and 3.0T suggest that the DESPOT1 method is an ideal candidate for implementation with *in vivo* dGEMRIC imaging and further investigations of early cartilage degeneration.

References:

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