Comparison of Short Echo Time T2 and T1rho measurements in menisci from subjects with osteoarthritis

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INTRODUCTION: Injury to the knee meniscus has been shown to precede cartilage degeneration and osteoarthritis[1]. Degenerative changes in the meniscus also increase with age[2]. In articular cartilage, T1ρ values have been found to be inversely correlated with the proteoglycan content and distribution, while T2 values have been found to correlate with collagen content and orientation[3,4]. However, comparatively little is known about the variations in T1ρ and T2 values of the meniscus. MRI measurements of early degenerative changes in the meniscus have been difficult to obtain due to rapid T2 decay. Quantitative measurements of the meniscus with information on zonal variations could be critical in the early detection of meniscal degeneration or sub-critical damage. In this study, we optimized a 3D spin lock and SPGR sequence to obtain short echo times (TE) and accurately measure the T1ρ and T2 values in medial and lateral menisci from patients with osteoarthritis.
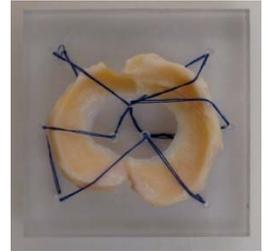
METHODS: Eleven menisci were obtained as incidental surgical waste from patients undergoing total knee replacement procedures. Each specimen was bound with sutures to a custom-made plexiglass plate (Fig. 1) and embedded in 3% (w/v) agarose to further immobilize the specimen and minimize artifacts from the air-tissue interface. Prior to gelation, vacuum was applied to the embedded specimens to minimize air bubbles. T1ρ- and T2-weighted images were acquired using a Magnetization-Prepared Angle-Modulated Partitioned k-Space Spoiled Gradient Echo Snapshots (3D MAPSS) sequence that has a magnetization preparation followed by an immediate SPGR acquisition during transient signal evolution[3]. Images were taken with a 3T GE MR scanner (GE Healthcare, Waukesha, WI) with a quadrature wrist coil. Imaging parameters were TR 6.9ms, FOV 10cm, matrix 256x256, BW ±31.5kHz, number of excitations (NEX) 1, and 26 sagittal slices with 2mm thickness. To optimize the sequence for the short T2 meniscus, the pulse sequence was designed to achieve TE 1.8ms for SPGR readout. T1ρ-weighted images (Fig. 2A) were collected at 6 spin-lock durations (TSL) (0, 4, 12, 20, 30, and 40ms) with spin-lock frequency 500Hz, and T2-weighted images (Fig. 2C) were collected at 6 echo times (0, 6.8, 13.6, 20.4, 27.2, and 40.8ms). Regions of interest (ROIs) were defined in the anterior horn, central body, and posterior horn for both the T1ρ- and T2-weighted images. Pixel intensities for different TSLs and TEs were fit via Matlab (Mathworks, Inc) with a mono-exponential equation (Fig. 3) to obtain the T1ρ and T2 time constants for all pixels from each ROI (Fig. 2B,D). For both T1ρ and T2, differences between aspects (medial/lateral) and among regions (anterior/body/posterior) were evaluated using a General Linear Model with Tukey's test for pairwise comparisons, treating the donor as a random variable. The relationship between T1ρ and T2 was examined via Pearson's correlation. Significance was set at $p<0.05$.

Figure 1: Meniscal sample mounted on the plate

RESULTS: Both T1ρ and T2 times varied significantly between the lateral and medial menisci and among regions (Fig. 4). The central body exhibited significantly shorter T1ρ and T2 values than either the anterior or posterior horn in both medial and lateral menisci. For both parameters, the lateral menisci exhibited greater variations among regions than did the medial menisci. For all regions pooled together, there was a strong, positive correlation (r=0.855, p<0.001) between T1ρ and T2.
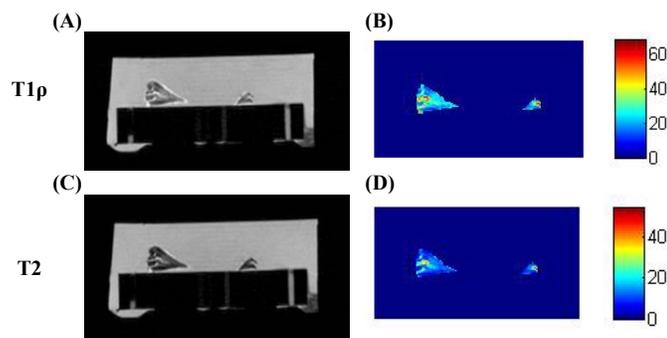
Figure 2: Representative (A) T1ρ image at TSL=20ms and (B) T1ρ map. Representative (c) T2 image at TE=20.5ms and (D) T2 map.

DISCUSSION: In this study, we found that short echo time T1ρ- and T2-weighted images revealed consistent regional variations in menisci from subjects with osteoarthritis. The T1ρ and T2 values observed in this study for menisci retrieved at total knee replacement were larger than values previously reported for healthy menisci. In osteoarthritic knees, both cartilage and meniscus T1ρ and T2 values have been shown to increase significantly compared to healthy volunteers[5,6], and the longer times in the present study may reflect the likely degenerative state of these menisci. The significantly higher values of both T1ρ and T2 in the horns could indicate more advanced degeneration in those regions, but could also reflect underlying regional differences in tissue composition and structure. The close correlation value between the T1ρ and T2 values may indicate a correlation between proteoglycan and collagen content. Subsequent histology and biochemical analyses, which can be conducted in much more detail in *ex-vivo* tissues, will provide further insights regarding the relationship between T1ρ and T2 values and tissue structure and content of the different regions in the meniscus, potentially allowing the development of protocols for detection of early degenerative changes via MRI.

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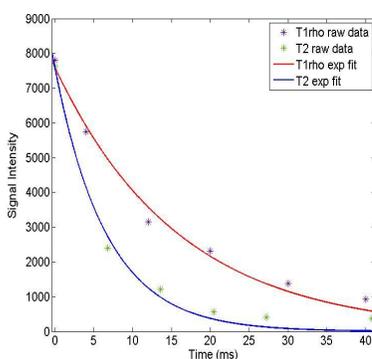
Figure 3: Representative T1ρ and T2 decays fit with a mono-exponential function.
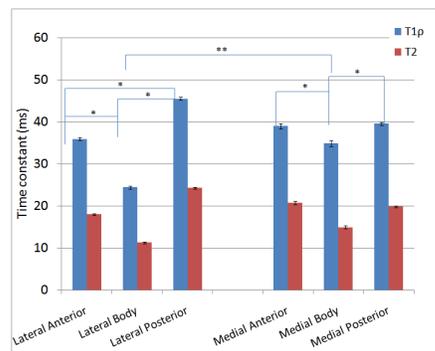
Figure 4: Variations in T1ρ and T2 with location. Mean ± SEM. * indicates significant variations among regions of medial or lateral meniscus; ** indicates significant difference between medial and lateral menisci.