MULTIPARAMETRIC MRI ASSESSMENT OF CADAVER ACHILLES TENDON AT 7T

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Introduction: Studies that have examine the histopathological characteristics of tendinopathy have revealed a number of degenerative changes associated with the tendon extracellular matrix, such as tenocyte dedifferentiation, altered cellularity, disruption of collagen fibers, increased vascularity, accumulation of lipids and glycosaminoglycans (GAGs), and calcium deposits [1]. Magnetic resonance imaging (MRI) has been used to diagnose Achilles tendinopathy based on the manifestation of morphological changes in the tendon [2]. The goal of this in vitro validation study was to investigate the feasibility of biochemical MRI techniques, such as sodium imaging, T2 mapping, fast imaging with steady state precession (FISP), and reversed FISP (PSIF), as potential markers for collagen, glycosaminoglycan and water content in the Achilles tendon.

Methods and Materials:. All MRI examinations were performed on a 7 Tesla field strength MR scanner (Siemens Healthcare, Erlangen Germany), operating with a maximum gradient strength of 45 mT/m. For sodium, a sodium-only, 15-channel transmit/receive knee coil (QED, Quality Electrodynamics LLC, Cleveland, OH) was used. For bSSFP (balanced Steady-State Free Precession) imaging and T2 mapping, a 28-channel knee coil was used (QED, Quality Electrodynamics LLC, Cleveland, OH) was used. Five fresh cadaver ankles (two males, two females, with a mean age of 48 ± 8 years), were acquired from a local anatomy department and were used in this study. Each tendon was divided into three regions: the muscle-tendon junction (MTJ); the mid portion (MID); and the insertion portion (INS). To acquire a sodium images from the AT, a 3D-GRE (gradient echo) sequence, optimized for sodium imaging, was used. The T2 relaxation times were obtained from T2 maps that were reconstructed using a multi-echo, spin-echo technique with a repetition time (TR) of 1200ms. Six echo times (TE) were collected (11.9ms, 23.8ms, 35.7ms, 47.6ms, 59.5ms, and 71.4ms). To acquire FISP images of cadaver ankles, three-dimensional, partially balanced, steady-state gradient echo pulse sequences were used with the following sequence parameters: TR/TE 6.96/2.46 ms; FOV 220 x 220; acquisition matrix 384 x 384; voxel size 0.57 x 0.57 x 2 mm; flip angle 22°. GAG content was examined biochemically; the results are reported as micrograms of GAG per milligram of sample dry weight. The correlations between individual parameters (T2, FISP and PSIF signal, sodium SNR, values, GAG and water content) were calculated using a Pearson correlation coefficient (r), statistical difference of the samples was calculated using Wilcoxon 2-tailed test.

Results: The median of the bulk sodium signal was 378.8 (IQR: 343.5 - 568). The median of the sodium SNR, calculated from the sodium signal, and the standard deviation of noise was 9.6 (IQR: 8 - 14.1). For bulk T2 values, the median was 15.7 (IQR: 11.6 - 22) ms. The median for the bulk PSIF signal was 21.07 (IQR: 14.73 - 32.23), and for the FISP signal, 52 (IQR: 38.4 - 85.22). The bulk GAG content was 1.2% (IQR: 0.8 - 1.8) of the dry weight and the bulk water content was 67.2% (IQR: 66.9 - 70.7) of the dry weight. With regard to the correlations between individual parameters, the highest Pearson correlation coefficient was found between sodium SNR and GAG content (r = 0.71, p = 0.007). A relatively high correlation was found between sodium SNR and FISP (r = 0.52, p = 0.025), and between the PSIF signal and T2 values (r = 0.51, p = 0.036).

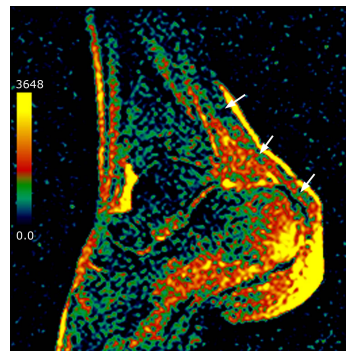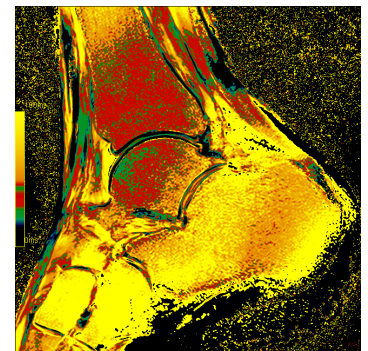Fig. 1. FISP image   Fig. 2. PSIF image   Fig. 3. sodium signal image   Fig. 4. T2 map

Conclusion: In this study, multi-parametric MRI was used to image cadaver ATs. The correlation between immunohistologically assessed GAG and water content was high in some cases, especially with sodium SNR. This study has some limitations: With the given setup, it was not possible to measure the shortest component of T2 values. Also, the FISP sequences with diffusion-sensitizing gradients do not provide any useful signal from tendons; therefore, any calculation of an apparent diffusion coefficient (ADC) map is problematic. The results of this study showed that the biochemical content of the AT can be quantitatively evaluated by multi-parametric MRI. It seems that FISP signal in tendons is influenced by both collagen fiber organization and orientations, as well as water and GAG content. It has been shown that sodium MRI can be a successful clinical marker for GAG content in articular cartilage [3]. The results of this study validated the analogue in tendon tissue.

References: [1] Kannusz P. Et al. The Journal of bone and joint surgery 1991;73(10):1507-25, [2] Schweitzer ME, et al, AJR 2000;175(3):613-25, [3] Reddy R. et al, Magn Reson Med 1998;39(5):697-701.