UTE T2* decay analysis of the rabbit supraspinatus tendon at 7T

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TARGET AUDIENCE: Musculoskeletal radiologists, orthopaedic shoulder surgeons and therapists.

PURPOSE: The rabbit supraspinatus tendon is a common model to investigate healing following rotator cuff repair[1,2]. This model allows for post-surgical histological and mechanical testing to evaluate tendon healing. However, a non-invasive quantitative method to characterize structural outcomes would be advantageous. Various approaches may be used, including MRI T2 mapping, proteoglycan sensitive techniques (T1rho), and ultra-short echo time (UTE) imaging combined with T2* decay analysis, all of which have been found to give useful information about the condition of the tendon[3,4]. Previous studies have found differences in T2* between normal and pathologic tendons using mono- and bi-exponential signal decay analysis[5,6]. The objective of this study was to investigate the T2* decay of the rabbit supraspinatus tendon (*ex vivo*) using a 3D UTE sequence at high magnetic field strength (7T).

METHODS: Six rabbit shoulder tendons inserted on their humeral heads, maintained in saline buffered solution at 4° C to prevent desiccation and enzymatic degradation, were scanned with a 7T GE/Agilent Discovery MR901 using a 15 cm inner diameter birdcage coil for signal transmission and a 2 cm surface coil for signal reception. All tendons were aligned with their main axis along the main magnetic field (B_0) to minimize bias between the specimens due to the magic angle effect. The T2* decay was imaged using a 3D UTE sequence with twelve different TEs = 0.09, 0.15, 0.2, 0.3, 0.5, 0.8, 1.0, 1.5, 2.0, 4.0, 6.0, 10.0ms. Other parameters were: TR = 12ms, flip angle = 8°, field of view = 45×36×26mm^3, number of spokes = 48026, receiver bandwidth = 250kHz, spatial resolution = 0.2×0.2×0.5mm^3, total acquisition time for T2* imaging = 1h 55min. The T2* signal decay was analyzed offline by fitting the images pixel wise to four different decay models using Matlab: Two mono-exponential models -- $S1=S_m \cdot \exp(-t/T2_m^*)$ and $S2=S_m \cdot \exp(-t/T2_m^*)+C$ -- and two bi-exponential models -- $S3=S_s \cdot \exp(-t/T2_s^*) + S_l \cdot \exp(-t/T2_l^*)$ and $S4=S_s \cdot \exp(-t/T2_s^*) + S_l \cdot \exp(-t/T2_l^*)+C$. T2* parameter maps were generated and two ROIs were chosen to calculate mean T2* values in the tendon. ROI1 was placed at the tendon proper, ROI2 near the bone insertion. The two ROIs were chosen for their importance in supraspinatus tendon surgical repair, where the reattached tendon at the bone insertion is expected to undergo structural and compositional change to form an enthesis.

Figure 1

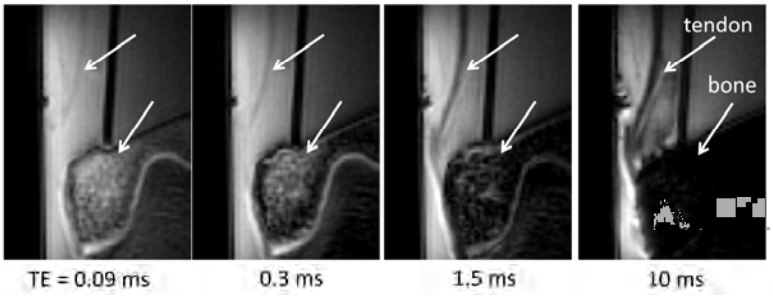
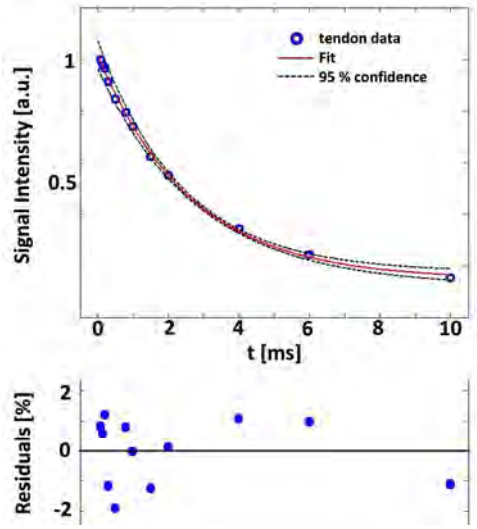


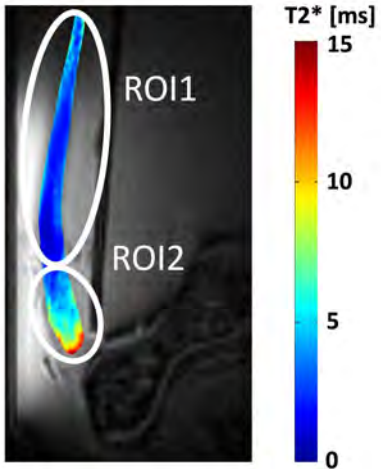
Figure 2



RESULTS: Figure 1 shows four (of the twelve) sagittal UTE images of a rabbit supraspinatus tendon and their humeral head. At TE = 0.09ms the tendon signal is similar to that of the surrounding saline solution. With increasing TE, the tendon becomes clearly visible as a darker structure. Figure 2 shows the typical tendon signal decay and the best fit (lowest residuals and lowest deviation of the 95% confidence intervals from the fitted result) using the mono-exponential ($S2=S_m \cdot \exp(-t/T2_m^*)+C$) model function. The T2* signal revealed a mono-exponential decay in the tendon. Figure 3 shows representative T2* parameter maps using the mono-exponential analysis (model S2). T2* resulted in 3.2±1.3ms (ROI1) and 7.9±3.1ms (ROI2).

DISCUSSION: 3D UTE can be used to acquire T2* maps from the rabbit supraspinatus tendon with high resolution. Due to the short T2* of the tendon at 7T, UTE is a superior method to acquire quantitative T2* maps. Although bi-exponential T2* decay in human tendon has been reported at 3T[5], our study demonstrated a mono-exponential T2* signal decay in rabbit supraspinatus tendon. The higher field strength (7T) results in T2* shortening which impairs a bi-exponential decay analysis. Also the parallel orientation of the tendon main axis to B_0 might shorten the T2* due to the magic angle effect. The 3D UTE sequence is currently used to investigate the healing process of the rabbit supraspinatus tendon after surgical repair. This UTE protocol for pre-clinical application might also be useful to measure T2* in other tissues with short T2* (like bones).

Figure 3



CONCLUSION: T2* of the rabbit tendon can be quantified using high resolution 3D UTE imaging. The T2* signal analysis of the supraspinatus tendon using TEs from 0.09ms to 10ms revealed a mono-exponential decay at 7T.

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