[1]H Relaxation Properties of Achilles Tendons Measured by 3D-UTE at 3T and 7T: a Feasibility Study

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Introduction: The clinical MRI sequences are predominately used for visualizing long T_2 tissues. Highly oriented tissues (such as tendons ($T_2 \sim 1.5$ms), menisci ($T_2 \sim 5$ms), ligaments ($T_2 \sim 5$-10ms) or cortical bone ($T_2 \sim 0.5$ms)) give little to no signal using conventional sequences. However, recent developments in the field of ultra-short TE sequences allow to acquire the signal directly from rapidly relaxing tissues. Tendons consist of collagens (mostly type I collagen), proteoglycans (in small quantities, $\sim 3\%$), glycoproteins, water and cells [1]. Mechanical demands of Achilles tendons are accomplished by high level of fibers orientation which results in extremely short MR relaxation parameters. To our best knowledge, T_2^* in Achilles tendon at 7T has not been investigated yet. Therefore, the aim of this study was to investigate ^{1}H transverse relaxation of Achilles tendon in vivo in healthy volunteers with 3D-UTE sequence [2] at 3T and 7T MRI.

Methods and Materials: Six volunteers included in the study were consequently measured at both field strength (3T and 7T, both Siemens Healthcare, Erlangen Germany). Two similar eight channel knee coils (both, In Vivo, Gainesville, FL, USA) were used at either field strength. 3D dataset was acquired by half-pulse 3D-UTE sequence with radial k-space sampling. The reconstruction was performed using density compensation with Rho filter, regridding algorithm and 3D-iFFT to produce resulting images. In each sequence run, eight different TEs were used: 3T - {0.07, 0.14, 0.21, 0.49, 1.05, 1.89, 2.45, 3.01, 4.0} ms; 7T - {0.07, 0.20, 0.30, 0.46, 0.59, 0.74, 1.00, 1.50} ms. The rest of the sequence parameters was the same for each scanning: TR, 400ms; averages, 2; bandwidth, 560 Hz/px; matrix, 256x256; flip-angle, 12°, FOV, 300mm. T_2^* maps were generating by mono-exponential fitting on pixel-by-pixel basis in custom-built IDL (RSI, Boulder, CO) script using mpcurvefit routine (Craig B. Markwardt, NASA/GSFC Code 662, Greenbelt,MD20770). Morphological evaluation was performed on digitally subtracted images at TE of 0.07 and 1.5ms. Coefficient of determination (R^2) was stored for later T_2^* correction. Resulting T_2^* maps were overlaid with first echo (0.07ms) image on which six region-of-interests were drawn (Fig 1. and 2.). R^2 weighted mean values of T_2^* were recorded [3] and the comparison between values from two field strengths was assessed by paired Student t-test; p value less than 0.01 was considered statistically significant.

Results: Morphological analysis show very high signal from Achilles tendon, mean thickness was 4.6 ± 0.8 mm in upper part, 7.6 ± 1.9 mm in middle part and 4.2 ± 1.3 mm in lower part (measured through the centers of individual ROIs). Bulk T_2^* at 3T was 0.98 ± 0.08 ms and at 7T 0.41 ± 0.1 ms. T_2^* values for either ROI are summarized in the Table 1. Statistical significance of mean T_2^* difference was found in all regions except for LP and MP.
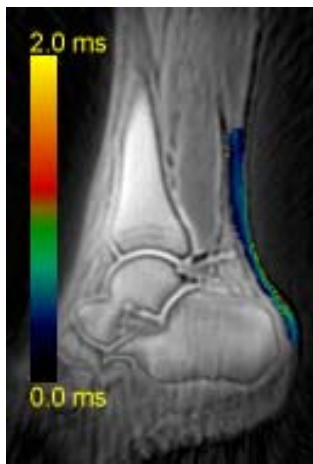

Fig. 1 Anatomical image of the ankle overlaid with T_2^* map (pseudo-colored and indexed according to colorbar on the left).
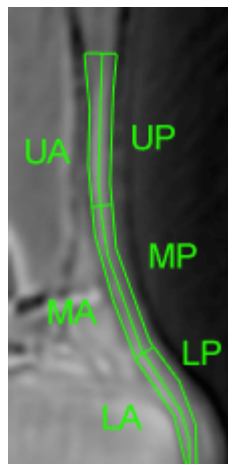

Fig. 2 Definition of ROI selection. Lower part was difficult to select in some cases, therefore the enthesis was omitted for evaluation.

field strength	3T		7T		
ROI	T_2^*	stdev	T_2^*	stdev	p
UA	0.80	0.15	0.37	0.12	<0.01
UP	0.77	0.12	0.41	0.06	<0.01
MA	0.89	0.22	0.31	0.10	<0.01
MP	1.00	0.39	0.48	0.20	0.04
LA	0.97	0.23	0.29	0.11	<0.01
LP	1.24	0.56	0.61	0.42	0.12
BULK	0.98	0.08	0.41	0.10	0.012

Table 1. Summary of T_2^* measured with 3D-UTE sequence and the corresponding p-values. Mean areas for individual ROIs were: UA 161 mm[2], UP 151 mm[2], MA 66 mm[2], MP 96 mm[2], LA 62 mm[2], LP 61 mm[2].

Conclusion: This study showed the ability of 3D-UTE sequence to assess T_2^* of rapidly relaxing tissues like Achilles tendon in vivo. Very high contrast of the tendon led to an accurate segmentation. The comparison of the mean T_2^* between 3T and 7T was found to be significantly higher at lower field strength which is implied by higher inhomogeneity at higher field strength. T_2^* values calculation was very robust with standard deviation less than 8% between the subjects. The study will continue with the enrollment of the patients with tendinopathy and inflammation-based diseases to use T_2^* mapping as a potential clinical tool for early diagnosis of these pathologies.

[1] Wang et al. Journal of Biomechanics 39, 2006, pp. 1563–1582; [2] Nielles-Vallespin, S. et al, Magnetic Resonance in Medicine, 47, 1, 2007, pp. 74-81; [3] Juras V. et al., Medical Physics 37, 6, 2010, pp. 2813-2821;