High Resolution 3D Ultrashort Echo Time Imaging of the Achilles Tendon at 7T

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Purpose: For musculoskeletal MRI, ultra-high-field MRI systems provide opportunities for assessing high-resolution morphology, enabled by their intrinsic high SNR. With conventional imaging sequences, the Achilles tendon is normally dark due to its short T2 relaxation time; therefore, evaluating the pathology has been only possible by looking at an increase in signal intensity or morphologic changes in the surrounding tissues. However, direct visualization of the tendon may allow for detecting early degeneration changes and guiding treatment following traumatic tendon injuries.[1-2] The purpose of this work was to demonstrate the feasibility of depicting the microstructure of the in vivo Achilles tendon using 3D ultrashort echo time (UTE) imaging at 7T.

Methods: Our UTE pulse sequence used a minimum-phase RF pulse (with a time-bandwidth product of three and pulse duration of 432 us) for slab-selective excitation along the superior/inferior direction. A VERSE algorithm was applied to minimize the TE further.[3] For the acquisition, a three-dimensional radial imaging scheme that supported anisotropic FOV shapes was used.[4]

Four healthy volunteer scans were performed at a MR950 7T scanner (GE Healthcare, Waukesha, WI) using a 32 channel phased-array head coil (GE Healthcare, Waukesha, WI). To locate the foot inside the head coil, the upper part of the phased-array coil was shifted off from the center of the coil. Imaging parameters included 308 us TE (the time between the peak of the RF and the start of acquisition), 7.3 ms TR, 7° flip angle, 0.65 x 0.65 x 0.65 mm^3 isotropic resolution, ±250 kHz bandwidth, 1.024 ms readout time, 13 x 13 x 11.9 cm^3 FOV, and 15 minute scan time. To improve the dynamic range of the tendon signal, a fat saturation pulse with 4 ms duration was applied every eight sequence repetitions. For comparison, standard 2D fat-suppressed fast-spin echo imaging with 2.4 ms TR, 31.8 ms TE, echo train length of 6, and 4 mm slice thickness was performed.

Results: Figure 1a-c shows fat-suppressed 3D UTE images from one volunteer. With an isotropic voxel size, UTE images can provide high-resolution ankle morphology in arbitrary planes. The Achilles tendon is well-depicted, generating fascicular patterns resulting from tendon fiber structures. Here, low signal stripes possibly represent fascicles (shorter T2) while intervening high signal stripes represent endotenons (longer T2).[5] Fat suppression only fails in the subcutaneous fat of the posterolateral calf (pink dashed arrow). With the standard fast-spin echo sequence (Fig. 1d), the Achilles tendon is dark except one single bright line attributed to the tendon fascicular pattern.[6]

Discussion: 3D UTE imaging at 7T can depict the Achilles tendon's microstructures within a clinically feasible scan time. The 3D isotropic imaging allows for evaluating tendon microstructures in arbitrary planes, which is useful in assessing these complex structures. Using RF pulses for fat suppression is more beneficial at high field because the direct saturation of the short T2 tendon can be minimized owing to the increased separation between the fat and water resonant frequencies. Characterizing the internal Achilles tendon structure could allow for earlier diagnosis of degeneration changes and evaluating tendon healing processes after therapy. Spatial resolution is still a limiting factor in delineating the fine microstructures of the tendon, but development of dedicated extremity phased-array coils at 7T will improve SNR and enable us to achieve higher spatial resolution.

Conclusion: High-resolution 3D UTE imaging at 7T can delineate microstructure of the in vivo Achilles tendon. Future work includes comparing the structures between the normal Achilles tendons and abnormal Achilles tendons and evaluating the diagnostic usefulness.

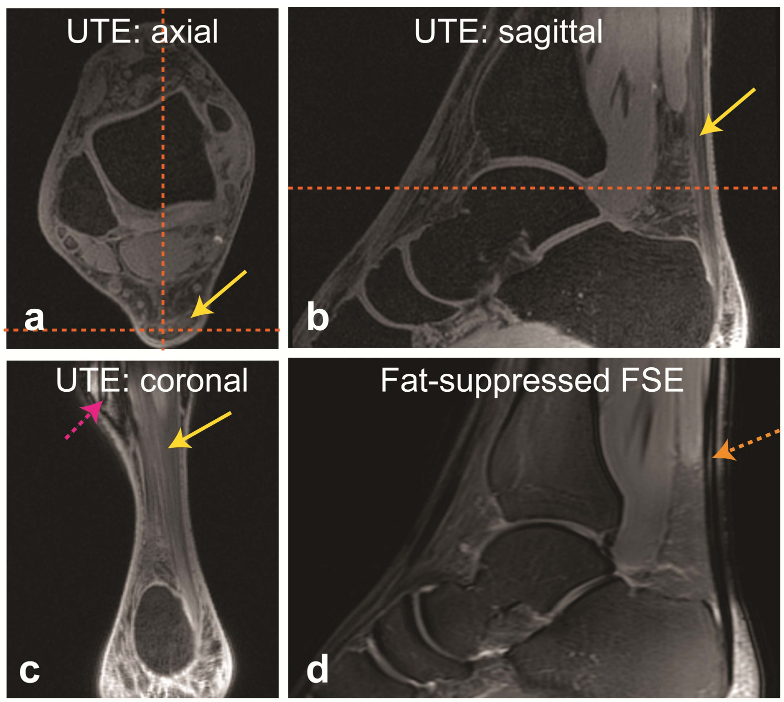

Figure 1. (a-c) 3D UTE images with 0.65 mm isotropic resolution of the ankle reformatted in the axial, sagittal, and coronal planes. Plane locations are denoted as orange dashed lines. Fascicular patterns can be seen within the Achilles tendon (yellow solid arrows). (d) Standard fat-suppressed fast-spin echo image. The Achilles tendon provides no signal but one single line (denoted by an orange dashed arrow) attributed to the tendon fascicular pattern.

References

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Acknowledgement
Supported by NIH R01AR057336.