Orientational effect on Achilles tendon investigated with ultrashort TE spectroscopic imaging (UTESI) sequence

J. Du[1], B. C. Pak[1], A. Takahashi[2], R. Znamirowski[1], S. Statum[1], G. M. Bydder[1], and C. B. Chung[1]

[1]Radiology, University of California, San Diego, San Diego, CA, United States, [2]Global Applied Science Laboratory, GE Healthcare Technologies, Menlo Park, CA, United States

INTRODUCTION

Achilles tendon is MR "invisible" with conventional clinical pulse sequences. When the orientation of the highly ordered, collagen-rich fibers is shifted from 0^0 to B_0 to 55^0 to B_0 (the magic angle), dipolar interactions are decreased and their T2s are often considerably increased (1, 2). The bulk magnetic susceptibility of tendons also varies up to three parts per million (ppm) with orientation to the static magnetic field with the maximum change at 90° compared to that at 0° to B_0 (3). The magic angle effect and frequency shift effect have only been investigated on small bore spectrometer using small tendon samples. Here we applied an ultrashort TE spectroscopic imaging (UTESI) technique to investigate these effects using whole ankle specimens on a clinical 3T scanner.

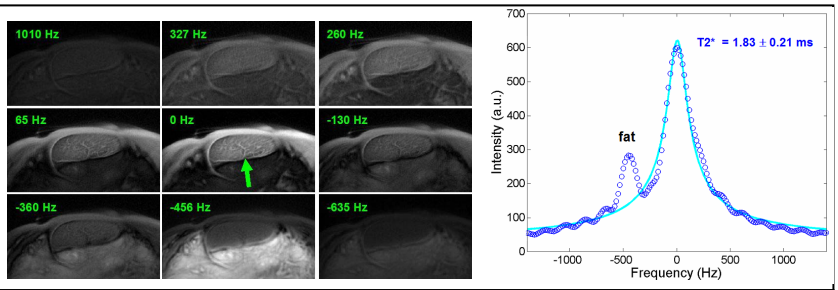

Fig 1 *shows selected UTESI images at different resonance frequencies (left) and line shape fitting of the broad magnitude spectrum for Achilles tendon (right) which shows a short T2* of 1.83 ± 0.21 ms at 0^0 relative to B_0 field. The fascicular pattern in tendon is well depicted with a high spatial resolution of 0.2×0.2×2.0 mm^3 under a total scan time of 12 minutes. Fat signal is peaked at -456 Hz, consistent with the chemical shift between fat and water at 3T.*

MATERIALS AND METHODS

The UTESI sequence employs half pulse excitation followed by multi-echo variable TE radial ramp sampling to generate variable TE images and spectroscopic images for short T2 tissues (4). Quantitative information such as T2*, chemical shift and resonance frequency shift can be directly calculated from the magnitude spectroscopic images. Four cadaveric ankle specimens were harvested for this study. UTESI imaging was performed at 11 angular orientations (0°, 15°, 30°, 45°, 50°, 55°, 60°, 65°, 75°, and 90°). The position of the ankle and angle to B_0 will be standardized using an ankle brace with an internal goniometer. Other acquisition parameters were: FOV = 10 cm, TR = 60 ms, minimal TE = 8 µs, TE delay = 200 µs, up to 4 echoes, echo spacing = 6 ms, flip angle = 45°, BW = ±62.5 kHz, readout = 512 (actual sampling points = 284), number of projections = 2025 which was interleaved into 45 groups (each group 45 projections), slice thickness = 2 mm, NEX = 2, sagittal or axial imaging plane. T2* was quantified through line shape fitting of the magnitude spectrum for each angular orientation (4). Resonance frequency shift, defined as the difference between the water peak and fat peak, was investigated as a function of orientation angle.

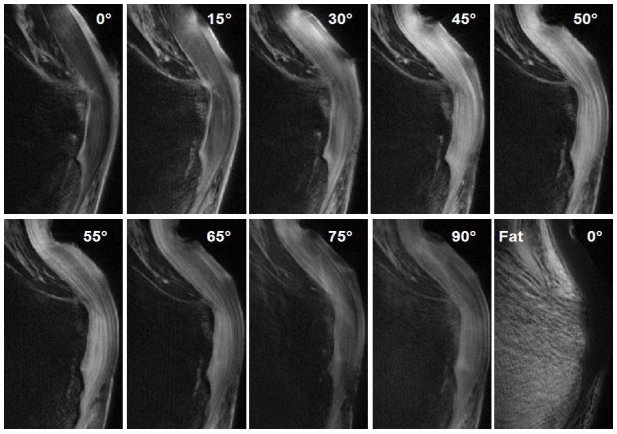

Fig 2 *The water peak of the UTESI spectroscopic images of the Achilles tendon at a series of angular orientation ranging from 0^0 to 90^0 demonstrate a magic angle effect (increased signal) at 55^0 relative to B_0 field. Fat peak at 0^0 is also shown just for reference.*

RESULTS AND DISCUSSION

Figure 1 shows typical axial UTESI images and spectral fitting for T2* quantification for the Achilles tendon at 0^0. Figure 2 shows the sagittal water peak images at a series of angular orientations. A significant signal increase was observed when the fibers were orientated 55^0 relative to B_0 field. Figure 3 shows the UTESI magnitude spectrum at different angular orientations. It clearly shows that the broad spectrum at 0° to B_0 becomes narrower at 55°, and then broader again as the orientation angle increases to 90°. Furthermore, the resonance frequency was shifted due to directional susceptibility of the Achilles tendon. Figure 3 also shows the fitted T2* as a function of the orientation angle. Spectral and frequency shift have been investigated previously by Fullerton et al (1, 3) using a small bore spectrometer and small tendon samples, but have never been investigated on clinical scanners using whole ankle samples or in vivo studies of volunteers or patients. UTESI makes it clinically feasible to study these effects quantitatively in human subjects.

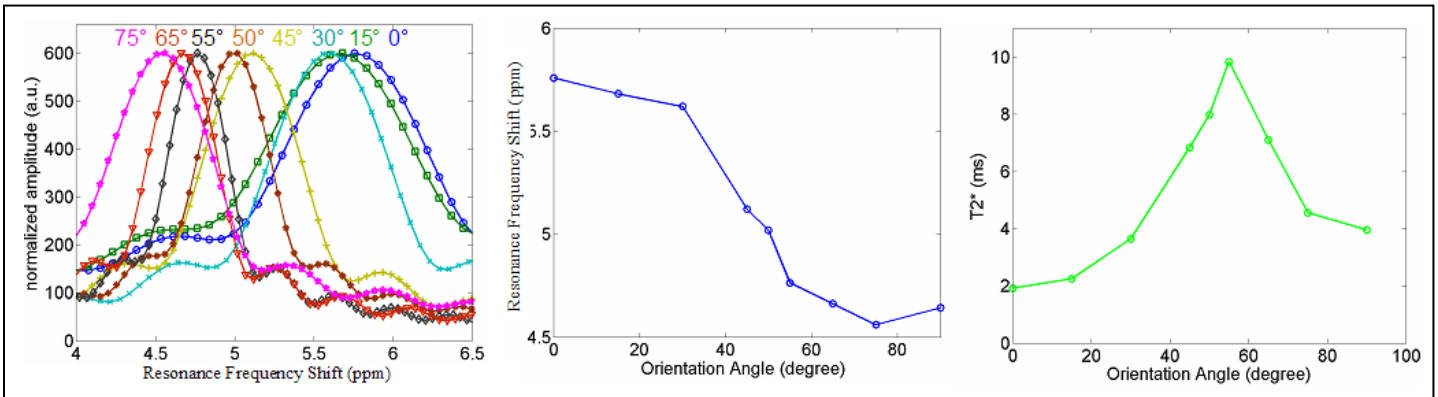

Fig 3 *UTESI spectrum of the Achilles tendon at different angular orientation from 0^0 to 90^0 (left) shows spectral narrowing at 55^0 and a continuous directional frequency shift (middle). T2* increases from 2 ms at 0^0 to 10 ms at 55^0, and then drops to 4 ms at 90^0 (right).*

CONCLUSIONS

Magic angle and resonance frequency shift effects due to bulk susceptibility can be investigated for the first time on a clinical scanner in vitro or in vivo using UTESI sequence, which can also be used to morphologically and quantitatively evaluate a variety of short T2 tissues in human body.

REFERENCES

1. Fullerton GD, Cameron IL, Ord VA. Radiology 1985; 155:433-435.
2. Henkelman RM, Stanisz GJ, Kim JK, Bronskill MJ. MRM 1994; 32:592-601.
3. Krasnoselskaia LV, Fullerton GD, Dodd SJ, et al. JMRI 2005; 54:280-288.
4. Du J, Hamilton G, Takahashi A, et al. MRM 2007; 58:1001-1009.