Magnetic Resonance Imaging of Entheses of the Foot at 11.7T

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INTRODUCTION: Entheses are regions of the body in which tendons or ligaments are connected to bone. They are usually fibrous or fibrocartilaginous. In the latter, calcified and uncalcified fibrocartilage are interposed between the tendon/ligament and bone. The cartilaginous tissues have mechanical properties intermediate between those of the soft tissue (tendon/ ligament) and the hard tissue (bone) and this helps disperse mechanical stress in the junctional region. Functional entheses are also seen where tendons or ligaments are subjection to compression as with the tibialis posterior tendon (TPT) where it wraps around the medial malleolus. In this situation uncalcified fibrocartilage, which resists compression, is seen in the tendon. The tissues of entheses have short T2s and previous studies have employed short or ultrashort TE sequences in 2D form to visualize them using clinical systems operating at 1.5-3.0T (1-3). In this study we wished to determine whether it was possible to observe more detail in larger and smaller entheses by using an 11.7T small bore system with dedicated coils and both 2D and 3D pulse sequences.

MATERIALS AND METHODS: Following institutional policy, tissues from two cadaveric feet were imaged using an 11.7T USR Bruker Biospin MR system (Billerica, MA). This was equipped with 750 mT/m gradients, two transmit/receive resonators of 60 and 72 mm internal diameter, and two four element receive only arrays. A 15 mm internal diameter transmit receive solenoid was also used. A 2D dual echo spin echo (SE) pulse sequence was used (40-60 x 40-60 x 400-600um spatial resolution), TE 7-9 ms and 14-18 ms, TR 3500-5000 ms, fat saturated with number of excitations (NEX) = 6-10 of total duration 4-7 hours. This was used in sagittal, coronal and axial planes. In addition a 3D gradient echo (90-50 um^3 isotropic) TE 6-8 ms, TR 25-31 ms, flip angle 10-13º, fat saturated sequence was used. The NEX was usually 20-30 for total scan duration of about 4-5 hours. The cadaveric foot samples were initially frozen and thawed prior to imaging over a 4-6 hour period. Specimens were carefully immobilized within the coils.

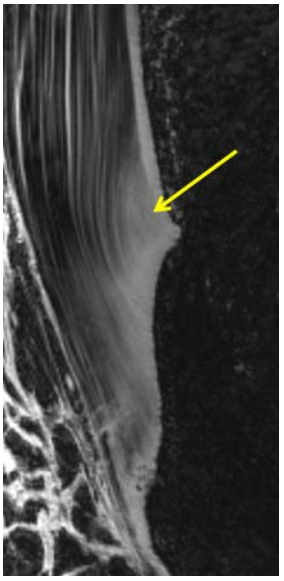

Figure 1. 3D GRE image in the sagittal plane shows collagen fascicles coursing through the sesamoid fibrocartilage (arrow).

RESULTS: *Achilles tendon*: Enthesis and sesamoid fibrocartilage were readily seen in 2D and 3D images together with detail of the retrocalcaneal bursa. Fiber structure was observed in the enthesis fibrocartilage (**Fig 1**). *Tibialis Posterior Tendon (TPT) at the level of the medial malleolus:* High signal was observed in the functional enthesis of the TPT together with perpendicular fibers (**Fig 2**). *TPT Navicular Insertion*: Fibrocartilage was seen at the insertion with fiber directions readily demonstrable (**Fig 3**). *Central slip of the Extensor Tendon of the Toes*: High signal was seen within the tendon at the level of the proximal interphalangeal joint, consistent with fibrocartilage. *Collateral Ligaments*: High signal consistent with fibrocartilage was seen within the collateral ligaments. *Plantar Plate*: Evidence of fibrocartilage was seen at the insertion of the plantar plates into the middle and distal phalanges.

DISCUSSION: Higher resolution images showed greater detail of the bursa and fiber structure of the entheses of the Achilles tendon. The functional enthesis of the TPT has not been previously demonstrated with MR and the perpendicular fiber structure is a new finding. An array of fiber detail was seen in the navicular insertion of the TPT. The fiber cartilage of the central slip of the extensive tendon has not been previously been demonstrated with MR. The collateral ligaments entheses are also a new finding as is the appearance of the distal part of the plantar plates. Fibrocartilage has a longer T2 than tendons or ligaments while uncalcified fibrocartilage generally has a shorter T2. The higher field allowed imaging at higher spatial resolution with tissue contrast similar to that obtained at lower fields. 3D imaging of entheses was performed for the first time. The images provide an excellent guide to what may be seen at lower field using clinical systems and were consistent with previous anatomic studies (4-6).

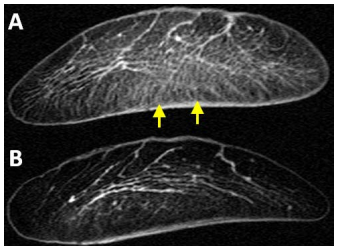

Figure 2. 2D SE axial image at the level of the retromalleolar groove (A) shows increased signal, consistent with fibrocartilage deposition and perpendicular fibers (arrows), which were not evident at a more distal level inferior to the medial malleolus (B).

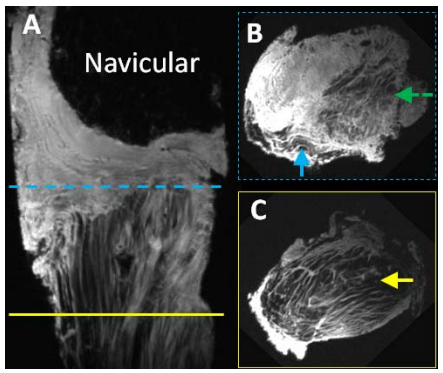

Figure 3. 3D GRE image of the TPT navicular enthesis in long axis (A) and in short axes (B and C), demonstrating abundant fibrocartilage which the tensile tendon inserts onto. Lines in A indicate location of short axes images. Arrow in (B) demonstrates continuing plantar fibers and dashed arrow indicates tendon insertion onto fibrocartilage. Arrow in (C) demonstrates fascicular pattern of TPT.

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