

Magnetic Resonance Imaging of the Pulleys of the Flexor Tendons of the Toes at 11.7T

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Purpose: We have obtained high resolution, high field (11.7 Tesla) Magnetic Resonance (MR) images of the pulleys of the flexor tendons of cadaveric toe specimens. Although the anatomy of the pulley system has been described in one previous article, there have been no previous MRI descriptions of the pulley system of the toes published in the imaging literature. A detailed understanding of toe pulley anatomy is likely to be of benefit in diagnosing tenosynovitis and recognizing the effects of trauma.

Methods: Two cadaveric great toes and four lesser toes were imaged on an 11.7 Tesla small animal MR imaging system (Bruker Biospin) using receiver arrays and a custom built, small solenoid coil. 2D dual echo SE scans in axial, sagittal and coronal planes were obtained with representative parameters: 40x40x400 μm^3 voxel size, TE 7/14 ms, TR 3500 ms, and fat saturation. In addition 3D spoiled gradient echo scans were obtained with parameters: 90-150 μm^3 isotropic voxel size, TE 6 ms, TR 25 ms, Flip angle 10°, and with or without fat saturation. Specimen orientation was with the long axis of the toe either parallel or perpendicular to B_0 . Cadaveric foot samples were obtained frozen, thawed for 4 hours, and imaged. Some specimens were fixed in 10% formalin for 24 hours and imaged again.

Results: Differences in T2/T2* from intrinsic origin and/or due to the magic angle effect provided high contrast between tissues. The pulley system was clearly seen when the long axis of the toe was oriented perpendicular to B_0 and the pulley fibers were parallel to B_0 . All the annular (A) pulleys were demonstrated in the great and lesser toes. The A2 pulley in the great and lesser toes and the A4 pulley in the lesser toes were very prominent, displaying a U-shaped configuration and attaching directly to the periosteum. The A1 and A3 pulleys in the greater or lesser toes, and the A5 pulley in the lesser toes were smaller, more flattened and attached to the respective plantar plates. The cruciform C2 pulley was also clearly seen in the lesser toes and was smaller and thinner (**Figure 1**).

Discussion: The appearances of the pulleys of the toes have not been previously described with MR imaging. The A5 pulley, which has only previously been described in the 2nd to 5th fingers, was also present in the lesser toes. The MR visualization of the pulleys included features not seen or reported in descriptions of the finger pulleys such as the internal structure and magic angle effects (**Figure 2**). Validation was performed by direct inspection of anatomic specimens. Relative to clinical systems used for comparable cadaveric studies of the finger, the performance of the MR system used in this study was enhanced by the use of a greater static field strength, higher gradient strength, optimized coils as well as much longer scan times. This allowed use of much higher spatial resolution sequences. The TEs were shorter than those typically employed with clinical systems resulting in relatively higher signal for the same T2. The shorter TEs were important because the pulleys and tendons generally have short T2s and so appear low signal on conventional clinical images.

Conclusion: Exquisitely detailed anatomy of the pulley system of the flexor tendons was apparent in the 11.7T MR images, allowing similarities and differences between the pulley system in the foot and that in the hand to be identified.

References: 1. Martin MG and Masear VR. Foot & Ankle International 1998; 19: 113. 2. Slattery D, Aland C, Durbridge G, et al. Journal of hand Surgery (Eur) 2013 Jul 22 (Epub ahead of print). 3. Fullerton GD, Cameron IL and Ord VA. Radiology 1985; 155: 433. 4. Doyle JR. J Hand Surg Am. 1989; 14: 349.

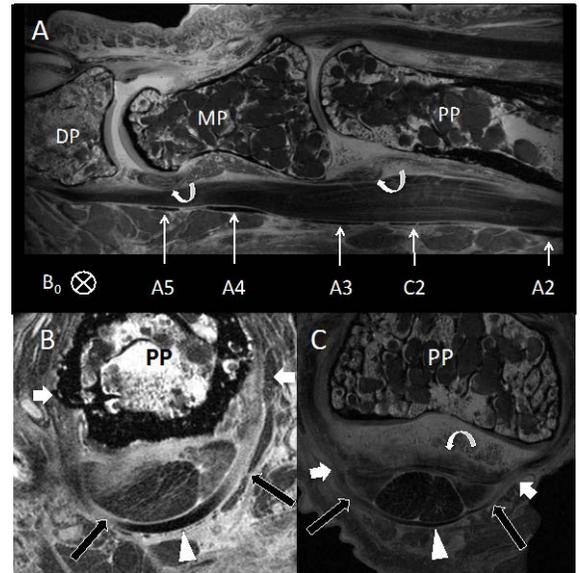


Figure 1. Sagittal and axial fat saturated SE scans of the 4th toe showing the annular (A2-A5) and cruciate (C2) pulleys. The A2 (B) and A3 pulleys (C) and its attachment sites (white arrows) to the proximal phalanx (PP) and plantar plate (curved arrow) respectively are demonstrated in detail. Note the signal intensity of the pulleys is low inferiorly (arrowhead) and increases laterally (black arrows) due to the magic angle effect. Flexor tendons (*).

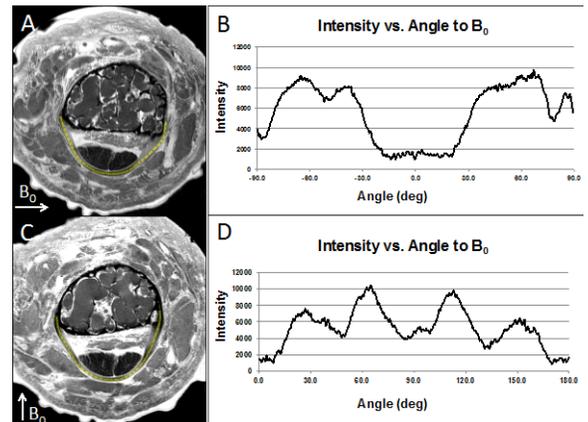


Figure 2. Short axis MR images of the 4th toe and respective plots showing the signal intensity (SI) changes along the A4 pulley. The magic angle effects are clearly demonstrated when the pulley fibers are oriented parallel to B_0 (A, B) and perpendicular to B_0 (C, D). Plots (B, D) are of the signal intensity along the lines indicated in the images.