MRI of the Pulleys of the Flexor Tendons of the Fingers at 11.7T

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Target audience: MR scientists and radiologists interested in the structure and function of the musculoskeletal system.
Purpose: To image the flexor pulley system of the fingers, identify factors which determine image contrast and correlate the results with structure and function.
Introduction: The pulleys of the finger maintain the position of flexor tendons adjacent to the proximal and middle phalanges, and stabilize the tendons during joint motion[1]. They may be disrupted by injury (typically in rock climbers) or become stenotic causing trigger finger. A basis for interpretation of MR images has been established with in vitro studies of cadaveric fingers but in these studies it only proved possible to show the annular A2 and A4 pulleys[1]. The A1, A3 and A5 pulleys were not directly visualized and nor were the three cruciate pulleys (C1-C3)[2]. The objective of this study was to provide a more complete description of the pulleys of the flexor tendons of the fingers, and establish a basis for visualizing them with in vivo studies.
Materials and Methods: Six human fingers (index, middle and little) were harvested, frozen and thawed then imaged in accordance with institutionally approved protocols. Four fingers were subsequently dissected with removal of the surrounding connective tissue to show the pulleys and re-imaged. MRI examinations were performed using an 11.7T (117/16) Bruker Biospec (Billerica, MA) system with 750 mT/m gradients using a 38 mm transmit/receive (T/R) resonator, a four coil rat brain receive only array and an in-house 12 mm T/R solenoid. The fingers were orientated with their long axes parallel or perpendicular to Bo. In the latter position the fingers were examined either with their antero-posterior (AP) or medio-lateral (ML) axes parallel to Bo. Fat saturated multi-slice multi-echo (MSME) sequences (TR=3000 ms, TE=8, 16 ms) voxel size 50-70 x 50-70 x 500 μm, NEX=8-14 were used in axial and sagittal planes. The scan duration was typically 4-6 hours.
Results: With the finger parallel to Bo, the A2 and A4 pulleys were demonstrated as relatively thick U-shaped structures attached to the phalangeal periosteum. Three layers could be seen in the pulleys. High signal was frequently seen within the pulley in the regions medial and lateral to the tendons (Fig. 1). With the finger perpendicular to Bo (AP or ML axes parallel to Bo) symmetric high signals were seen within the pulleys consistent with magic angle effect (Fig. 2). The A1, A3 and A5 pulleys were thinner and more splayed, and attached to the adjacent plates (Fig. 3). They were often of higher signal than the A2 and A4 pulleys. Fiber structure was evident in the plates and adjacent collateral ligaments. The cruciate pulleys were sometimes identifiable in the sagittal plane as small low signal areas, but were best seen in the axial plane where they were often of high signal comparable with the surrounding connective tissue. They were thin, generally U-shaped, often multiple, and often incompletely shown in single axial images (Fig. 4). Visual inspection of the surgically dissected sequences confirmed the presence of pulleys. Images of these (with the surrounding connective tissue removed) also showed pulleys confirming that these were what was being imaged, rather than incidental adjacent connective tissue.

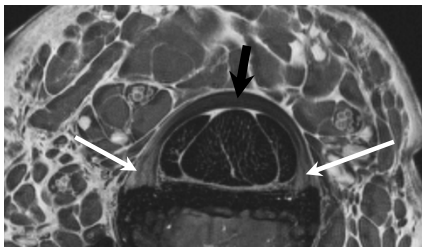

Fig 1. Axial image of A4 pulley (black arrow). Bo parallel to finger, MSME sequence. The pulley shows high signal medially and laterally within it (white arrows).

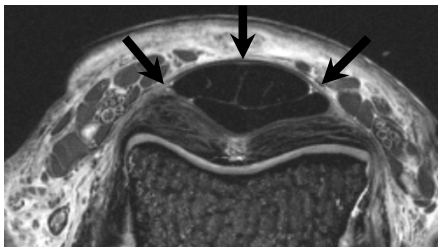

Fig 2. Axial image of A3 pulley (black arrows). Bo parallel to finger, MSME sequence. The pulley is thinner, more splayed and attaches to the underlying plate.

Fig 3. Axial image. Cruciate pulley (black arrows). Bo parallel to finger, MSME sequence. The pulley is of high signal and there is little contrast with the surrounding connective tissue anteriorly.

Discussion: Images at higher field strength using longer scan times and specific coils showed pulleys and structure within them that have not previously been reported with MRI. Magic angle effects were a major determinant of image contrast. Evidence of different fiber directions was seen in the A2 and A4 pulleys with contrast attributable to this effect. With Bo parallel to the finger, fibers of the cruciate pulleys were oblique to Bo where they crossed the flexor tendons. This may account for their relatively increased signal, and the loss of contrast with the higher signal from the surrounding connective tissue. The previous difficulty in directly imaging A1, A3 and A5 pulleys may be due at least in part to their smaller size as well as magic angle effects. Comparable results to these have been published in studies of the pulleys of the toes which were visualized in detail at 11.7T although they had not been described before in studies with MRI[3]. This study identifies the MR features of each of the described groups of pulleys and provides a basis for understanding the contrast with surrounding tissues as well as how they might be seen at higher field strengths using clinical systems.

References

1. Doyle JR. Anatomy of the flexor tendon sheath and pulley system. J Hand Surg Am. 1989;14: 349-351.
2. Hunger O, Chung CB, Lektraul N, et al. Pulley system in the fingers. Radiology. 2000;217: 201-212.
3. Tafur M, Iwasaki K, Statum S et al. MRI of the pulleys of the flexor tendons of the toes at 11.7T. Skeletal Radiol. 2014 (E-pub Oct 2).