Visualization of Entheses with Ultrashort TE (UTE) Pulse Sequences

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Introduction: The insertion of tendons and ligaments into bone (entheses) is an area of considerable interest functionally, histologically and clinically (1-3). The transmission of force from tendon to bone is accompanied by changes from fibrous connective tissue to uncalcified fibrocartilage to calcified fibrocartilage then to cortical bone. Periosteum associated with entheses may also be fibrocartilaginous. Within tendons sesamoid fibrocartilage may be seen. The presence of fibrocartilage in tendons and periosteum is associated with a compressive load and shear forces. In addition to these functional and histological features the target region for the seronegative spondyloarthritides is generally thought to be the enthesis. To date features of the normal enthesis have not been demonstrable with magnetic resonance (MR) imaging since the relevant tissues all have short T2s and produce little or no signal with conventional imaging techniques. We have implemented an ultrashort TE pulse sequence with a TE of 80 microseconds which is much shorter than conventional clinical sequences and have imaged entheses at different sites in the body.

Subjects and Methods: The basic pulse sequence employed a half radiofrequency (rf) excitation followed by radial imaging of k-space in one direction. This was followed by the other half radiofrequency excitation with the gradient polarity reversed, and repeated radial mapping of k-space. The two sets of data were added to give a single radial line of k-space, and the process was repeated through 360^o in 512 steps. The data were mapped onto a 512 x 512 grid and reconstructed by 2D Fourier transformation to give an image (4-7). Four sets of images with TEs of 0.08, 5.95, 11.08 and 17.70 ms were acquired. In addition to the basic sequence, versions with frequency based fat suppression were employed. With each of these sequences difference images formed by subtraction of one of the subsequent echo images from the first were produced. Fields of view of 12–20 cm were employed with slice a thickness of 4 mm on Siemens 1.5T Sonata and Symphony MR systems. 6-12 multiple interleaved slices were obtained. TRs of 500 ms were used with flip angles (for long T_2 relaxation components) of $45\text{-}80^o$ and slice gaps of 10 - 100%. Studies were conducted using 8 x 6 cm and 8 x 5 cm surface, spine, shoulder and body receiver coils. Six normal volunteers (5 male, 1 female aged 29 to 59 years) were examined. The Achilles tendon, patellar tendon, pelvis, lumbar spine, shoulder and elbow were studied.

Results: In studies of the Achilles tendon, enthesis periosteal and sesamoid fibrocartilage were demonstrated as high signal areas corresponding in detail with previously reported anatomic studies. There was a marked reduction in signal from these tissues on the second and later echo images. The periosteal fibrocartilage was more obvious in subjects with a prominent superior tuberosity at the ankle joint. The retrocalcaneal bursa was evident with both UTE pulse sequences and conventional sequences. The patellar tendon insertion displayed high signal, a double contour and evidence of periosteal and sesamoid fibrocartilage. In the pelvis high signal was seen at the insertions of rectus abdomen and the hamstring tendons. High signal areas were also seen at the ligamentous insertions of the spine. The supraspinatus tendon showed high signal at its inferior (humoral) aspect consistent with the presence of fibrocartilage. Magic angle effects resulted in both an increase in signal for the supraspinatus tendon and an increase in the signal from short T2 components on difference images. Increased signal was seen around the medial and lateral epicondyles at the lower end of the humerus.

Discussion: The use of UTE pulse sequences allows structures which have not previously been visualized to be demonstrated at the insertion of tendons – these include enthesis, periosteal and sesamoid fibrocartilage. These structures are of high signal with the UTE images consistent with a short T1. Their signal decreased rapidly on successive echo images consistent with a short T2. Sesamoid fibrocartilage could be distinguished from adjacent fibrous connective tissues in tendons by its higher signal intensity and much less prominent fascicular pattern. Fibrocartilaginous periosteum is associated with a compressive load which typically occurs with the Achilles tendon when there is a prominent superior tuberosity. There were notable similarities in the structure of the entheses of the insertion of Achilles, patellar and supraspinatus tendons. The use of UTE sequences may also provide the opportunity to visualize early features of disease in the seronegative spondyloarthritides.

References

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