Tendon Imaging Using 3D Ultrashort TE Scanning

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Introduction

Ultrashort echo-time imaging (UTE) is a technique to image otherwise invisible short-T_2 components in tendons, ligaments, etc. [1]. 3D radial free-induction-decay (FID) sampling schemes can be used for volumetric UTE imaging with isotropic resolution [2]. 3D image data allow the extraction of non-planar slices for the visualization of complex anatomies, e.g., the course of tendons in a joint. Conspicuity of tendon tissue can be improved by creating images that contain short-T_2 components only, either by forming a difference image between the short-TE FID and a later echo, or by long-T_2 component suppression using preparation pulses [3]. This contribution demonstrates the potential of non-planar slice extraction from 3D UTE subtraction image data for tendon visualization in joints.

Methods

Figure 1(a) depicts a typical 3D UTE sequence. After a non-selective excitation pulse and a coil-dependent switching time, the readout gradient is ramped up, and the acquisition of the FID is started. Thus, k space is mapped radially starting at $k = 0$. After the FID, an optional gradient echo can be acquired. In order to ensure isotropic k-space coverage, projections are arranged in the 3D fashion depicted in Fig. 1(b) [4]. With echo times below 100 µs, this technique enables the detection of species with T_2 in the submillisecond range.

In-vivo data have been acquired on healthy volunteers, whose informed consent was obtained beforehand. Scanning was performed on clinical whole body scanners (Achieva, Philips Medical Systems) at 1.5 T and 3 T. Standard local receive coil arrays allowed T/R switching times of about 20 µs. A software extension enabled 3D radial FID scanning with immediate online image reconstruction. The excitation block pulse had a duration of 48 µs for a flip angle of 10°. FID acquisition was started at $TE_1 = 30$ µs. For a 3 T scan of the ankle, a subsequent echo was acquired at $TE_2 = 2.3$ ms, where fat and water spins are in phase. The data-acquisition window was 562 µs for the FID and 998 µs for the echo, FOV = 180 mm with a 192^3 matrix. 73728 projections were acquired with a repetition time of TR = 12.2 ms, resulting in a total scan duration of 15 minutes. A coil array consisting of two elliptical surface coils (14 × 17 cm) was used for signal reception. For a 1.5 T scan of the hand, the later echo was acquired at the fat-water-in-phase echo time $TE_2 = 4.6$ ms. The data-acquisition window was 686 µs for the FID and 1158 µs for the echo, FOV = 170 mm with a 176^3 matrix. 46464 projections were acquired with a repetition time of TR = 8.9 ms, leading to a total scan duration of 7 minutes. A 3-element coil array (coil diameter 12 cm) was used in these scans.

A reformatting tool was used to extract curved subvolumes from the isotropic 3D image data [5].

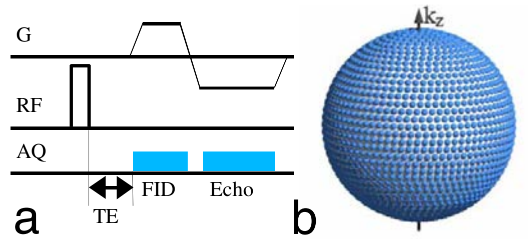

Figure 1: 3D UTE sequence. a) Ultrashort TE sequence applying a non-selective excitation pulse and dual echo (FID/echo) sampling. b) Isotropic distribution of radial profiles in 3D k space.

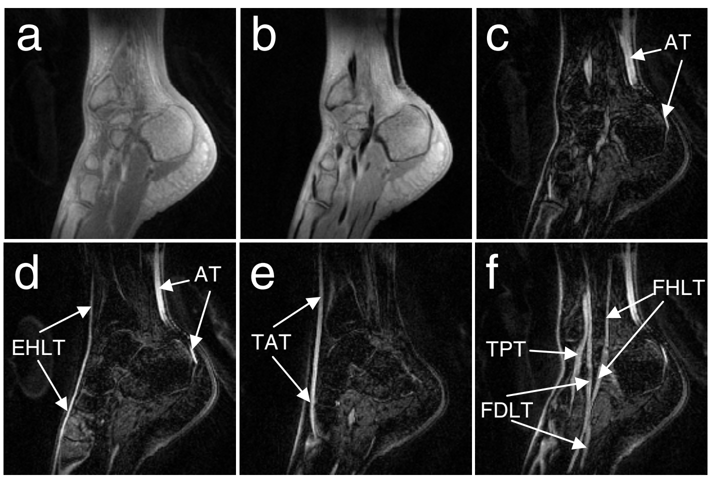

Figure 2: 3D UTE dual-echo data of the right ankle at 3 T. (a) FID image obtained at TE = 30 µs. (b) Echo image at TE = 2.3 ms. (c) Difference image highlighting short-T_2 components. (d-f) Reformatted difference images. The course of several tendons can be followed: Achilles tendon (AT), extensor hallucis longus (EHLT), tibialis anterior tendon (TAT), flexor digitorum longus tendon (FDLT) crossing the flexor hallucis longus tendon (FHLT), tibialis posterior tendon (TPT).

Results

Figure 2 shows images from a 3D dual echo UTE scan at 3 T. While the FID image (a) yields high signal from all tissues, tendons and cortical bone show hardly any signal at the later echo time (b). A subtraction image highlights short-T_2 components only (c). Extraction of different curved subvolumes allows the visualization of the complete path of various tendons through the ankle (d-f).

Figure 3 shows image data from a scan of the right hand at 1.5 T. From the FID (a) and echo data (b), a 3D subtraction data set was created (c). Again, non-planar subvolumes have been extracted. These are displayed as 3D views onto the curved hyperplane, once from above the hand showing the finger extensor tendons (d), once from below showing the flexor tendons (e).

Discussion and Conclusion

The combination of UTE dual echo imaging with 3D data acquisition allows the visualization of complex anatomical structures containing short-T_2 components, e.g. tendons. While high signal from tendon tissue can be obtained using 2D UTE imaging as well, reformatted 3D UTE image data facilitates the delineation of the complex course of tendons in joints. This can be helpful for the assessment of 3D tendon anatomy, e.g. for the diagnosis of injuries or abnormalities, or the assessment of functionality after tendon transfer [6].

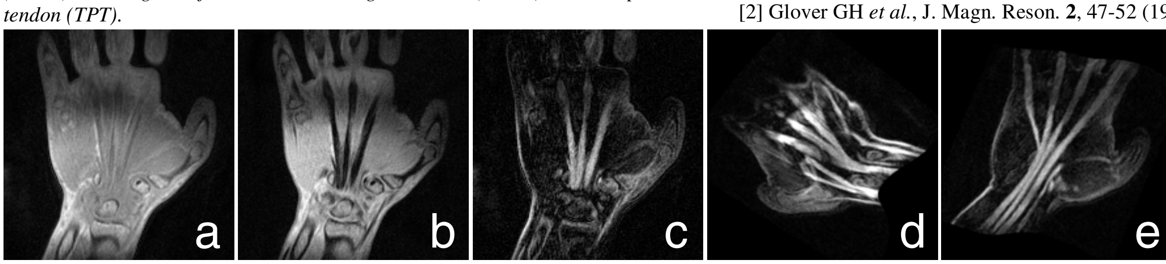

Figure 3: 3D UTE dual-echo data of the right hand acquired at 1.5 T. (a) FID image at TE = 30 µs. (b) Echo image at TE = 4.6 ms. (c) Difference image highlighting short-T_2 components. (d,e) Reformatted hyperplanes containing tendons: (d) Top view on finger extensor tendons. (e) Bottom view on finger flexor tendons.

References

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