Postoperative Evaluation of Cruciate Ligament Reconstruction Involving Metallic Implants Using 3D Ultrashort TE Imaging

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Introduction

Ultrashort echo-time (UTE) imaging offers the possibility to visualize signal components exhibiting short T_2, as present in tendons, ligaments, and other highly ordered tissues [1]. Due to the short TE and high-bandwidth sampling, UTE imaging is furthermore rather insensitive to susceptibility effects and artifacts caused by metal implants or paramagnetic particles [2]. These two characteristics in combination with the 3D isotropic image data reconstructed from 3D radial UTE scans [3,4] make it the ideal tool to image the knee after cruciate ligament reconstruction. The tendon used for reconstructing the ligament can be visualized despite its short T_2, its complete path can be followed by extracting curved slices from the 3D data, and the artifact level close to the metal fixations is low. In this study, the 3D UTE technique is applied at 1.5 T to image a reconstructed anterior cruciate ligament (ACL) several years after surgery.

Methods

Figure 1(a) depicts the 3D UTE sequence. After a non-selective excitation pulse and a coil-dependent switching time, the FID is sampled. *k* space is mapped radially starting at *k* = 0. After the FID, a gradient echo is acquired. *k* space is covered in the 3D fashion shown in Fig. 1(b) [5]. With echo times TE_1 below 100 µs, the detection of species with T_2 in the sub-millisecond range is possible.

In-vivo data were acquired from a patient 7 years after ACL reconstruction following a complete ACL rupture. For reconstruction, parts of the semitendinosus tendon had been extracted and threaded through drilled tunnels in the femur and tibia. A metal button and a disc had been used to fixate the tendon.

Scanning was performed on a clinical whole-body scanner at 1.5 T (Achieva 1.5T, Philips Medical Systems). A 2-element local receive coil array (coil diameter 12 cm) allowed fast tuning within about 50 µs. A software extension enabled 3D radial FID/echo scanning with immediate online reconstruction. The excitation block pulse had a duration of 48 µs for a flip angle of 10°. FID acquisition was started at TE_1 = 60 µs, an echo was acquired at the first water-fat-in-phase echo time TE_2 = 4.6 ms. The sampling window was 686 µs for the FID and 1158 µs for the echo. The FOV was 160 mm with a 160^3 matrix. 51200 projections were acquired with a repetition time of TR = 10.0 ms. Difference images highlighting only short-T_2 components were calculated by subtracting the echo from the FID image using a scaling factor. Reformatting was applied to extract curved subvolumes from the isotropic 3D image data [5].

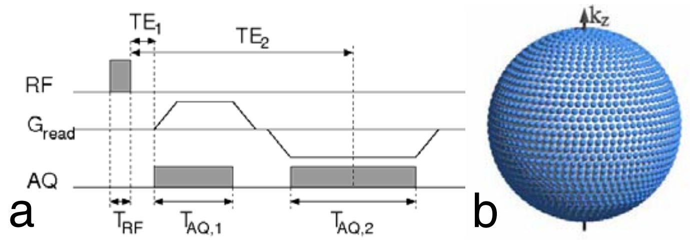

Figure 1: 3D Ultrashort TE "dual echo" sequence. a) After a non-selective excitation pulse, the FID is sampled at the echo time TE_1. A later gradient echo is acquired at TE_2. b) Distribution of radial profiles in 3D k space.

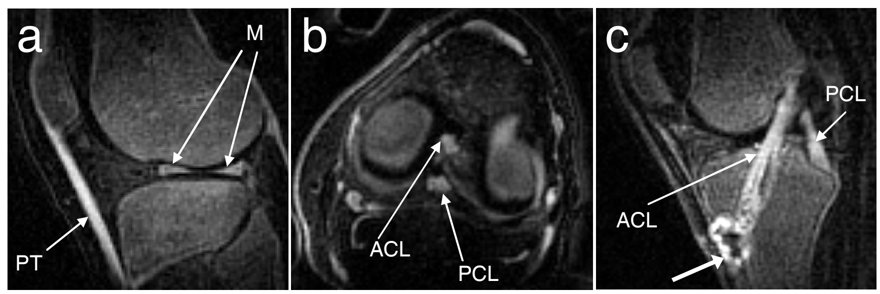

Figure 2: 3D UTE difference image data of the knee at 1.5 T. (a) Sagittal slice highlighting the patellar tendon (PT), the meniscus (M), and short-T_2 species in the bones. (b) Transverse slice showing ACL, PCL, and various tendons passing through the knee region. (c) Reformatted view showing the lower part of the reconstructed ACL and the natural PCL. The metal disk used to fixate the reconstructed ACL appears as an artifactuous region in the difference image (arrow).*

Results and Discussion

Figure 2 shows selected slices of the 3D difference image data set. Short-T_2 species in tendons and ligaments are highlighted, but also susceptibility artifacts close to the tibial metal implant (c). The difference image shows the tendon used for ACL reconstruction. For an almost artifact-free visualization of the surroundings of the metal implants, the FID image can be used. Figure 3 shows reformatted FID and echo images of a dual echo (FID/echo) scan in comparison with an X-ray exposure. The two different MR contrasts, offered by the FID and echo image, in combination with the isotropic 3D resolution allow assessment of the tendon condition over its complete length. Figure 4 shows the reduction in artifact level close to the metal implant at ultrashort TE.

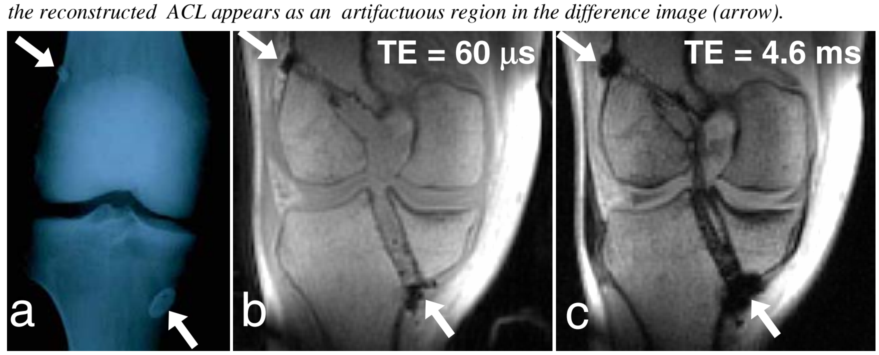

Figure 3: X-ray exposure and reformatted 3D UTE FID/echo data. (a) X-ray exposure showing the metal implants (arrows). (b) FID data (TE = 0.06 ms). Reformatted view showing the complete length of the drilled tunnel and the tendon used for ACL reconstruction. (c) Same view for the echo data (TE = 4.6 ms). The arrows indicate the positions of the metal implants.

Conclusion

3D UTE imaging is superior to other imaging techniques in avoiding susceptibility-induced artifacts. Combined with its ability to visualize short-T_2 components in tendons, 3D UTE imaging is a good choice for volumetric imaging of ligament reconstruction involving metal implants. The technique also has the potential to reduce susceptibility artifacts around larger metal implants used in other musculoskeletal interventions.

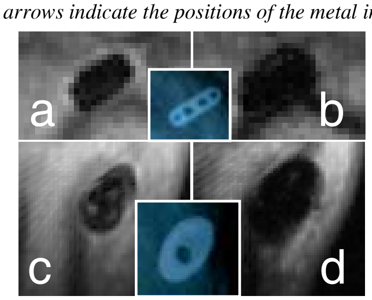

Figure 4: Metal implants used for fixation. (a,b) Femoral endo button. (c,d) Tibial disc. The insets show the implants in an X-ray exposure. The FID image (TE = 0.06 ms) has a small metal artifact around the implants (a,c), which is much more pronounced in the echo image (TE = 4.6 ms) (b,d).

References

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