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

J. Rahmer and P. Börnert
Philips Research Europe, Hamburg, Germany

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 TE1 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 semitendinous 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 TE1 = 60 µs. An echo acquisition was already performed at the first water-fat-in-phase echo time TE2 = 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 160×160×160 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. Reformating was applied to extract curved subvolumes from the isotropic 3D image data [5].

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. 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 FID image can be used. 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.

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.

References