High Contrast 3D IDEAL Ultrashort TE (UTE) Imaging

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Target audience: Physicists who are interested in UTE imaging

Purpose:MR imaging with ultra-short echo times (UTE) dramatically enhances signal from short T2 species (1). Short T2 components are separated from longer components by either: 1) long T2 suppression through magnetization preparation, 2) subtraction of a later echo from the initial echo or 3) fitting a T2* decay curve with a multicomponent model. The latter two methods fail in regions of elevated B0 inhomogeneity. Here we report a new 3D IDEAL-based UTE imaging method which uses least squares fitting to explicitly calculate and compensate for B0 inhomogeneity while separating signal from short T2 (signal present only in first echo), long T2 species (signal present in all echoes), and fat.

Methods: A 3D UTE sequence was implemented on a 3T scanner (MR750, GE Healthcare, Waukesha, WI, USA) utilizing a short selective pulse to immediately followed by multi-echo 3D radial ramp sampling for data acquisition. IDEAL allows one to model various signal contributions and B0 inhomogeneity simultaneously. We developed the following signal equation for a three species signal model (short T2, all other water, and fat):

$$s(t) = (\rho_{T2} e^{-t/T2} + \rho_W + \rho_F C_F(t)) e^{-\varphi t} \quad \text{Equation 1}$$

where ρ_{T2} represents short T2 species with negligible signal after the first echo, ρ_W represents long T2 water, ρ_F is fat with multi-peak chemical shift $C_F(t)$, and φ is off-resonance and T2* decay. Images were acquired for the entire knee joint and Achilles tendon of a healthy volunteer in separate 10 minutes scan time utilizing: five echoes acquired starting at 80µs with 1.8ms echo spacing, resolution=0.5mm isotropic, 16cm^3 FOV, BW=±125 kHz, flip=7°. Individual echo images were reconstructed and then processed by the IDEAL algorithm with the signal modeled in Equation 1.

Results: Figure 1 shows conventional UTE (top) and IDEAL-UTE (bottom) images for a human knee in the sagittal plane. Long T2 components are completely suppressed in the short T2 image provided by IDEAL-UTE. Compared to simple, conventional difference image on the top row, the short T2 image from IDEAL-UTE demonstrates a significant contrast increase from the menisci. In Figure 2, we compared performance of the previously described Inverted Double Half RF pulse (IDHRF) (2) used to null excitation of fat and longer T2 species with the IDEAL-UTE in the Achilles tendon. While IDHRF showed the desired suppression near the Achilles tendon, it fails in other areas (red arrows) due to errors in field inhomogeneity. The short T2 image of the IDEAL-UTE shows enhanced depiction of the Achilles tendon, other tendons not visualized in the IDHRF image, and uniform fat and water suppression over the entire joint. The fractions of short and long T2 components can also be obtained from water and short T2 images.

Fig. 1 (a) sagittal images of UTE short echo, (b) second echo, (c) subtraction , (d) IDEAL-UTE water image, (e) IDEAL-UTE fat image and (f) IDEAL short-T2 image. More distinct visualization of the bow-tie shaped (arrows) meniscus is seen in (f).

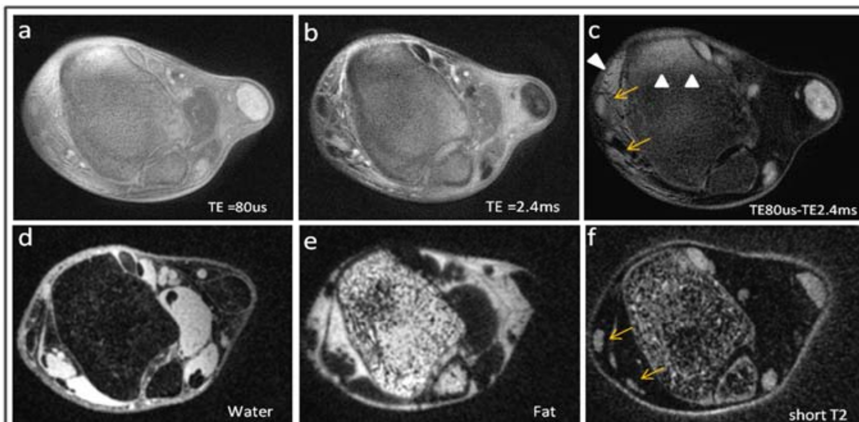

Fig. 2. Axial images of IDHRF UTE, (a) short TE, (b) second echo, (c) subtraction and (d) IDEAL UTE water image, (e) IDEAL fat image and (f) IDEAL short-T2 image. IDHRF UTE failed to suppress all bone marrow (arrow heads) and some tissue near the skin (arrows) which obscures anterior tendons.

Conclusion: The 3D UTE SPGR sequence with multi-echo acquisition and IDEAL reconstruction provides high contrast imaging of short T2 species despite B0 inhomogeneity while also robustly suppressing fat.

References

1. Robson, MD et al., J Comput Assist Tomogr 2003;27(5):825-846.
2. Al saleh, H et al., ISMRM 2011.