Comparison of long-T_2 suppression techniques for 3D Ultrashort Echo-Time Imaging

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Introduction

Ultrashort echo-time (UTE) imaging can be used to visualize short-T_2 species present in a variety of tissues, like tendons, ligaments, or cortical bone [1]. However, the signal in UTE images is often dominated by long-T_2 components. To selectively show only the short-T_2 signal components, different approaches have been proposed using appropriate magnetization preparation [1,2] or multi-echo techniques subtracting the long T_2 signal components [3]. In this work, 3D UTE imaging is performed with the main focus on musculoskeletal applications, to compare a magnetization preparation approach with the "dual echo" approach for long-T_2 suppression.

Methods

Imaging has been performed on a clinical 1.5 T scanner (Achieva, Philips Medical Systems) using a 3-element surface coil array (element diameter: 7.5 cm) with the aim to visualize short T_2 components in the ankle of healthy volunteers. A software extension allowed very short echo times, which were limited by the tune delay of the employed coil to 70 µs. The basic signal sampling sequence consisted of a non-selective excitation pulse and a 3D radial free-induction decay (FID) readout (cf. Fig.1). For all experiments, the same scan parameters have been used (128^3 matrix, FOV = 200 mm, excitation angle: 10°, angular sub-sampling: 50%, 24576 projections in total). The preparation sequence is illustrated in Fig. 1. Long-T_2 species were flipped into the transverse plane by a 90° low amplitude, long duration symmetric Sinc-Gauss (40 ms, 2 side lobes on each side) or block pulse (10 ms, not shown) and dephased by a successive crusher gradient. Both preparation pulses show good suppression of long T_2 components, with a T_2-cutoff of approximately 3.5 ms (M_z/M_0 = ½). A fat suppression sequence was performed afterwards. To increase scan efficiency, compared to existing approaches [2], multiple ultrashort TE readouts (n=8) were performed after magnetization preparation. A train of eight readouts has been found to be an optimal compromise between scan-acceleration and signal contamination caused by signal recovery (T_1) of the suppressed long T_2 components. In these experiments, TR was set to 4 ms, the preparation repetition interval to 250 ms, resulting in scan duration of 13 min for a 3D volume data set. For visualization, the reconstructed 3D image data was reformatted using the SoapBubble Tool [5]. For the "dual echo" approach no preparation was performed. In addition to the FID, a gradient echo was formed and sampled from the same transverse magnetization. The echo time TE_2 was set to 4.6 ms, where fat and water spins are in-phase at 1.5 T. Thus, for this sequence, TR increased to 7.3 ms resulting in a total scan time of 3 min. In all experiments volume shimming was applied to reduce off-resonance related effects. SNR was assessed in the region of the extensor digitorum longus tendon and Achilles tendon.

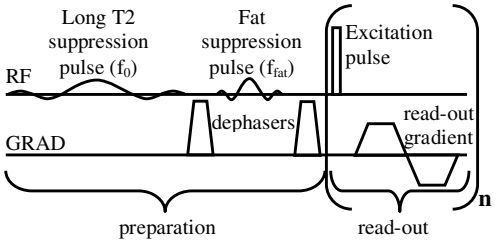

Figure 1: Scheme of UTE sequence using long T_2 and fat suppression based on standard preparation pulses

Results and Discussion

Figure 2 depicts a slice of a selected 3D "dual echo" data set of the right ankle (FID: Fig. 2a, echo: Fig. 2b). Figure 2c shows the difference image of Fig. 2a and 2b, highlighting the fast T_2 components. Results of the long-T_2 magnetization preparation sequence are shown in Fig. 3. Figure 3a shows data obtained employing only the T_2 preparation sequence. The remaining fat signal hampers the selective visualization of the short signal components. In Fig. 3b, fat suppression was applied additionally resulting in an excellent contrast underlining the necessity of the additional preparation. Tendons and periosteum become visible. Figure 3c shows a reformatted image of the 3D data set, visualizing main tendons along their path in the 3D volume. In contrast to the dual echo approach, applying long-T_2 and fat suppression yields the short-T_2 image without post-processing. However, off-resonance artifacts can degrade image quality, as visible at the top of Fig. 3b. The low bandwidth of the T_2 preparation pulse makes it sensitive to off-resonances, even though shimming was applied to reduce this complication. By using a block pulse of similar T_2-selectivity, off-resonance effects even increase. The difference images of the acquired dual echo data set show a better SNR of a factor of 2 in comparison to the magnetization prepared short-T_2 ones irrespective of using Sinc-Gauss or block pulses. This is contrary to the expectation that a difference image increases the noise level by a factor of sqrt(2) for the short T_2 components. We attribute this to the fact that preparation pulses have also an effect on short-T_2 components.

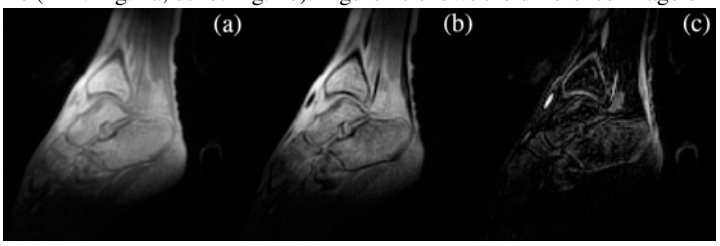

Figure 2: Selected slice of a 3D data set of the right ankle acquired with the "dual echo" method. (a) FID image, TE = 70 µs. (b) Echo image, TE = 4.6 ms, (c) difference of (a) and (b).

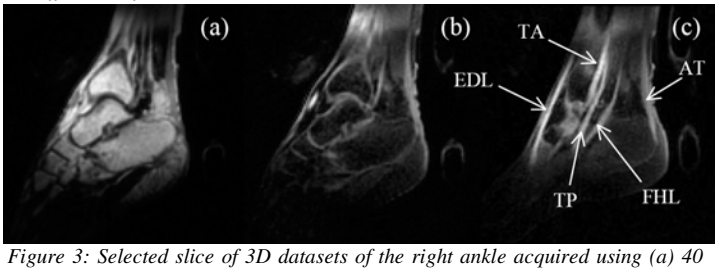

Figure 3: Selected slice of 3D datasets of the right ankle acquired using (a) 40 ms Sinc-Gauss T_2-preparation pulse, (b) T_2-preparation and fat suppression. (c) Reformatted image of T_2-prepared and fat suppressed data. Abbr.: TA: tibalis anterior tendon; TP: tibalis posterior tendon; EDL: extensor digitorum longus tendon; FHL: flexor hallucis longus tendon; AT: Achilles tendon

Conclusion

Two approaches to enhance short-T_2 signal in 3D UTE scans were compared: a "dual echo" technique and a magnetization preparation technique. While magnetization preparation directly yields the desired image contrast, the "dual echo" scanning requires the formation of a subtraction image as a post-processing step. However, since the magnetization preparation approach has to use rather long T_1-related shot intervals between preparations, the "dual echo" technique is more time-efficient with respect to the total scan time. It is furthermore less sensitive to off-resonance effects and, interestingly, in the demonstrated data shows better short- T_2 component SNR.

References

[1] Robson MD, *et al*, J. Comp. Assist. Tomogr. 27, 825-846 (2003); [2] Larson PE, *et al*, Proc. ISMRM 13, 7861 (2005); [3] Rahmer J, *et al*, Proc. ISMRM 13, 1074 (2005); [4] Pauly JM, *et al*, Proc. SMRM 12, 145 (1992); [5] Etienne A, *et al*, MRM 48, 658 (2002); [6] Gurney P, *et al*, Proc. ISMRM 13, 787 (2005)