High-Resolution Ultrashort TE Imaging of the Human Wrist at 3 T

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Introduction

Imaging at ultrashort echo times (UTE) in the order of 100 µs allows the detection of protons exhibiting very short T2 relaxation times. These are typically found in ordered tissue like tendons, ligaments, or the periosteum [1]. Due to the timing constraints to be met, UTE imaging is very hardware demanding and critical with respect to the signal-to-noise ratio (SNR). To avoid image blurring of fast relaxing species, short data acquisition windows have to be used resulting in a low SNR. The combination of UTE imaging and sub-millimeter/microscopic resolution further aggravates the SNR problem due to the small voxel size. This contribution describes the use of high field strength, advanced receive coil technology, and data correction methods to improve the SNR in 2D UTE applications to image the human wrist.

Methods

For slice selection in 2D UTE imaging, dedicated self-refocused half-Sinc RF pulses are used. Two measurements with alternate slice selection gradient are averaged to yield proper slice selection for each k-space projection [2]. The free-induction decay (FID) is sampled as fast as possible after excitation using a radial k-space trajectory, which samples the center of k-space first. Signal sampling starts immediately at the beginning of the radial read-out gradient ramp-up. The echo time (TE) is defined as the time between the magnetic center of the RF pulse, which coincides here with the end of the RF waveform, and the start of the data sampling near k = 0. The use of different RF coils for transmission and reception limits this time in the current implementation. Thus, the transmit body coil has to ring down for about 50 µs for safety reasons and subsequently the scanner allows to activate the receive coil array [3], which has a tune delay of 50 µs. Since sampling is already performed on the rising slope of the gradient, imperfections due to eddy currents and finite amplifier response have a strong effect on image quality, resulting in low frequency component distortions. Therefore, the actual readout-gradient shape has been measured and deviations from an ideal trapezoidal shape have been taken into account using a simple analytical eddy-current model to calculate of the actual k-space trajectory. Moreover, prior to gridding, density correction was performed to compensate for the non-isotropic radial k-space sampling pattern. Image reconstruction and coil combination, which is performed using the sum of squares approach, are fully integrated into the scanner reconstruction software.

Experiments were performed on phantoms and healthy volunteers using a 3 T whole-body system (Gyroscan Intera, Philips Medical Systems) equipped with a four-element surface coil array for reception (element ∅: 50 mm) [3] and a body coil for excitation. Multi-slice radial UTE imaging (slice thickness 3 mm, 512×512 matrix, FOV 250 mm) was performed, requiring 2×512 measured projections per slice. Repetition time (TR) and flip angle were set to 25 ms and 10°, respectively. TE ranged between 0.1–1.0 ms, while the acquisition window was restricted to 500 µs to limit T2 blurring.

Results and Discussion

Different structures of the wrist anatomy can be visualized with a high SNR and high spatial resolution. One slice of a multislice measurement at different echo times is displayed in Fig. 1. At TE = 100 µs, signal from finger flexor tendons (arrows) is visible, which shows no intensity at conventional echo times of 1 ms. Other anatomical structures show high signal in the UTE image and low intensity in the longer TE images. Strong water-fat artifacts appear in the 1 ms images, which are not present in the UTE image, because there is no time to accumulate off-resonance-related phase errors. Especially in high-field applications, chemical shift decomposition can degrade image quality at echo times usually considered as short (1 ms).

The application of a dedicated receive-coil array resulted in a sufficiently high SNR for the small voxel size and sampling window used. It is important to note that these experiments were performed on a standard clinical scanner (no hardware modifications). However, improvements in the timing and duration of the transmit-receive switching process will allow the reduction of TE below 100 µs for dedicated receive-only coils.

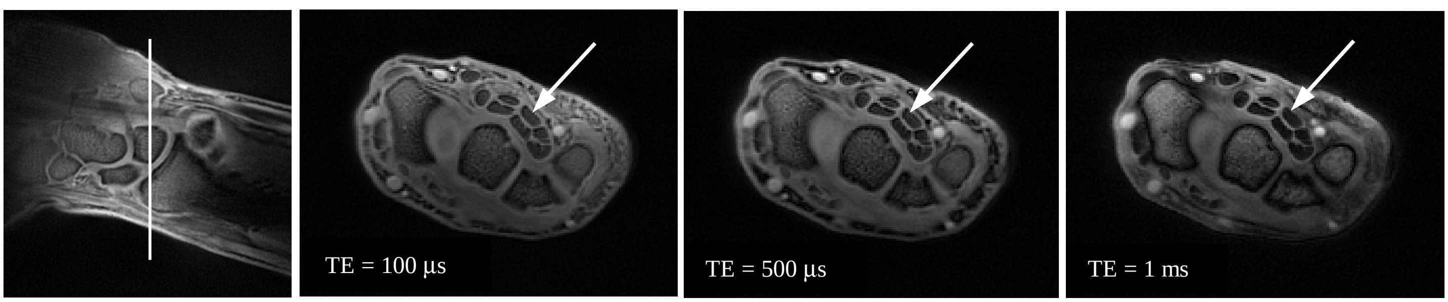

Fig. 1: UTE wrist images using a four-element phased surface-coil array at 3 T. The coronal image was recorded at TE = 100 µs. The line indicates the slice position of the transverse views. The flexor tendons (arrows) belong to the tissues which only at ultrashort echo times contribute to the signal.

Conclusion

This contribution shows the feasibility of high-resolution multi-slice 2D UTE imaging for the visualization of anatomical structures of the human wrist at 3T. At ultrashort echo times, signal from fast-relaxing tissue components such as tendons can be detected and contributes a new, short-T2 contrast. Further studies have to show the diagnostic value of this contrast. The high SNR obtained using high field strength and multi-element surface-coil technology furthermore opens the door to the application of parallel imaging techniques for measurement time reduction in the future.

References.
[1] Gatehouse P, *et al.*, Clin. Radiol. **58**, 1-19 (2003).
[2] Pauly J, *et al.*, Proc. SMRM, 28 (1989).
[3] Leussler C *et al.*, Proc. ISMRM **11**, 2370 (2003).