3D Ultrashort Echo-Time Imaging using a 32 Channel Receive Array

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Introduction

3D radial free-induction-decay (FID) sampling schemes can be used for ultrashort echo-time imaging (UTE) [1]. With echo times in the order of 100 µs and below, this technique enables the detection of species with T_2 in the submillisecond range. Short-T_2 components are found for instance in highly ordered tissues of the musculoskeletal system, but can also be indicative of pathologies like hemachromatosis of the liver, aortic plaque, or degenerative diseases of the spine [2]. 3D UTE imaging yields isotropic resolution and avoids slice selection problems related to the half-Sinc excitation technique used for 2D UTE imaging [3]. However, long scan times necessary for the acquisition of high-resolution 3D data are prohibitive for some applications, e.g., breathhold scans. Using a large number of local receive coils [4], the signal-to-noise ratio (SNR) can be increased considerably. Thus, scan time reduction using strong angular undersampling is possible without extensively compromising the image quality. In this contribution, we demonstrate the acquisition of isotropic 3D data of the abdomen in a single breathhold using 3D radial FID scanning with 32 receive coils.

Methods and Results

Figure 1 depicts a typical 3D UTE sequence. After a non-selective excitation pulse and a transmit-receive switching time that determines the minimal TE, the readout gradient is ramped up, and the acquisition of the FID is started. *k* space is mapped radially starting at $k = 0$. To achieve isotropic *k*-space coverage [5,6], projections are aligned in the 3D fashion depicted in Fig. 1. The center of *k* space is strongly oversampled, so that density compensation has to be performed before reconstruction, which involves 3D gridding. Magnitude images are combined using coil sensitivity maps derived from low-pass filtered image data [4,7].

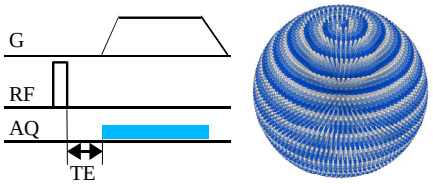

Figure 1: Left: 3D ultrashort TE sequence applying a non-selective excitation pulse and FID sampling. Right: 3D coverage of k space using an isotropic arrangement of radial projections. Different colors correspond to inter-leaved subsets of projections.

In-vivo data have been acquired on healthy male volunteers (age ~32) whose informed consent was obtained beforehand. Examinations were performed on a 1.5 T scanner (Achieva, Philips Medical Systems) equipped with a 32-element whole-body coil array. Two sets of 4×4 coils were positioned below and on top of the volunteer, respectively. After body coil excitation, RF energy ring down and receive-coil tuning for signal reception took 180 µs. The excitation block pulse lasted 84 µs. FID acquisition for minimal TE was started directly after tuning the receive coils, i.e., at TE = 180 µs after the end of the RF pulse. The data-acquisition window was 420 µs, FOV was 400 mm^3 with a 144^3 matrix, and the excitation angle was 15°. *k* space has been undersampled by factors of 10 and 15 with respect to the angular Nyquist limit, which is πN^2 for FID sampling to a matrix of size N^3. Figure 2 shows slices of three 3D data sets of the abdomen acquired using 3D radial FID sampling with the 32-coil array. The top and center row show short-TE data acquired in 15-second breathhold scans with and without SPIR fat suppression, respectively (TE = 180 µs, TR = 2.4 ms, angular subsampling factor 10). The bottom row shows fat/water in-phase data acquired in a 30-second breathhold (TE = 4.6 ms, TR = 7 ms, subsampling factor 15).

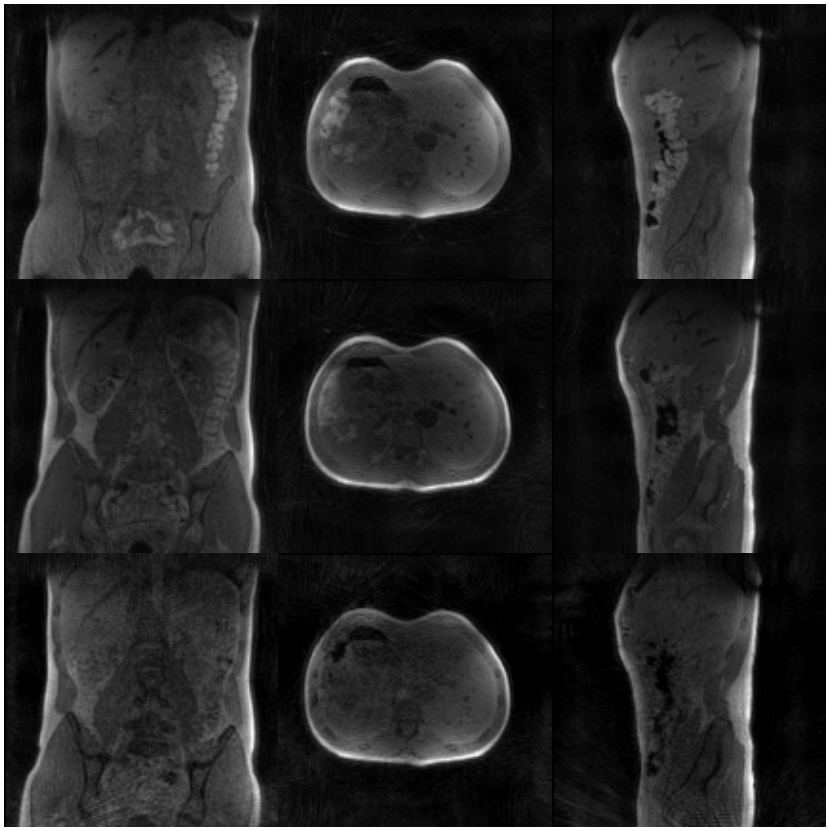

Figure 2: Selected slices of isotropic 3D UTE data sets of the abdomen, acquired in breathhold scans with 32 channels. Top row: fat suppressed, TE = 180 µs. Center row: no fat suppression, TE = 180 µs. Bottom row: no fat suppression, TE = 4.6 ms (in-phase).

Discussion and Conclusion

Despite high angular undersampling factors, images show only few subsampling artifacts (streaking). Using sensitivity maps derived from the coil images, good suppression of streaking in areas away from the individual coils is achieved. Image uniformity is not perfect, but is expected to improve when an additional body coil image is acquired as reference sensitivity map. The short-TE images in Fig. 2 (upper two rows) show signal at bone structures such as the pelvis, that is already decayed in the in-phase images (bottom row). Also, colon contents become clearly visible at short TE, with an increased contrast in the fat suppressed scans. The long TE necessary for in-phase acquisition leads to off-resonance related phase accrual, which, together with the higher angular subsampling in this scan, degrades the FID image quality. This prohibits the calculation of reliable difference images, that would be useful to bring out short-T_2 contrast. FID and subsequent in-phase-echo sampling in a single scan, with appropriate phase correction for the echo projections, can resolve this problem. However, due to data size limitations, this method has not been applied here.

Parallel imaging using a 3D radial FID sampling scheme yields high quality isotropic data at ultrashort echo times. Massive angular undersampling reduces the acquisition time strongly, so that a complete anatomic region can be acquired with large volume coverage in a single breathhold scan. In the abdominal region this can be useful for looking at short-T_2 components in the lumbar spine, the liver, or potentially for screening for aortic plaque. In the future, higher undersampling factors are expected to be possible by making better use of coil sensitivity information through the application of a SENSE or GRAPPA reconstruction.

References

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