3D Ultrashort Echo-Time Imaging of the Head

J. Rahmer[1], P. Börnert[1], H. Eggers[1]

[1]Tomographic Imaging Systems, Philips Research, Hamburg, Germany

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, the detection of species with transverse relaxation times T_2 in the submillisecond range is possible. 3D UTE imaging yields isotropic resolution and avoids slice selection problems related to the half-Sinc excitation technique used for 2D UTE imaging [2]. Beside highly ordered tissues of the musculoskeletal system, a number of tissues in the head contain short-T_2 components and thus yield increased signal in UTE images, among them white matter, the pituitary gland, and dentine [3]. Short echo times also reduce susceptibility issues in the nasal sinuses. Furthermore, pathologies like demyelination or plaque formation lead to changes in short-T_2 signal [3]. Moreover, UTE sequences can be used to reduce signal dropout induced by iron loaded contrast agents, e.g. used to trace labeled stem cells in molecular imaging. In this contribution we demonstrate the utility of 3D radial FID sampling for the acquisition of isotropic 3D head data sets with short-T_2 contrast in a single measurement.

Methods

Figure 1 depicts a typical 3D UTE sequence. After a non-selective excitation pulse and a transmit-receive (T/R) switching time that determines the minimal TE, the readout gradient is ramped up, and the acquisition of the FID and an optional subsequent echo is started. For the FID, *k* space is mapped radially starting at $k = 0$, while the echo is acquired in a standard fashion. In order to achieve isotropic *k*-space coverage [4], projections are aligned in the 3D arrangement depicted in Fig. 1. The center of *k* space is heavily oversampled so that density compensation has to be performed before reconstruction, which is done via 3D gridding. The acquisition of an echo image after the FID allows the generation of reliable difference images. Absolute and linear phase correction has been applied to the echo profiles to compensate off-resonance effects and gradient non-idealities [5]. Fat suppression using SPIR pulses (spectral presaturation using inversion recovery) or other magnetization preparation schemes are also feasible.

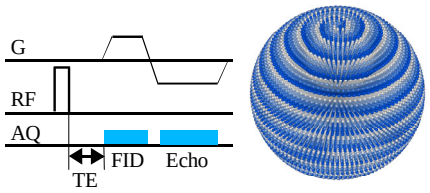

Figure 1: Left: 3D ultrashort TE sequence applying a non-selective excitation pulse. One readout acquires an FID and a subsequent echo. Right: 3D coverage of k space using an isotropic arrangement of radial projections. Different colors indicate interleaved subsets of projections.

In-vivo data have been acquired on healthy volunteers (age ~32) whose informed consent was obtained beforehand. Scanning was performed on a clinical 3 T whole body scanner (Intera, Philips Medical Systems) using a T/R head coil with a T/R switching time of 80 µs. Using a software extension, immediate online-reconstruction of the FID and echo image was available. The excitation block pulse had a duration of 84 µs. FID acquisition was started TE_1 = 80 µs later, while the echo was acquired at TE_2 = 2.3 ms, where fat and water spins are in phase at 3 T. The data-acquisition window was 534 µs for the FID and 880 µs for the echo, FOV = 250 mm^3 with a 176×176×176 matrix, and the excitation angle was 15°. 61952 projections were acquired with a repetition time of TR = 8.6 ms. For fat suppressed images, a SPIR pulse was shot every 16 excitations.

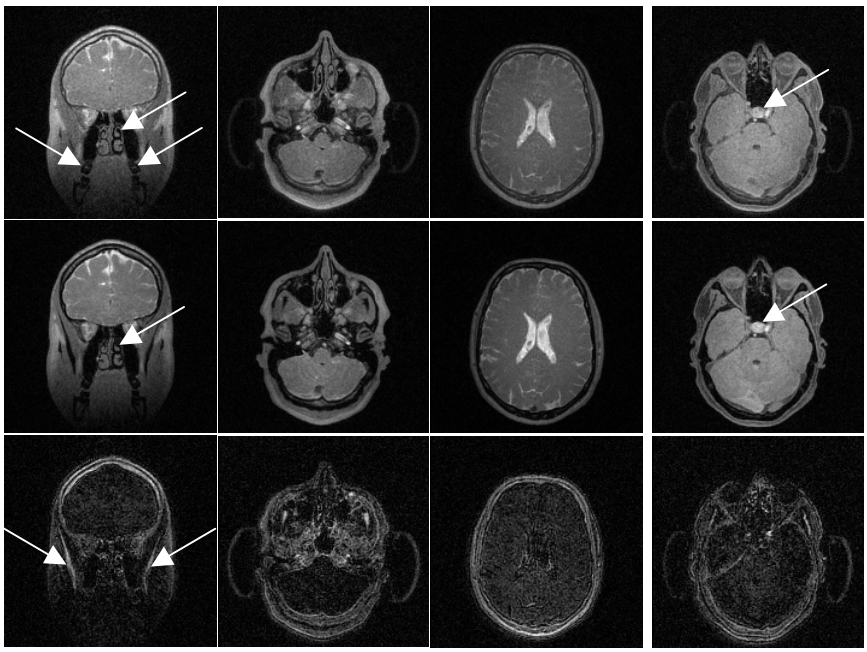

Figure 2: Selected slices of two 3D data sets of the head. The upper row shows FID images acquired at TE = 80 µs, the center row displays in-phase echo images (TE = 2.3 ms), and the bottom row shows difference images of the two. Images in the last column have been acquired with SPIR fat suppression, the first three columns belong to data without fat suppression.

Results and Discussion

Figure 2 shows slices of head data acquired without fat suppression in the first three columns and with fat suppression in the last column. The upper row shows FID images acquired at TE_1 = 80 µs, whereas the center row displays in-phase echo images at TE_2 = 2.3 ms. The bottom row shows difference images between the two. The coronal slices in the first column reveal short-T_2 components in the bone structures as well as a slight short-T_2 contrast in the brain matter, as visible in the difference image. In addition, the FID image shows more detail close to the nasal septum than the echo image (arrows). Furthermore, good signal from dentine is obtained in the FID image (lower arrows). The difference image also reveals short-T_2 components in the temporal muscles (arrows). The second column shows transverse slices with good short-T_2 contrast from the skull. Note that the plastic of the ear protection is visible in the FID and difference image. The difference image of the transverse view in the third column reveals short-T_2 components in the brain matter, while there is no short-T_2 contrast in the CSF in the lateral ventricles. In the fat suppressed image in the last column, both the FID and the echo have high signal from the pituitary (arrows).

Conclusion

3D radial FID sampling allows ultrashort-TE imaging with isotropic resolution. Using difference images with a later echo, a short-T_2 contrast can be visualized. With 3D datasets, the complete head anatomy is accessible, what can be useful for screening for neurodegenerative diseases that cause changes in short-T_2 contrast. The problem of rather long acquisition times required by 3D radial scans, which can be prohibitive for acquiring high resolution data, can be addressed by applying parallel imaging techniques in the future.

References

[1] Glover GH *et al.*, J. Mag. Res. **2**, 47-52 (1992). [2] Pauly J *et al.*, Proc. SMRM, 28 (1989). [3] Gatehouse PS, Bydder GM, Clin. Rad. **58**, 1-19 (2003). [4] Wong S *et al.*, Mag. Res. Med. **32**, 778-784 (1994). [5] Rasche V *et al.*, Mag. Res. Med. **34**, 754-761 (1995).