3D radial bUTE

C. Diwoky[1], and R. Stollberger[1]
[1]Institute of Medical Engineering, Graz University of Technology, Graz, Austria

Introduction

Fully balanced steady state free precession (bSSFP) acquisitions are known as the most efficient pulse sequences in the perspective of SNR per time. For high-field systems with higher resonance offsets and for imaging parameters resulting in longer repetition times the applicability of bSSFP is limited by banding artefacts. For a given scanning regime the shortest possible repetition time (TR) is therefore crucial to minimizing these artefacts. For high resolution imaging with sub-millimetre voxels the high SNR/time of balanced sequences would be particular valuable but with small FOV's the TR increases in dependence on the power of the gradient system. To overcome or improve this limitation we propose a balanced 3D-radial sequence, combined with properties known from ultra-short-time-to-echo (UTE) pulse-sequences.

Material and Methods

For the 3D bUTE sequence, the readout of the signal was changed as given in Fig.1. Half echoes are acquired during gradient switching with non-equidistant k-space sampling. Within one TR periode two signals (the bUTE FID and bUTE LE) will be sampled on a specific trajectory position. These signals can be used for two different images or can be combined for improved SNR. RF-excitation is done by a hard-pulse of 0.2ms duration. Reconstruction was performed with a conventional re-gridding procedure using a Kaiser-Bessel filter and Voronoi density compensation. The sequence was implemented on a 3T clinical system. The properties of the proposed sequence were investigated with phantom measurements and in-vivo experiments.

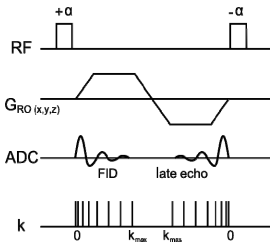

Fig. 1: Pulse diagram of the proposed bUTE approach.

Phantom: Gd-DTPA (Magnevist) and a SPIO contrast agent (Resovist) were used to get tissue-like T1/T2 times within Agar. Images were acquired with the new sequence and for comparison with a conventional echo-centered 3D-radial bSSFP sequence. The SNR was calculated for the bSSFP, bUTE FID, bUTE LE as well as the combined sum-of-squares image (bUTE AV). These values were used to compare the contrast between the phantom samples.

In-vivo: To assess the performance of the bUTE sequence in-vivo, a 3D high-resolution scan (voxel size 200µm³) was performed. The animal scan was realized in accordance to our local steering committee on an anesthetized WT-mouse within scan duration of about 7min.

Pulse sequences: The scans were performed with a wrist-coil for the phantom and a 2-CH surface coil for the in-vivo measurements.

bSSFP phantom: TR=6.26ms; TE=TR/2; FA=40°; under-sampling (US) ratio=0.64; matrix=192; FOV=80mm; NEX=1; phase cycles 2; scantime=5:42min.; bUTE phantom: TR=4.08ms; TE_{FID}=100µs; TE_{LE}=3.58ms; FA=40°; US ratio=0.64; matrix=192; FOV=80mm; NEX=1; phase cycles 2; scantime=6:24min.; bSSFP in-vivo: TR=8.62ms; TE=TR/2; FA=20°; US ratio=0.64; matrix=192; FOV=38mm; NEX=1; phase cycles 2; scantime=6:46min.; bUTE in-vivo: TR=4.44ms; TE_{FID}=100µs; TE_{LE}=3.76ms; FA=20°; US ratio=0.64; matrix=192; FOV=38mm; NEX=1; phase cycles 2; scantime=6:58min.

Results

The contrast of the bUTE FID and late echo bUTE LE differ minimally and the combined signal behaviour of FID and LE is comparable with the one acquired with the echo-centred conventional bSSFP (Fig.2 and 3). For very high isotropic resolutions (e.q. of 200µm) TR can be kept below 4.5ms (with 36mT/m, 100 mT/(m*ms), BW= 210Hz/pixel) compared to 8.7ms for the echo-centered bSSFP. In-vivo experiments (Fig. 4) showed artefact free images of a living mouse with isotropic resolution of 200µm.

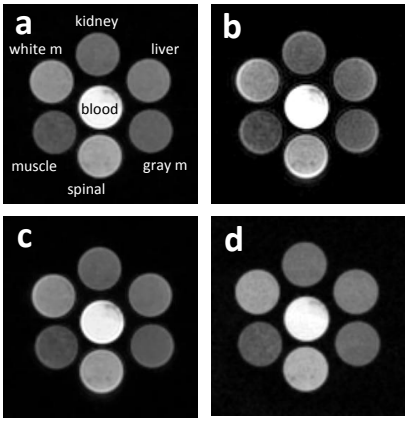

Fig.2: Phantom images of (a) bUTE FID, (b) bUTE LE, (c) bUTE AV and (d) for comparison the echo-centered bSSFP. The averaged SNR gain of bUTE AV compared to bSSFP is 20%.

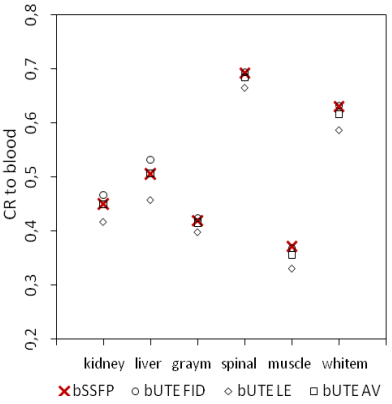

Fig.3: The contrast ratios (CR) between blood and 6 different tissue types show comparable behaviour for the bUTE and bSSFP acquisition.

Discussion

The bUTE approach seems to be a well suited candidate for balanced high resolution imaging even at high field strength. The more efficient sampling of the steady-state magnetization leads to a SNR/time gain (about 20% within this study) and the short TR reduces macroscopic banding artefacts as well as intra-voxel signal loss caused by the phase reversals of the bands [1,2]. The reduction of TR of the bUTE sequence is even more pronounced for higher resolution in comparison to conventional implementation. In principle some artifacts could occur from eddy currents and gradient delays, but compensation techniques [3] before and after the 2nd gradient lobe address this problem to a high extend. The signal behavior for the tissue-phantoms seems to be comparable to standard echo-centered bSSFP acquisitions. The contrast options for particles with short T2* will be investigated in future work.

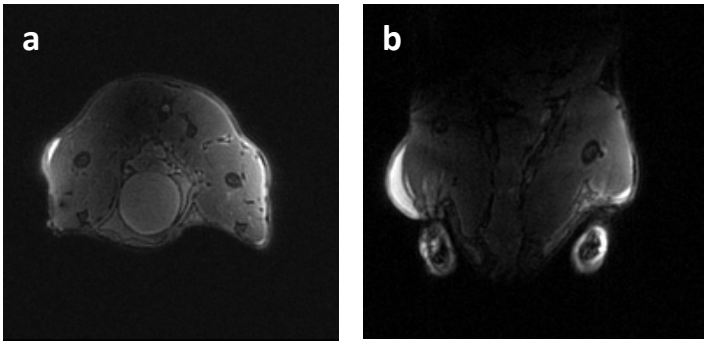

Fig.4: In-vivo isotropic 200µm³ scans acquired on a 3T clinical scanner within 7min acquisition time. bUTE transversal (a) and coronal (b) reconstructed images present artefact free, high SNR images. No banding is present in the 4,44ms-TR bUTE acquisition.

References

[1] Scheffler K., Henning J., *MRM* 2003; 49:395-397. [2] Lebel M.R. *et al.*, *MRM* 2006; 55:583-591. [3] Peters D.C. *et al.*, *MRM* 2003; 50:1-6.