Multi echo spiral imaging : Optimized k-space trajectories for T2* quantification.

N. Pannetier[1,2], M. Tachrount[1,2], C. Segebarth[1,2], E. Barbier[1,2], and L. Lamalle[3]
[1]Inserm, U836, Grenoble, France, [2]Université Joseph Fourier, Grenoble Institut des Neurosciences, UMR-S836, Grenoble, France, [3]IFR n°1, INSERM, Grenoble, France

Introduction

Effective and theoretical k-space trajectories differ due to eddy currents or gradient hardware imperfections. This is especially critical in fast imaging techniques using high gradient slew rates and amplitudes, with possibly complex k-space acquisition schemes (e.g. spiral, twisted projection). Although k-space trajectory calibration can be used to avoid distortions in reconstructed images, it is highly desirable to produce an effective trajectory as close as possible to the theoretical one. In particular, in multi-echo spiral imaging or in fast spiral spectroscopic imaging [1], it is important to reproducibly sample the k-space center at each echo time. The k-space translation vector separating start and end points of the spiral trajectory must thus be properly compensated for by an appropriate refocusing trajectory segment. In this study, we propose a fast two-step approach to obtain a well-refocused, multi-echo, spiral trajectory, and apply the latter to derive T_2* maps in glioma bearing rats.

Material and Methods

The proposed optimization scheme consists in 2 steps:
1) Using a convenient calibration technique [2], measure the effective multi-echo trajectory obtained by playing repeatedly the theoretical gradient waveforms. Estimate the difference between effective and theoretical trajectories as the measured translation vector between first and last points of the multi-echo readout.
2) Compute a new trajectory, taking into account in the refocusing part of each echo the measured translation vector, and use the associated gradient waveforms to acquire images.

MRI protocol: Acquisitions were performed at 7T (Bruker BioSpec Avance III) using volume/surface cross coils. Spiral-out trajectories were designed to sample a 128x128 matrix and a 30x30mm² FOV, with 16 interleaves. Eleven gradient echoes were acquired on a long T_2* phantom (signal to noise ratio was too low after 11 echoes). A short refocusing trajectory was derived taking into account the maximum gradient slew rate (~5664 mT/m/ms) and the gradient waveform dwell time (8µs). In this first implementation, we applied a same average refocusing correction to each echo. With this calibrated sequence (same geometry, T_R=1500ms, 1mm-thick single slice, scan time=24s), a T_2* map was derived from spiral multi-GEs acquired on glioma bearing rat brain. Twenty gradient echoes were sampled (T_E=[0.95,…,42.0ms]). For the final 9 non-calibrated echoes, the same refocusing rewinders were applied. T_2* values were estimated using a non-linear fit (Levenberg-Marquardt algorithm) and a two parameter exponential decay. Reconstruction and post processing were performed using homemade Matlab software.

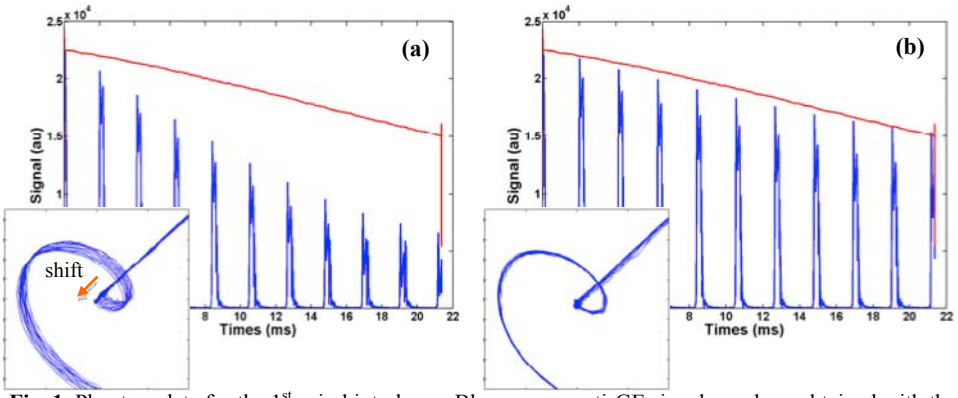

Fig. 1. Phantom data for the 1st spiral interleave. Blue curve: muti-GE signal envelope obtained with the uncorrected (a) theoretical gradient waveform and (b) after applying the corrected waveform. Red curve: FID signal envelope acquired with no gradient applied. Inserts show the corresponding measured trajectories close to k-space center.

Results

Fig.1. shows the MR signals from a 1mm-thick slice and the associated measured trajectories obtained with theoretical or corrected trajectory gradient waveforms. As a reference, we also acquired the FID from the same slice without applying the spiral-out gradient echo train. When applying gradient waveforms derived from a theoretical trajectory (Fig.1a), the echo amplitude rapidly decreases well below the FID envelope level. Using the proposed approach, for each echo the MR signal acquired in presence of spiral gradients nearly meets the FID envelope, indicating good but not perfect effective repeated sampling of k-space centers for all 11 echoes (Fig.1b). Higher signal is available at the end of the echo train than in Fig.1a. Fig.2a-d, present some of the GE images obtained *in vivo* on glioma bearing rat brain using the same calibrated acquisition sequence. Fig.2e presents the corresponding T_2* map, while Fig.2f details the signal evolution with T_E for a single voxel (blue dots), with fitted curve (red) superimposed. Tumor tissue seems to exhibit short T_2* values.

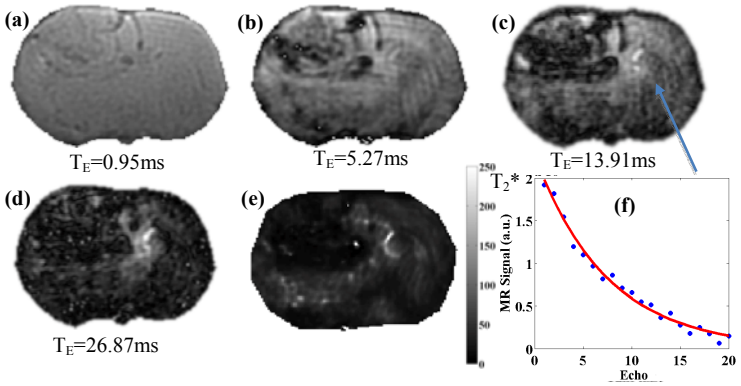

Fig.2. (a-d) Image examples at different echo times. (e) Computed T_2* map. (f) Blue dots: MR signal over echo time for a single voxel (indicative arrow in (c)). Red curve: exponential T_2* decay fit.

Discussion/Conclusion/Perspectives

We proposed and demonstrated a fast, two-step approach, to obtain well-refocused spiral trajectories for multi-echo spiral imaging. It can be used for spin or gradient echoes, with spiral-out or spiral-in readouts. In this first implementation, a same average refocusing correction was applied to all echoes, which might partly explain artifacts in the T_2* map. The technique will be further improved by applying corrections estimated per echo. These results tend to indicate that this fast T_2* mapping technique, with good spatial resolution, could be applied in DSC or DCE studies. A thorough validation of the technique by comparison with T_2* maps estimated from a standard cartesian MGE acquisition sequence is in progress,

References

[1] Tachrount M et al., 2009, ISMRM, 4312. [2] Zhang Y et al., 1998, MRM, 39, 999:1004