Preliminary results of IDEAL fat/water separation at 9.4T

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Introduction

An iterative Dixon algorithm (IDEAL) [1] was established for efficient fat/water-separation during the last years. Here the method was executed in-vivo on a dead rat on 9.4T in order to verify the high-field performance of IDEAL. Data were acquired with a vendor supplied 3D multi-gradientecho sequence.

Method

Experiments were performed on a 9.4T Bruker Biospec 94/20 small animal scanner with maximum gradient amplitude of 660 mT/m and maximum slew rate of 4750 mT/(m*ms). A dead rat was imaged in compliance with the local ethics committee. A multi-gradient echo sequence with flyback gradients was utilized for a three echo image acquisition. All three readout gradient lobes for data acquisition have the same polarity. IDEAL fat/water separation was performed according to the following steps:

1. Acquisition of 3D data with the following parameters: matrix size (readout*phase_encode*slice_direction) =256*256*128, FOV=65*94*120 mm^3, spatial resolution=0.26*0.37*0.94 mm^3, flip angle = 20°, TR = 7 ms, transversal orientation.
2. Echo times were TE1 = 1.14ms, TE2 = 2.05 ms, TE3 = 2.96 ms. The difference of 0.91 ms between the echoes gives a phase difference of 480° (equal to 120° [2]) for fat magnetization which is Δf = -1460 Hz off-resonance from water at 9.4T (estimated from a nonselective FID acquisition).
3. The echo images from each slice were downsampled to a 32*32 matrix. From this image set, a low resolution fieldmap was obtained with a region growing algorithm according to Yu et al. [3]. The start pixel of the region growing procedure was chosen by hand.
4. The low resolution fieldmap was upsampled to the original resolution. The iterative Dixon algorithm according to Reeder et al. was performed with the upsampled fieldmap as first estimation. The result of this step are the final fat and water images.

Remark: A 120° fat phase advance between two echoes would require an echo spacing of $\Delta TE = 1/(3*\Delta f) = 0.228$ ms. This is practically not applicable as simple examples with realistic values of voxel size and readout bandwidth illustrate. Even for a bipolar, EPI-like multiecho readout gradient an echo spacing of 0.228 ms can hardly be reached at 9.4T.

Results

Images at three echo times for slice #46 of the 128-slices-package are shown in Fig. 1 in phase and magnitude. Fatty tissue appears bright in all magnitude images due to short T1.

IDEAL reconstructed fat/water images are shown for three selected slices in Fig.2. Overall fat/water separation is good, however, there are small regions were the separation does not work properly and the assignment of signal to either fat or water swaps.

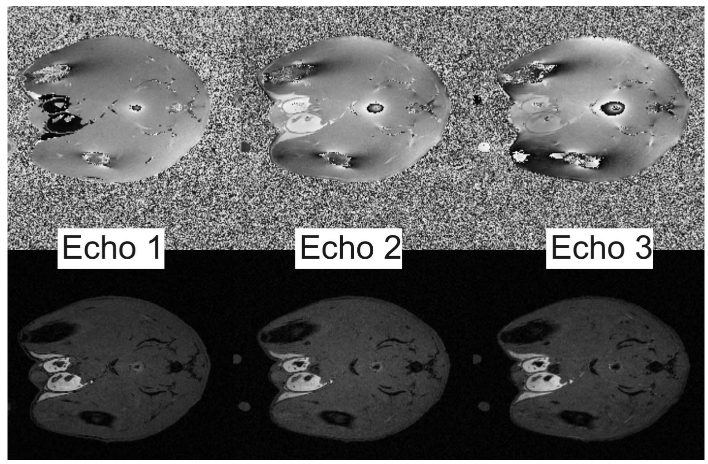

Fig. 1: Phase (top row) and magnitude (bottom row) abdominal rat images of a selected slice (#46) acquired at three echotimes.

Discussion

Due to the widely spaced resonances of fat and water, either only fat or only water suppression could easily be handled by conventional frequency selective saturation pulses. However, if both a water and a fat image are required at the same time, IDEAL fat/water separation would be a valuable means to accomplish this task by saving about half of the acquisition time in comparison with a two-shot fat and water suppression. Besides, the IDEAL algorithm can handle the separation of more than two resonances, which is advantageous for, e.g., separation of 13C hyperpolarized metabolites [4]. It is also possible to acquire data with an EPI-like multiecho readout gradient such that data is acquired with alternating readout polarity. This makes a number of additional correction necessary as described by Lu et al. [5]. Moreover, the presented results support the motivation of improving the performance of IDEAL by considering T2* decay and by multipeak-modeling for fat [6]. As soon as these approaches are implemented we plan to perform extended studies on the stability of IDEAL at 9.4T in vivo.

Further consideration needs to be given to the fact that due to the off-resonance frequency of fat (about 1400 Hz) at 9.4T makes a multiecho acquisition with precession angle of 120° practically impossible as unattainably high gradient amplitude and rise time would be of need, i.e. fat has to proceed by an additional cycle, i.e. by 480° between two echoes.

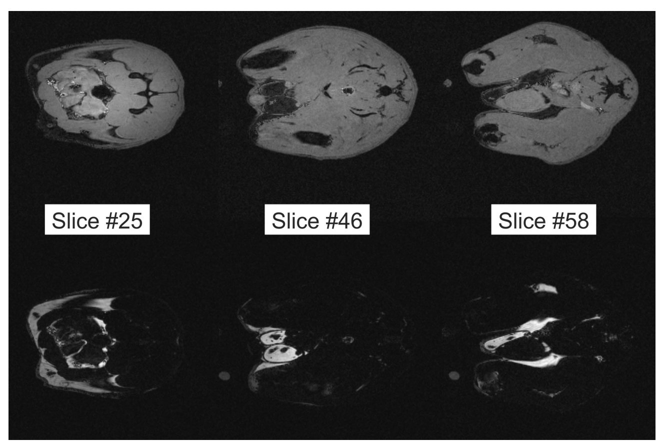

Fig. 2: IDEAL fat/water separation of three selected slices

References

[1] Reeder et al., Magn Reson Med (2004) 51(1):35-45. [2] Pineda et al., Magn Reson Med (2005) 54:625-635. [3] Yu et al., Magn Reson Med (2005) 54(4):1032-1039. [4] Leupold et al., Magn Reson Mater Phy (2009) 22:251-256. [5] Lu et al., Magn Reson Med (2008) 60(1):198-209. [6] Yu et al., Magn Reson Med (2008) 60:1122-1134.