Metabolite mapping with multiecho bSSFP and EPSI reconstruction

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Introduction

In some imaging applications it is desirable to separate multiple metabolites with high spatial resolution in short imaging time. Recently, Reeder and coworkers have demonstrated a novel iterative Dixon-type reconstruction technique for the separation of two or more metabolites imaged with gradient echoes and short TE increments [1]. A drawback of this approach is the complex post-processing including matrix inversions and robust initial field map estimations in heterogeneous regions. Echo planar spectroscopy imaging (EPSI) has been used for generating spectroscopic images and fat-water separation with high spatial and moderate spectral resolution [2] based on gradient echo and fast spin echo imaging. Here we demonstrate the feasibility for metabolite separation using a multi-echo balanced SSFP sequence with an EPSI reconstruction for rapid imaging with high SNR.

Method

A multi-echo balanced SSFP sequence as shown in Figure 1 was implemented on a 1.5 T Sonata system (Siemens Medical Solutions, Erlangen, Germany) with gradients supporting 40 mT/m amplitude and 200 T/m/s slew rate. In EPSI imaging, the alternating readout gradient simultaneously encodes one spatial dimension and one chemical shift dimension while the phase encoding gradients encode the other spatial dimensions. A 1D FT over the acquired echoes generates the spectroscopic images at discrete frequencies. The spacing between the echoes, ΔTE, determines the Nyquist frequency, f_N, of the spectral reconstruction (1). The spectral resolution Δf is inversely proportional to the product of the number of acquired echoes, M, and the echo spacing (2):

$$f_N = \frac{1}{2\Delta TE} \quad (1) \qquad \Delta f = \frac{1}{M \cdot \Delta TE} \quad (2)$$

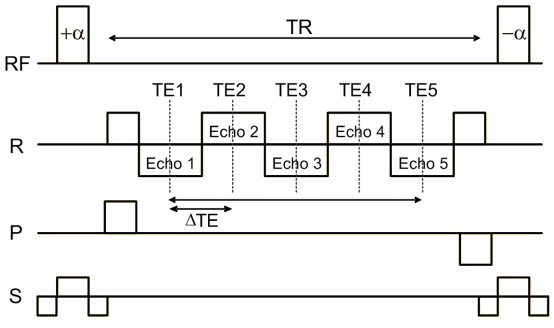

Fig.1 : bSSFP multiecho sequence, 5 echoes during one TR in this example.

Data inconsistencies between odd and even echoes caused by gradient delays, eddy currents, and other sources can lead to imaging artifacts. These artifacts are well known as ghost artifacts in EPI, while they become ghosts along the frequency direction in EPSI imaging. It is caused by an echo shift between odd and even echoes, which lead to a linear phase in the echo images in readout direction. It is corrected according to [3], where a correction of multiecho data for a sample containing metabolites with differences in chemical shift is described.

Results

The feasibility of metabolite separation with multiecho-bSSFP is demonstrated on phantom containing water, acetone and fat in separate bottles (Fig.2). During each TR of 10.24 ms were six echoes recorded with ΔTE=1.28 ms (Readout BW =930Hz/Px). Matrix size is 256*256, FOV = 300mm*300mm*5mm, flip angle is 60°. The sequence was prepared with 500 dummy cycles to drive the magnetization in the steady-state. The measured off-resonance frequencies were 127Hz for acetone and 234Hz for fat. Images in the frequency domain were reconstructed at 0HZ, +-130Hz, +-260Hz and -391Hz. The images at -130 Hz and -260Hz contain the metabolite information of fat and acetone. In vivo fat-water knee-images were taken on a healthy volunteer (Fig.3). Data: TR=11.04ms, 4 echoes, ΔTE=1.44ms, Matrix 256*256, FOV 300*300*5, α=60°. EPSI reconstruction yields the fat image at -231 Hz.

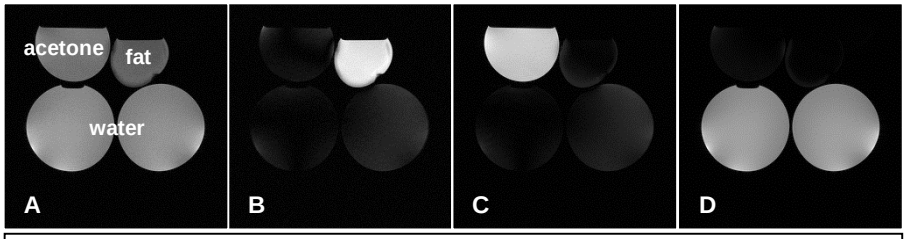

Fig. 2: Images resulting from multiecho bSSFP with EPSI reconstruction. Six Echoes were recorded, three of the six EPSI-reconstructed images are shown. A): Non-frequency selective bSSFP image. B) fat image, C) acetone image, D) water image.

Conclusion

This study demonstrates the feasibility of metabolite separation with a multi-echo bSSFP sequence and EPSI reconstruction to provide high SNR with rapid imaging. The spectral resolution of the method is limited by the maximum TR for imaging without banding artifacts, which depends on the quality of the shim. This also limits the number of achievable spectra images, which is identical to the number of the acquired echoes within one TR. Higher spectral resolution would only be achievable with longer TR values. Imaging of nuclei with lower precession frequencies than protons (31P) would allow for longer echo trains and higher spectral resolutions. The Nyquist frequency is determined by the minimal echo spacing, which could be decreased by additional acquisitions with shifted echo trains.

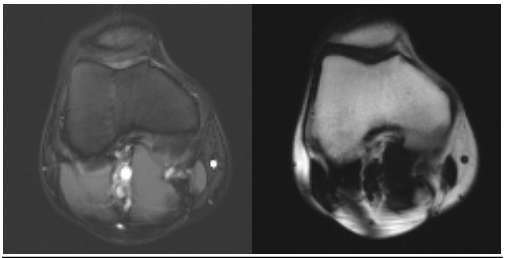

Fig. 3: in vivo knee images. left: water image, right: fat image. Reconstructed from a four echo bSSFP acquisition (see text)

References

[1] S Reeder et al., MRM **51**:35-45, 2004. [2] S. Posse et al., MRM **33**:34-40, 1995. [3] S Reeder et al., JMRI **9**:847-52, 1999.