Water-Fat Separation with a Dual-Echo Two-Point Dixon Technique for Pencil Beam Navigator Echo

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Target Audience: Scientists and engineers who have an interest in fat signal suppression in pencil beam excitation.

Purpose: Pencil beam excitation technique[1, 2] selects a cylindrical volume in a subject, and is widely used in respiratory navigation in cardiac and abdominal MRI. This technique uses a two-dimensional k-space trajectory during RF pulse application, which makes excitation time relatively long and the excitation profile sensitive to off-resonance. The off-resonance effect is large at 3 T, causing undesired excitation of subcutaneous fat (chemical shift: 447 Hz at 3T) outside the target region. The purpose of this work was to develop and demonstrate the feasibility of water-fat separation processing in pencil beam navigator using 2-point Dixon reconstruction with phase correction. [3]

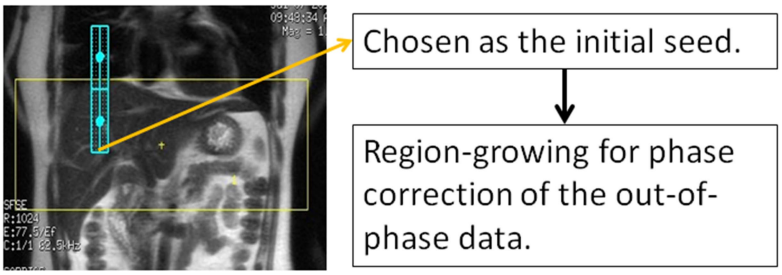

Fig. 1 Outline of initial seed selection for region-growing in phase correction.

Methods: *Water-Fat Separation:* We started with the previously reported method[3] and modified it for pencil beam navigator with a spiral k-space trajectory during excitation and a dual-echo data acquisition. After 1D inverse FFT of the dual-echo navigator signal, the phase correction was performed with the following steps:

1) Both the in-phase and out-of-phase navigator data were corrected with phase of the in-phase navigator data. Let *S0* and *S1* represent the corrected in-phase and out-of-phase data, respectively.

2) The initial seed was chosen for region-growing. This region-growing is for determination of the phase vector[3] *S1*□ to be used in correction of *S1* (step 4). Here we used a prior knowledge that the liver fat fraction is below 50%, [4] in other words, a pixel in the liver is in a water-dominant region. We also used a fact that an operator set navigator tracker bottom in the liver parenchyma (Figure 1). So, the bottom pixel was chosen as the initial water-dominant seed where *S1*□ is parallel to *S1*.

3) Starting with the initial seed pixel, *S1*□ was determined as parallel to *S1* if the angular difference between *S1* and summation of neighboring pre-determined three pixels' *S1*□ was below $\pi/2$ (water-dominant). Otherwise, *S1*□ was determined as antiparallel to *S1*. This operation was performed pixel-by-pixel, until *S1*□ was determined all over the navigator FOV.

4) Phase of *S1* was corrected with *S1*□ in each pixel.

After phase correction was completed, *S0* and corrected *S1* were added to produce the water-only navigator signal.

Data Acquisition: We performed the volunteer scan with 3D-SPGR on GE 3 T Discovery MR750w imaging system (GE Healthcare, Waukesha, WI, USA) with anterior and embedded posterior coil arrays. The dual-echo navigator sequence was inserted into the scan every 200 ms, with 20 mm diameter, 200 mm length and 256 readout points. Imaging parameters in the volunteer scan included: TR/TE = 3.3 ms/1.3 ms, slice thickness = 4.0 mm, 56 slices, and flip angle = 12°. Motion detection was performed with the edge detection by calculating the maximum difference in the navigator FOV.

Results: Dark bands were seen in the original in-phase and out-of-phase navigator signal, which resulted in inaccurate motion detection (Figure 2a,b). The dark bands were reduced in the processed water-only signal, and motion detection was improved by more accurate edge detection (Figure 2c).

Discussion: The signal outside the liver was not eliminated in the proposed method, probably due to phase discontinuity of subcutaneous fat signal near the receiver surface coils. This undesired signal can be eliminated with combination of other techniques (e.g. phase edge detection).

Conclusion: We have demonstrated that the water-fat separation of pencil beam navigator echo. It improved motion detection in 3D-SPGR.

References: 1. Pauly J, Nishimura D, et al. A k-space analysis of small-tip-angle excitation. J Magn Reson. 1989;81:43–56.
2. Hardy C, Cline H. Broadband nuclear magnetic resonance pulses with two-dimensional spatial selectivity. J Appl Phys. 1989;66:1513–1516.
3. Ma J. Breath-hold water and fat imaging using a dual-echo two-point Dixon technique with an efficient and robust phase-correction algorithm. Magn Reson Med. 2004;52(2):415–419.
4. Reeder SB, Robson PM, et al. Quantification of hepatic steatosis with MRI: the effects of accurate fat spectral modeling. J Magn Reson Imaging. 2009;29(6):1332–1339.

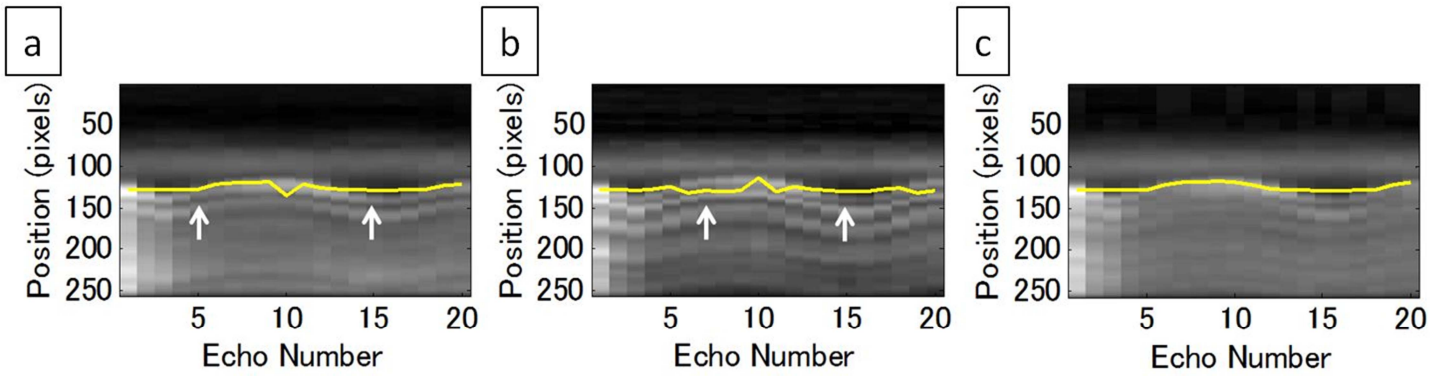

Fig. 2 Navigator signals and detected edges (yellow lines) of (a) in-phase, (b) out-of-phase, and (c) water-only navigator data. Arrows indicate dark bands caused by undesired subcutaneous fat excitation.