Chemical shift correction in fat-water separation using two-point Dixon SSFP

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Background

Steady state free precession (SSFP) sequences offer superior signal intensity in a relative short time. The potential of a dual-echo SSFP sequence has been investigated for breast imaging applications [1, 2], where fat signal is separated from the water signal using the two-point Dixon technique [3]. Dual echo SSFP provides robust water-only and fat-only images in the presence of B_0 and B_1 inhomogeneity. Due to the sensitivity of SSFP to off resonance, short TR is needed to minimize the banding artifact. The two echoes required for the two-point Dixon fat-water separation can be acquired using a bipolar gradient. Compared to mono-polar readout, a bipolar gradient can reduce echo spacing and therefore result in more efficient readout. However, due to the opposite chemical shift, mis-registration between images from the two echoes using bipolar readouts exists, as illustrated in Figure 1. In this work, we improved the dual-echo 3D SSFP sequence by correcting the bi-directional chemical shift error in two-point Dixon fat/water separation.

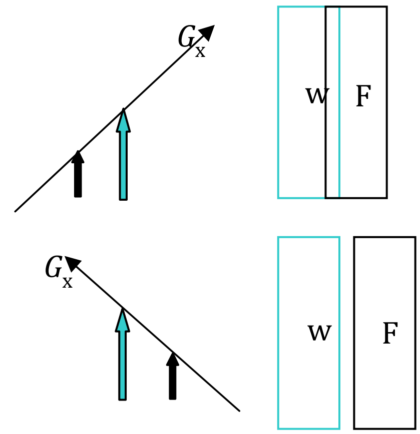

Fig. 1 Bi-directional chemical shift using (a) positive and (b) negative readout gradient. Fat (black) shifts in opposite direction relative to water (blue).

Methods

Sequence: A unique pulse sequence design consisting of a dual-echo readout with alternating bipolar gradient polarity in adjacent TR intervals is presented in Figure 2. To correctly reconstruct fat-only and water-only images, the in-phase image from one TR is combined with the out-of-phase image from the adjacent TR.

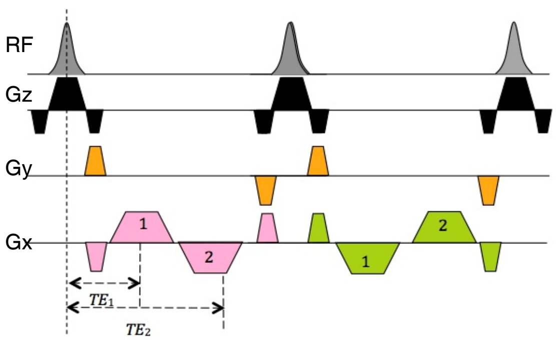

Fig. 2 Schematic diagram of the dual-echo SSFP sequence with alternating bipolar readout gradients in an interleaved fashion.

Image acquisition: All the imaging was performed on a 3T TIM Trio MR scanner (Siemens Ag, Erlangen, Germany). First, two bottles each filled with pure water(top) and oil (bottom), see Fig. 3(a), were imaged using the sequence shown in Figure 2. In addition, sequence with fixed bipolar readout polarity was implemented for comparison. The presented sequence was further examined on an *ex vivo* pork sample with imaging parameters: TR = 6.8 ms, and TE_1/TE_2 = 2.3/3.4 ms, FOV = 160x160 mm, matrix size = 128x128, 32 slices, slice thickness = 1 mm, leading to a voxel size of 0.9x0.9.x1 mm^3. The performance of fat-water separation from SSFP-based two-point Dixon was compared to that from chemical selective fat suppression pulses.

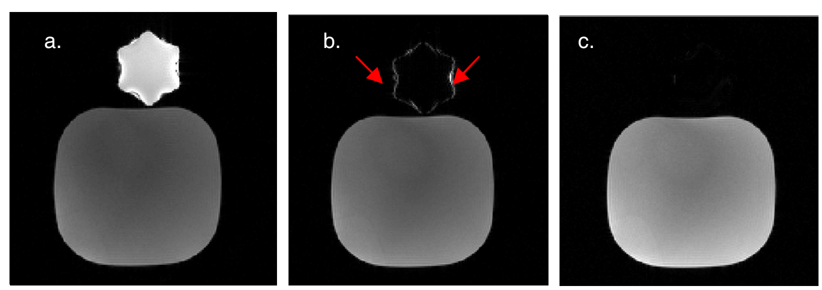

Fig. 3 (a) A phantom composed of pure water (top) and oil (bottom). Fat-only images reconstructed based on source images acquired using bipolar dual-echo SSFP sequence with (b) fixed polarity, and (c) interleaved alternating polarities.

Results

An example slice of the fat-only images obtained from imaging sequences with fixed and alternating bipolar readout gradients in adjacent TR are displayed in Figure 3 (b) and (c) respectively. As indicated by the arrows, the edges of the water bottle along readout direction (left to right) were incorrectly separated as fat-only signal. This implies the intrinsic error caused by the bi-directional chemical shift using the fixed bipolar readout gradient polarity. Figure 4(a, b) shows an example slice of the fat-only and water-only image from the 3D volume. For comparison, chemical selective pulse fat-suppressed image at the same imaging location is shown in Figure 4(c). Improved fat-suppression using the presented technique is clearly visible.

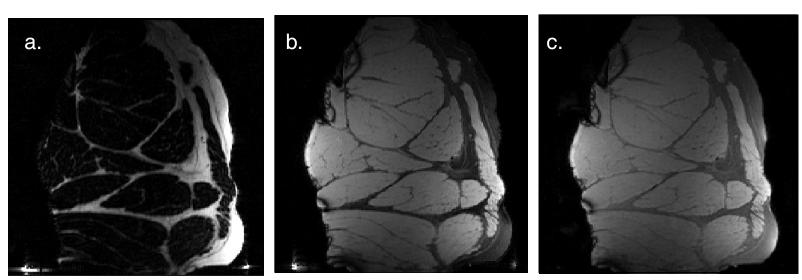

Fig. 4 An example slice of reconstructed (a) fat-only and (b) water-only images from ex vivo pork imaging. (c) fat suppression using chemical-selective pulse.

Conclusions

Fat-water separation using a 3D dual-echo SSFP sequence is improved by correcting the bi-directional chemical shift induced mis-registration. Both phantom and *ex vivo* imaging demonstrate the ability of the presented sequence for fat-water separation.

References

[1] C. Lee, et al., Proc. ISMRM 18, 2010, p. 4552. [2] Y. Wang, et al., Proc. ISMRM 20, 2012, p. 3840. [3] B. Coombs, et al., MRM, 1997, p. 884-889.

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