Two-Point Dixon Fat and Water Separation using 3D Dual-Echo SSFP Sequence in Breast Imaging

Yi Wang[1,2], Emilee Minalga[1,2], Allison Payne[2], Glen Morrell[2], and Dennis L. Parker[1,2]
[1]*Bioengineering, University of Utah, Salt Lake City, UT, United States,* [2]*Utah Center for Advanced Imaging Research, Salt Lake City, UT, United States*

Background

Balanced steady state free precession (bSSFP) sequences offer superior signal intensity in a relative short time. However, fat could appear very bright due to its high T2/T1 values. Fat signal suppression or elimination can be helpful to uncover information that might otherwise be obscured by fat, e.g., lesions and blood vessels in breast imaging. Dixon techniques have been developed to achieve fat and water separation, overcoming the issues of sensitivity to B_0 and B_1 field inhomogeneities faced by chemical shift and inversion recovery fat suppression techniques. It has been shown that the two-point Dixon method is sufficient to obtain fat-only and water-only images by using the square of the phase difference of the two echoes to estimate the field inhomogeneity map [1]. Initial work on achieving two-point Dixon fat and water separation in breast using the dual-echo SSFP sequence has been reported by Lee [2]. In this work, we simulate the signal behavior of the dual-echo SSFP to assist in choosing the optimal flip angle (FA) for in vivo breast imaging in a breast-specific MR guided high intensity focused ultrasound (MRgHIFU) system.

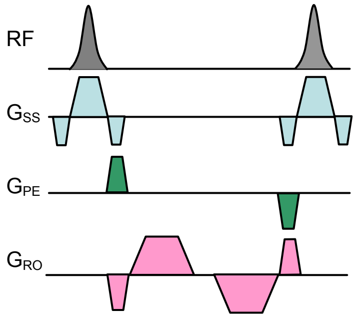

Fig. 1 Schematic diagram of the dual-echo SSFP sequence.

Methods

The signals for the dual-echo SSFP sequence, shown in Fig. 1, were simulated using the Bloch equations for FA's ranging from 10°–90° in steps of 20°. Other simulation parameters were TR/TE1/TE2 = 6.8/2.3/3.5 ms, T1/T2 for fat and fibroglandular tissue were 423/154 and 1680/71 ms respectively [3]. *In vivo* breast imaging was performed on a 3T TIM Trio MR scanner (Siemens Ag, Erlangen, Germany) using a breast-specific MRgHIFU system (designed and constructed at UCAIR) [4] without heating. The 11-channel RF coil [5] of the system was tuned / matched to the water used for acoustic coupling. With local institutional review board approval, two healthy subjects gave informed consent and were imaged using SSFP with: TR/TE1/TE2 = 6.8/2.3/3.5 ms with asymmetric echo, FA=30°, matrix size = 192x192x104, FOV = 168x168 mm^2, BW = 766 Hz/Px, giving a voxel size of 0.9x0.9x1.5 mm^3 with an acquisition time of 2:16 min. Before two-point Dixon reconstruction, zero filled interpolation (ZFI) was applied to improve the image visual appearance. A sub-slab maximum intensity projection (MIP) of the water-only images was also obtained.

Results

The simulated dual-echo SSFP magnitude and phase signals for fat and fibroglandular tissue are plotted vs. frequency offset, as shown in Fig. 2. Maximum fibroglandular signal is achieved at FA of 30°, which is used to obtain the following *in vivo* images. In Fig. 2 (b, c), phase signals at two TEs demonstrate the in-phase and opposed-phase between fat and fibroglandular tissue for the dual-echo SSFP signals.

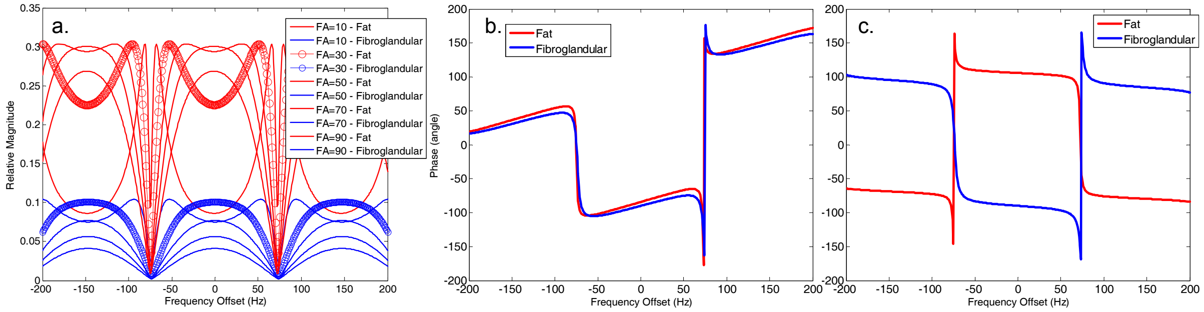

Fig. 2 Simulated dual-echo SSFP (a) magnitude and (b, c) phase signals as a function of frequency offset. Normalized magnitude signal were simulated at five FAs. Maximum fibroglandular signal is achieved at FA=30°. Phase signal is shown in (b) and (c) for in-phase (TE=2.3ms) and opposed-phase (TE=3.5ms) respectively.

Fig. 3 (a, b) shows an example sagittal slice of the water-only and fat-only image from the 3D volume. A sub-slab MIP of the water-only images is shown in Fig. 4. Despite the banding and motion-induced artifact at the water/air interface, fibroglandular tissues and blood vessels (arrow) are clearly visualized in the water-only images.

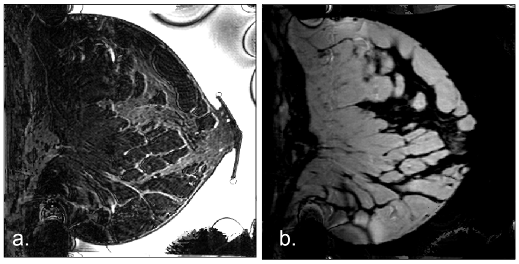

Fig. 3 An example saggital slice of reconstructed (a) water-only and (b) fat-only images. A tensioning device [4] was attached to the nipple for stabilizing the breast.

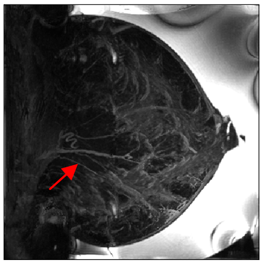

Fig. 4 Sub-slab MIP of the water-only images.

Conclusions

In this work, we investigated a two-point Dixon fat and water separation technique in the breast using a 3D dual-echo SSFP sequence. A Bloch equation based simulation was performed to help understand the fat and fibroglandular signal behaviors, and was further used to optimize the FA selection. Results show the potential of using the technique to visualize blood vessels in the breast. Image acquisition time could be further reduced by using parallel imaging. Future work will include comparing the 2- and 3-point Dixon techniques, and reducing banding artifacts. Contrast between blood and fibroglandular tissue could also be adjusted by varying image acquisition parameters and adding magnetization preparation.

References

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Acknowledgments: Supported by Siemens Health Care AG, The Ben B. and Iris M. Margolis Foundation, the Focused Ultrasound Surgery Foundation, NIH grant 1R01 HL48223 and 1R01 CA134599.