Improved Fat Suppression With High Resolution Balanced Steady State Imaging in the Breast

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INTRODUCTION: T2-weighted data can be utilized to improve lesion characterization in breast MRI [1]. While the Dynamic Contrast Enhanced (DCE) MRI remains the centerpiece of breast MRI, both signal intensity relative to surrounding tissue as well as depiction of lesion morphology in T2-weighted images can help to distinguish benign from malignant lesions [2]. However with TRs on the order of seconds, T2-weighted acquisitions are generally inefficient and are most often acquired with high in-plane resolution (<1mmx1mm) but low through plane resolution (3-4 mm). Balanced SSFP (bSSFP) acquisitions provide T2-like contrast and are more efficient (TR ~ 10 ms) allowing for acquisition of image data with high isotropic resolution in clinically feasible scan times. A radial bSSFP acquisition termed 3DPR-SSFP has been shown to provide improved depiction of lesion morphology with 0.6 mm isotropic resolution at 1.5 T in comparison to conventional T2-weighed acquisitions [3]. However, the level of fat suppression with the 3DPR-SSFP was variable due to patient induced B0 inhomogeneity. In this work we evaluate the performance of two methods to improve the level and uniformity of fat suppression 3DPR-SSFP while retaining the advantage of clear depiction of fine morphological detail in the breast. The first method is Weighted Combination SSFP (WC-SSFP) [4] which is an enhancement of the 3DPR-SSFP technique. The second method is IDEAL 3DPR-SSFP which utilizes a different chemical species separation method similarly implemented with a radial trajectory and bSSFP contrast.

THEORY AND METHODS: The original 3DPR-SSFP method utilizes Linear Combination SSFP [5] for fat-water separation as well as a radial trajectory to allow for acquisition of high resolution data while also meeting the short TR constraint of LC-SSFP. Initial investigation of this technique in the breast demonstrated the potential for lesion characterization by depicting lesion morphology at high resolution in multiple orientations [3]. However, the level of fat suppression with 3DPR-SSFP varied due to ripple in the LC-SSFP fat stopband and fat-water swaps occurred in regions of large B0 inhomogeneity. The first method investigated in this work is Weighted Combination SSFP (WC-SSFP) [4] which reduces the ripple in the stopband by reprocessing the 3DPR-SSFP data with a non-linear combination. The second method termed IDEAL 3DPR-SSFP utilizes the IDEAL chemical shift based fat-water separation method. In IDEAL 3DPR-SSFP two passes of the out and back trajectory used in 3DPR-SSFP, one shifted relative to the other in echo time, creates images at four echo times. IDEAL processing then calculates a B0 field map that corrects the individual echo images before separating signal into fat and water channels.

Unilateral 3DPR-SSFP and IDEAL 3DPR-SSFP datasets were acquired in 5 high risk screening patients on a GE Echospeed 1.5 T scanner with the GE HD 8-channel breast coil. All patients gave informed consent following IRB policies at our institution. Total scan time for each acquisition was 5 minutes. Both methods acquired a 320 isotropic matrix with a 20 cm field of view and 15º flip angle. The 3DPR-SSFP acquisition utilized a TR of 2.7 ms and receive bandwidth of ± 125 kHz while the IDEAL 3DPR-SSFP acquisition utilized a TR of 4.5 ms and a receive bandwidth of ± 83.33 kHz. The 3DPR-SSFP data was processed with the WC-SSFP method. Contrast was measured in all five patients between fibroglandular tissue (S_1) and a region of fat suppression (S_2) using $(S_1-S_2)/S_1$. A qualitative comparison was then performed by a radiologist with breast MRI experience to assess over all image quality, consistency of fat suppression throughout the breast as well as performance of the fat suppression in regions of large B0 inhomogeneity, particularly in the superior and inferior regions of the breast.

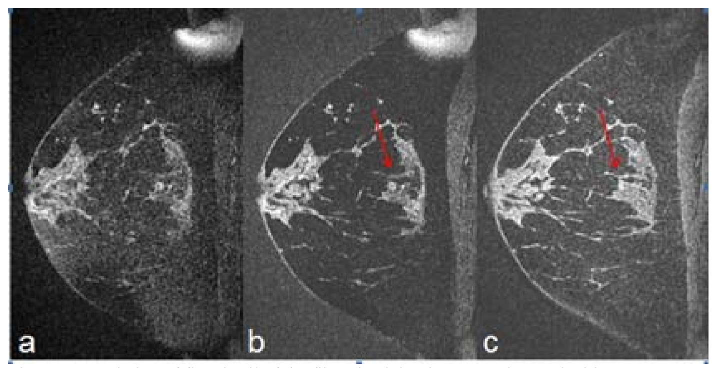

Figure 1. Depiction of fine detail of the fibroglandular tissue are obscured with 3DPR-SSFP (a) because of the variable level of fat suppression. Both 3DPR-SSFP with WC-SSFP (b) and IDEAL 3DPR-SSFP (c) provide a more consistent level of fat suppression allowing for better delineation of fine fibroglandular structure. IDEAL 3DPR-SSFP (c) also resolves fat-water swap due to B0 inhomogeneity in superior region of the breast. Red arrows: Note tiny gap in fibroglandular tissue in WC SSFP (see text)

RESULTS AND DISCUSSION: Contrast measurements between fibroglandular tissue and suppressed fat were 0.58, 0.88, and 0.68 with 3DPR-SSFP, 3DPR-SSFP processed with WC-SSFP and IDEAL 3DPR-SSFP respectively. Contrast was most improved using 3DPR-SSFP with WC-SSFP but both methods provided a more consistent fat suppression across the breast in comparison to the original 3DPR-SSFP (Figure 1). IDEAL 3DPR-SSFP was more effective at resolving fat-water swaps in regions of large B0 inhomogeneity where the 3DPR-SSFP WC-SSFP method did not (Figure 1). Breast tissue was clearly best defined and differentiable in IDEAL 3DPR-SSFP, but WC SSFP showed better contrast in breast tissue versus surrounding fat. Though the 3DPR-SSFP with WC-SSFP demonstrates the highest contrast between fat and fibroglandular tissue, small extensions of fibroglandular tissue are somehwhat obscured with WC-SSFP (Figure 1b, red arrow) in comparison to IDEAL 3DPR-SSFP (Figure 1c red arrow). Image quality was assessed as equivalent between the two methods.

CONCLUSIONS: Both 3DPR-SSFP and IDEAL 3DPR-SSFP demonstrate the ability to achieve high isotropic resolution and bSSFP contrast using radial acquisitions and different chemical species separation techniques while also improving the level and uniformity of fat suppression. Future work will include analysis of the depiction of lesion morphology and lesion contrast between the two techniques and differentiation of benign versus malignant will be analyzed for the potential of increasing specificity of T2(-weighted) images.

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