Bilateral Breast Imaging using IDEAL Fat-Water Separation and an Undersampled 3D Radial bSSFP Acquisition

L. C. Henze-Bancroft[1], C. J. Moran[2], S. B. Reeder[3,4], F. Kelcz[4], and W. F. Block[3,5]
[1]Department of Biomedical Engineering, University of Wisconsin - Madison, Madison, WI, United States, [2]Department of Radiology, Stanford University, Stanford, CA, [3]Department of Medical Physics, University of Wisconsin - Madison, Madison, WI, [4]Department of Radiology, University of Wisconsin - Madison, Madison, WI, [5]Department of Biomedical Engineering, University of Wisconsin - Madison, Madison, WI

INTRODUCTION: Bilateral breast MRI is becoming increasingly important as the screening of high risk women with MR becomes more prevalent. T2-weighted breast images improve the differential diagnosis of breast MRI by providing additional information on the morphology and tissue characterization of structures identified during the dynamic contrast enhanced scan.[1] The predominant T2-weighted Fast Spin Echo (Turbo Spin Echo) clinical imaging methods require that each breast be scanned separately to facilitate B0 shimming. Spatial resolution is typically limited to 2-3 mm 2D sagittal slices. Previous work using 3D radial SSFP acquisitions has demonstrated the value of obtaining isotropic voxels in similar times as unilateral 2D FSE exams[2,4], but only in unilateral exams. In this work, we investigate the ability of a 3D balanced SSFP sequence, VIPR-IDEAL[3,5], to provide B0 corrected, bilateral, fat and water separated images with T2-like contrast and 0.6 mm isotropic resolution in a single scan without increasing acquisition times.

THEORY AND METHODS: Scan times in IDEAL sequences are typically longer because all echoes sample the same k-space points. In VIPR-IDEAL, each echo is comprised of a unique set of radial lines to reduce this scan time penalty[3]. When reconstructing the IDEAL water images in this manner, undersampled signal from water is removed while some penalty is paid in residual fat aliasing[3,6].

VIPR-IDEAL uses a 3D radial bSSFP sequence with an out and back trajectory to collect 4 different echoes with the odd echoes in one pass and then even echoes in the other. The four echo times (0.3, 1.5, 2.7 and 3.9 ms), compared to three echo times in most IDEAL implementations, provides overdetermined data for decomposition in the difficult B0 environment of the breast. Data acquisition is split into two passes to accommodate the desired TR of 4.6ms, selected to keep fat and water centered in the pass bands of the bSSFP sequence, while allowing time to spatially encode for high resolution. We have previously demonstrated the ability of this method to provide high isotropic fat and water separated images in both the knee and the breast[3,4].

Bilateral breast imaging requires doubling the FOV, which would normally require four times as many excitations for a 3D radial scan if only one receiver coil were used. Due to the benign point spread function of 3D radial trajectories, the number of needed excitations is determined by the number of resolution points across the sensitivity pattern of each receiver coil (the PILS effect)[7] in multi-coil studies.

Here we compare bilateral and unilateral VIPR-IDEAL image volumes at similar scan times to determine the ability of an 8-channel coil to effectively localize signal to each breast. All scans utilized a GE Echospeed 1.5T scanner, a GE HD 8-channel breast coil, 4.6 ms TR and a 15° flip angle. For the unilateral case, a 320x320x320 image matrix over a 20 cm FOV was acquired in 5 min scan using a +/-83.33 kHz receiver bandwidth and a 6 cm shim volume centered over the breast. For the bilateral case, the same resolution was achieved using a 576x576x576 matrix over a 36 cm FOV. System constraints with the increased sampling rate (+/-250 kHz), however, limited scan time to 4 minutes. Fat suppression was measured using the following equation: $Fat_{sup} = (F_f - F_w)/F_f$ where Fat_{sup} is the percentage of fat suppressed in an ROI containing fat tissue, F_f is the signal value of that ROI in the fat image and F_w is the signal value in the water image.

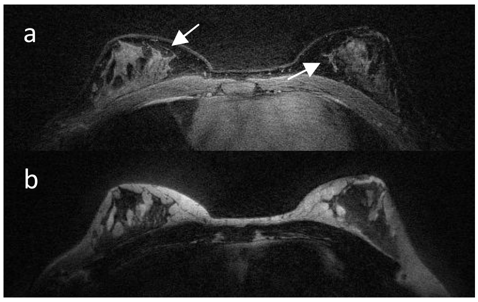

Figure 1: Bilateral VIPR-IDEAL axial reformat showing good separation between water (a) and fat (b) across the both breasts and clear depiction of fine structures (arrow).

RESULTS AND DISCUSSION: Using this method, we were able to achieve robust fat/water separation throughout the volume, as shown in Figure 1, despite large field inhomogeneities due to the numerous air tissue interfaces present across the FOV. Fine structures are preserved as indicated by the arrows in Figure 1.

The bilateral acquisition came with a penalty of increased noise as shown in Figure 2. A likely cause of the increased noise is increased undersampling artifact in the bilateral images due to the enlarge FOV combined with the limit of a four minute scan time. This can be addressed in the future by removing the data in real time to allow for increased scan time or by transitioning to the new generation of scanners where this constraint has been removed.

The calculated percentage of fat suppression (Fat_{sup}) in the unilateral image was 99% while in the bilateral case it was 96%. This measurement is picking up the noise-like artifact caused by the unique set of radial lines used in each of the IDEAL echoes. Phase shifts between the undersampled fat signal at different echo times leads to incomplete cancellation of fat in the IDEAL decomposition[3,6]. This can be addressed in the future by using the IDEAL fat image to estimate and then decrease the aliased fat signal in the water image during reconstruction.

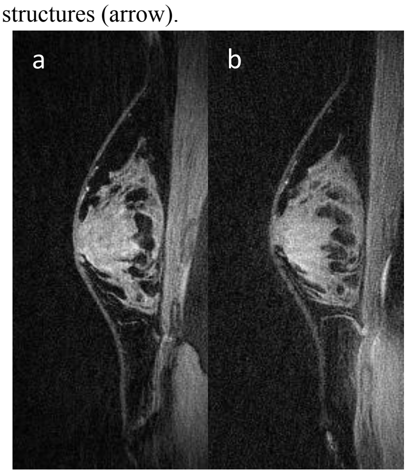

Figure 2: Comparison of unilateral (a) to bilateral (b) breast scan using a sagittal excitation. Fine detail is well represented in both images but a higher noise level is evident in the bilateral images.

CONCLUSION: VIPR-IDEAL provides robust fat/water separation in the difficult imaging environment of the bilateral breast in a single 4 minute scan. Using this method, 0.6 mm isotropic resolution can be achieved across both breasts simultaneously. Bilateral imaging without any increase in scan time is not yet possible. However, the IDEAL method may allow for methods to estimate and remove unwanted aliased signal form undersampling.

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