Non-Cartesian Compressed Sensing with Fat/Water Decomposition: Feasibility Study for High Performance Breast DCE-MRI

Jorge E Jimenez[1], Leah C Henze Bancroft[1], Roberta M Strigel[1,2], Kevin M Johnson[1], Scott B Reeder[2,3], and Walter F Block[1,3]
[1]*Department of Medical Physics, University of Wisconsin-Madison, Madison, WI, United States,* [2]*Department of Radiology, University of Wisconsin School of Medicine and Public health, Madison, WI, United States,* [3]*Department of Biomedical Engineering, University of Wisconsin-Madison, Madison, WI, United States*

Introduction: Capturing the dynamic aspects of intra-tumoral heterogeneity in breast cancers is important for monitoring response to neoadjuvant chemotherapy (NACT) for breast cancer[1]. Successful MR methods must combine capabilities for rapid acquisition, reliable fat suppression, and significant data undersampling. We present our first experience in making three MR technologies mutually compatible: IDEAL signal decomposition, L1-based compressed sensing (CS) reconstruction, and a 3D radial trajectory; Vastly undersampled Isotropic Projection (VIPR).

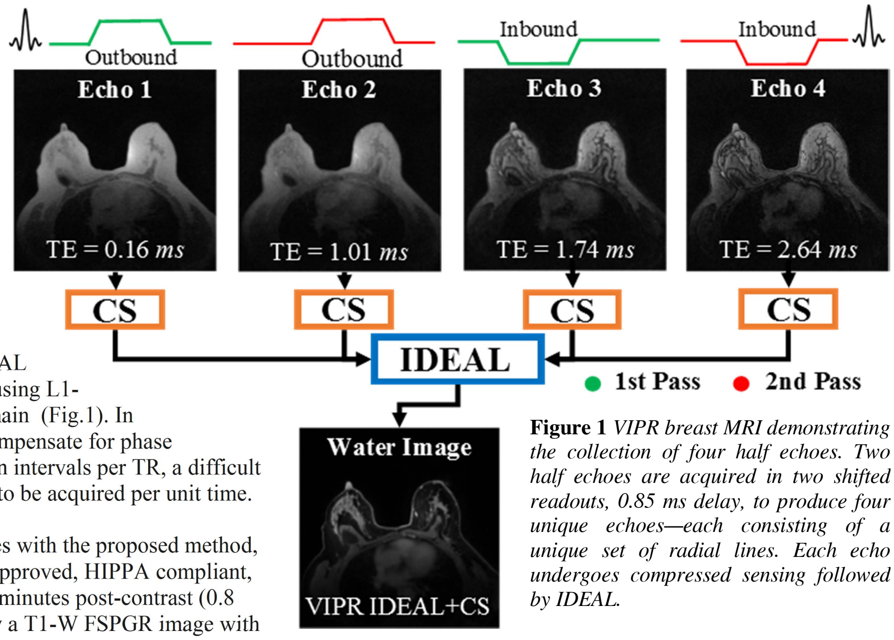

Figure 1 *VIPR breast MRI demonstrating the collection of four half echoes. Two half echoes are acquired in two shifted readouts, 0.85 ms delay, to produce four unique echoes—each consisting of a unique set of radial lines. Each echo undergoes compressed sensing followed by IDEAL.*

Theory: We modified a bSSFP out and back 3D radial trajectory[3,4] to produce T1-Weighted (W), radiofrequency spoiled signal contrast. Interleaving of the echo times into two passes, as shown in Fig. 1, allows for rapid acquisition while producing the necessary measurements for IDEAL fat/water decomposition[4]. The 3D radial trajectory of VIPR is also well suited for compressed sensing methods, as it combines variable density sampling and pseudorandom undersampling of the periphery of k-space. Prior to the IDEAL processing, each echo is reconstructed with a CS algorithm using L1-norm minimization of a wavelet transform in the spatial domain (Fig.1). In addition, IDEAL generates field maps that can be used to compensate for phase errors in a train of echoes. Allowing multiple data acquisition intervals per TR, a difficult task in non-Cartesian imaging, effectively allows more data to be acquired per unit time.

Methods: To demonstrate feasibility prior to dynamic studies with the proposed method, we demonstrated our approach at the conclusion of an IRB approved, HIPPA compliant, DCE-MRI research study. VIPR images were acquired nine minutes post-contrast (0.8 mm isotropic imaging, 167 s scan), immediately followed by a T1-W FSPGR image with 2-point Dixon fat separation (0.8 x 0.8 x 1.6 mm spatial resolution; parallel imaging factor 2 x 2; 62 second acquisition). Imaging was performed on a 1.5T MR scanner (Optima 450W, GE Healthcare) with an 8-channel breast coil.

Results / Discussion: The results of the VIPR IDEAL breast MRI with CS are demonstrated in Fig. 2, demonstrating the potential benefits of isotropic resolution by improved depiction of detail. There is signal-to-noise (SNR) improvement due to CS and reliable fat/water decomposition with the iterative four-point IDEAL method. Comparison with T1-W FSPGR with 2 pt. Dixon is provided as a reference.

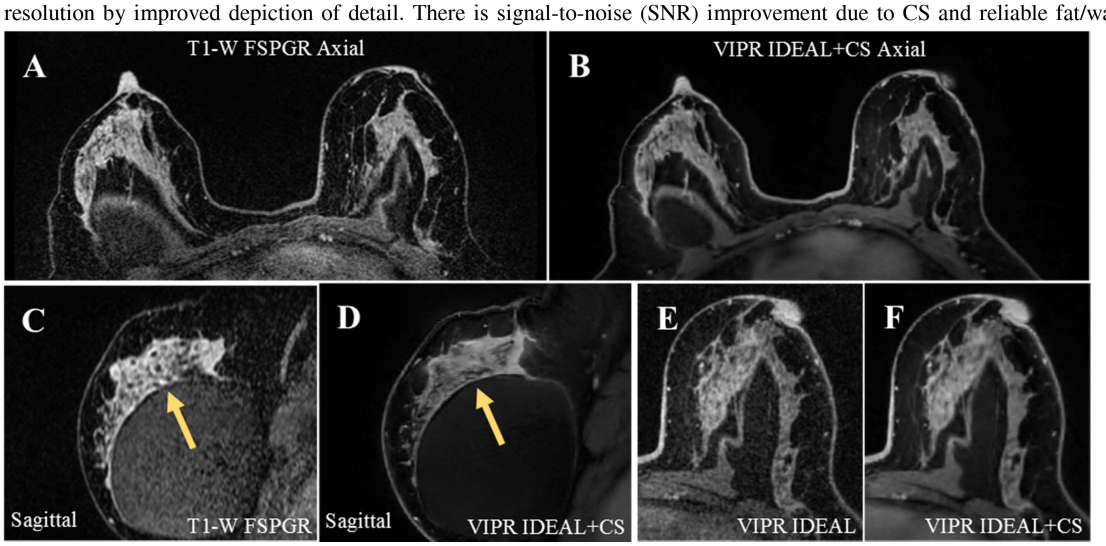

Figure 2 *A, C) Axial and Sagittal T1-Weighted FSPGR MRI with two-point Dixon fat separation in as patient with silicone breast implants. B, D, and F) Bilateral axial and sagittal VIPR IDEAL with compressed sensing provides complete fat removal and thus high contrast with fibroglandular tissue. (D) Noise due to undersampling in VIPR IDEAL (E) is minimized with CS (F).*

Conclusion: We successfully demonstrate incorporation of IDEAL and CS to 3D T1-Weighted VIPR breast MRI capable of providing high isotropic resolution. The addition of CS markedly improved image quality and SNR. Further study is necessary to determine the lower limit of the temporal footprint the method will support in preparation for a clinical breast MRI protocol using VIPR DCE breast MRI incorporating CS and fat separation with IDEAL.

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