Bilateral Breast DCE-MRI with Retrospective Variable Temporal and Isotropic Spatial Resolution

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INTRODUCTION

Variations in temporal and spatial resolution continue to exist in Dynamic Contrast-Enhanced (DCE) MRI of the breast [1-3]. Although a minimum frame rate of 1 frame/minute has been generally agreed upon, investigations continue on the possible benefits of either higher temporal or spatial resolution for DCE breast exams. We present a modified Vastly undersampled Isotropic Projection (VIPR) acquisition tailored to bilateral breast imaging. The acceleration factor in VIPR increases as the available contrast increases and as signal within the imaged object becomes sparser, both advantageous in mask-subtracted CE breast imaging. The acquisition of interleaved trajectories with variable k-space density in VIPR also allows for retrospective temporal filtering that can flexibly tradeoff temporal and spatial resolution. The objective of this work is to demonstrate the feasibility of VIPR acquisition as a method to provide isotropic high spatial and variable temporal resolution in breast MRI.

MATERIALS AND METHODS

The VIPR acquisition was originally designed to comprehensively image the entire torso, brain, or knee using a single axial slab and had no capabilities for off-isocenter imaging. Bilateral breast imaging with an axial slab would require a large readout resolution of 320 - 400 points over a 40 cm FOV for adequate resolution. Since the number of radial lines necessary to cover k-space increases as the square of the readout resolution, the increase in readout resolution over our conventional VIPR studies would require both a longer TR and longer scans to adequately cover k-space. Instead the VIPR sequence was modified to acquire two thin sagittal slabs, each restricted to one breast. This method is tailored to the morphology of the breasts and the limited sensitivity patterns of individual coils in a phased-array breast coil. Real-time frequency demodulation, provided on most platforms today, allows the acquired data to be imaged about the center of each breast rather than the center of the magnet. Therefore, we can image a 16-20 cm spherical FOV using approximately 160 readout points about the center of each breast and avoid imaging unwanted tissue between the breasts. While imaging each breast with alternate TRs reduces performance by a factor of 2 compared to an axial acquisition, cutting the readout resolution in half generates a four-fold increase in k-space sampling efficiency.

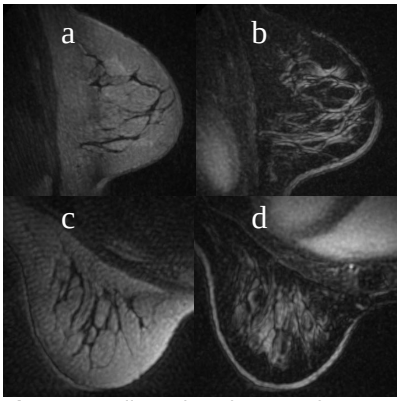

Figure 1. Unilateral study, 120 s frame (a) Sagittal reformat mask (b) sagittal reformat subtracted CE (c) axial reformat mask (d) axial reformat subtracted CE.

Imaging was performed using a General Electric Signa 1.5T TwinSpeed scanner (GE Healthcare, Milwaukee, WI) with a 7-channel Biopsy Breast Coil (MRI Devices Corp., Waukesha, WI). Four half echoes were acquired each TR, traversing k-space with a trajectory similar to a bow-tie [4]. A 2.6 ms readout duration causes partial fat cancellation between the first and fourth half echo, preferable in DCE. Demodulation about the center of each breast limits inconsistencies between projections and reduces regridding errors by reducing phase changes in k-space for voxels closer to the edge of the FOV. As we acquire during varying gradient readout amplitudes, the off-center FOV demodulation signal is not a constant frequency as in Cartesian scans. A real-time frequency signal was programmed using the GE EXCITE receiver hardware for proper demodulation.

Single and bilateral exams were performed on phantoms to test the thin slab excitation and the reduced FOV (TR/TE/FA/BW; 3.6 ms/0.4 ms/25/125 kHz, FOV; 20 cm x 20 cm, 160 x 160 x 160 matrix). Initial unilateral studies were performed on two volunteers. A mask image was acquired over 2 minutes followed by intravenous injection (0.2mmol/kg) of Gd-DTPA (Omniscan, GE Healthcare) and a subsequent 2-minute acquisition. Data were acquired over 120 s and reconstructed first as a single time frame and then in 6 x 20s times frames. Acquisition time doubles for bilateral scans. Subtraction images were then generated according to our standard clinical protocol for DCE-MRI.

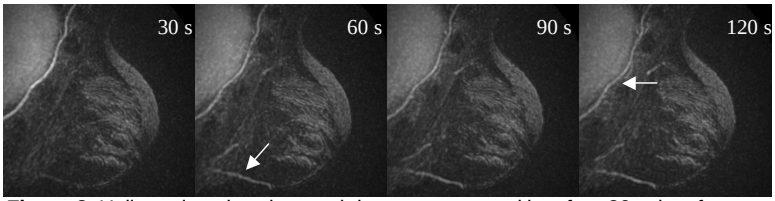

Figure 2. Unilateral study subtracted data reconstructed into four 30 s time frames.

RESULTS AND DISCUSSION

Figure 1(a-b) shows a sagittal reformat of the mask image volume (a) and subtracted CE image (b) acquired with 1.25 mm isotropic resolution over 120 s. Figure 1(c-d) shows an axial reformat of a mask (c) and the corresponding subtracted CE image (d) from the same exam. Both views show robustness to motion artifact and high spatial resolution. The subtracted data was also reconstructed into four 30 s time frames. Figure 2 shows a sagittal oblique MIP over the entire breast at each time point with the expected loss in SNR due to the shorter scan time. Each time frame was created from a strict 30 s interval with no sharing of data between frames. The contrast kinetics are demonstrated in the appearance of vessels at the second time point, in the washout of contrast in the heart (Figure 3) and in the internal mammary artery from the first time to the last. These examples demonstrate two levels of the retrospective temporal resolution that can be applied to lesion contrast uptake analysis.

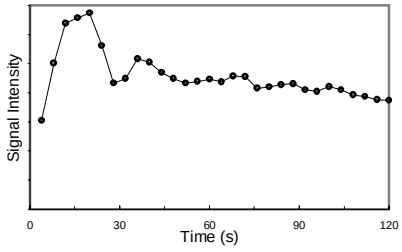

Figure 3. The contrast uptake curve for an ROI in a chamber of the heart (from same scan as Figure 2) demonstrates retrospective variable temporal resolution.

CONCLUSIONS: We have established the feasibility of the application of the VIPR acquisition sequence to breast DCE-MRI. The spatial resolution and temporal resolution demonstrated in these volunteer studies merit the continued investigation of VIPR in DCE-MRI of the breast. While the focus of this work was to test the method on normal breast tissue, we intend to validate these findings in patient volunteers with breast lesions.

REFERENCES: 1. Huang W et al., Radiology 232: 585-591 (2004) . 2. Song et al., MRM 52:815-824 (2004). 3. Lee S et al., Radiology 226: 773-778 (2003) 4. Kuhl C et al., JMRI 12: 965-974 (2000) 5. Brodsky E et al Proc. 11th ISMRM: 322 (2003)