Volume-Interleaved SENSE for Bilateral Breast Imaging

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INTRODUCTION

Dynamic contrast-enhanced MRI (DCE-MRI) is a highly sensitive method of performing breast cancer screening in women with BRCA1/2 mutations [1]. In the TR-interleaved scan protocol [2], each breast is immobilized between sagittally-oriented plates with embedded receive coils (see Figure 1a). The position of the lateral plates is patient-specific and provides high SNR due to the coils` proximity to the tissue. After the intravenous injection of a gadolinium-based contrast agent, a rapid time series of images is obtained from separate breast volumes by exciting and acquiring data in a "back-and-forth" manner (see Figure 1b).

The accuracy of DCE-MRI for breast cancer screening depends on the quality of morphological and contrast-kinetic information available from the time series of images. Hence, we seek an increase in either spatial or temporal resolution, as is allowed by parallel MRI methods such as SENSE [3]. However, for acceleration to be practical it must be accompanied by only modest SNR losses. In the present work, we evaluated the SNR performance of SENSE acceleration using a recently developed 8-coil array (Sentinelle Medical Inc., Toronto, Canada) and breast phantoms.

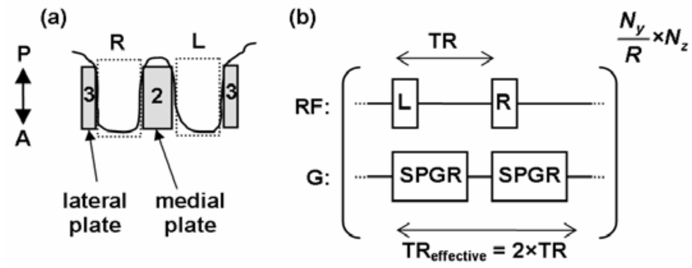

Figure 1: TR-interleaved protocol. (a) Schematic with axial view: Breasts are immobilized between plates with an embedded 8-coil array (4 per breast). The dotted box shows the excitation volume. Right (R), left (L), anterior (A), and posterior (P) directions are indicated. (b) Simplified pulse sequence showing alternate acquisition of left and right volumes. Undersampling in this case was done in the k_y direction (S-I).

METHODS

To simulate the interleaved sequence, one volume was scanned with a 3D spoiled gradient-echo (SPGR) sequence using the left side of a symmetrical 8-coil breast array on a 1.5T system (GE Signa). The breast array provided three lateral coils and one medial coil per breast. TR was chosen to reflect the effective TR experienced by each volume during the TR-interleaved sequence (see Figure 1b). Scan parameters were as follows: TR/TE/flip = 18ms/4.2ms/15°, matrix size: 256×256×32, FOV: 180×180×77mm^3, NEX = 1, BW = 31.25kHz. The phantoms contained cooking oil surrounding four tubes with $MnCl_2$-doped water to mimic the arrangement of fat and fibroglandular tissues in the breast. SENSE acceleration was simulated in MATLAB by zeroing one out of every two (R=2) phase encoding lines in the superior-inferior (k_y) phase encoding direction of the full k-space dataset. Voxel exclusion by thresholding was used to remove pixels outside the object. Sensitivity values were obtained from the same 3D dataset through the scalar division of unaccelerated (full FOV) images constructed from individual coils by a root sum-of-squares (RSS) reference image combined from all coils. A polynomial fit was then performed on the sensitivity distribution to reduce the effects of noise. The noise covariance matrix was obtained from 256^2 noise-only samples collected in a separate 2D SPGR scan of air using the same bandwidth as above. The relative SNR of the resulting images was calculated as $(R^{1/2}g)^{-1}$, where g is the coil geometry factor.

RESULTS

Sample images for RSS and SENSE reconstruction are shown in Figure 2. The acceleration corresponded to a scan time decrease from 2:24 to 1:12 minutes for a full, 2-volume interleaved acquisition. Average calculated g-factors (with standard deviation over all values) were 1.1 (σ = 0.3) across all included pixels, or 1.2 (σ = 0.4) in regions of overlap in the reduced FOV images (i.e. where g > 1). The worst performance occurred at the medial side of the volume, where mean and maximum g-factors were 1.4 (σ = 0.8) and 6.1, respectively, and residual aliasing artifacts were visible. The average g-factor of 1.1 corresponds to an average relative SNR of about 0.64 across the volume, which is about 90% of the optimal value of 0.71 ($R^{-1/2}$).

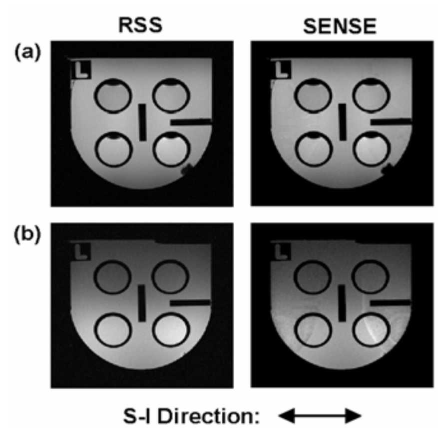

Figure 2: Sample image slices from RSS (left column) and SENSE (right column) reconstruction. (a) A slice close to the lateral side, where low g-factors were achieved. (b) A slice close to the medial side, where residual aliasing was visible.

DISCUSSION AND CONCLUSIONS

The ability to exclude the empty space between the breasts and to apply different gradient shims to each volume are two intrinsic advantages of the interleaved approach compared to scans that encompass both breasts in a single, larger volume. VIBRANT is one example of a commercially-available protocol in which one volume is scanned and SENSE is applied in the slice encoding direction. However, even the unaccelerated interleaved approach achieves scan times comparable to those of VIBRANT due to its efficient coverage of the immobilized breast tissue.

The incorporation of SENSE acceleration allows the intrinsic benefits of the interleaved protocol to be combined with a further reduction in scan time. Before this is accomplished, the trade-off between flexibility for patient size and optimization of noise performance in the coil array must be considered. For example, the relatively poor performance observed at the medial boundary of the volume may have occurred because there were insufficient sensitivity differences between coils at some locations, possibly due to the size of our phantoms. Nevertheless, the average SNR loss observed in this experiment is acceptable given the intrinsically high SNR of the 8-coil array, indicating that SENSE acceleration is practical for the TR-interleaved breast screening sequence.

REFERENCES

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