View-sharing and Compressed Sensing in Two-Point Dixon-based DCE-MRI

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Purpose: High spatiotemporal resolution multiphasic DCE-MRI entails a tradeoff of spatial and temporal resolution. To address the tradeoff, schemes that use pseudorandom k_y-k_z sampling trajectories followed by view-sharing (VS) to generate dynamic phases have been proposed.[1,2] For high spatial frequencies, the temporal footprint is much higher than the nominal temporal resolution, and newer reconstruction methods have been proposed as a means of eliminating VS and reducing temporal footprint.[3,4] In this work, we compare composite VS images with a novel reconstruction method integrating VS, compressed sensing (CS), parallel imaging, and Dixon-based fat-water separation. The reconstruction exploits multiple sources of data redundancy, allowing new tradeoffs in the spatial and temporal resolution of fat and water images.

Methods: We used two CS reconstruction methods to improve temporal footprint: 1) a novel "water CS" approach that uses VS to reconstruct fat and CS to reconstruct water by minimizing $\|y - F_u S D\,[w^T\ f_c^T]^T\|_2^2 + \lambda\|\Psi w\|_1$ over only a water image w, where f_c is a fat image from VS, D is a linear transformation from water and fat to echoes based on a phase map estimated from the composite image with a phase unwrapping method,[5] Ψ is a wavelet transform, S are sensitivity maps estimated from the calibration region using the ESPIRiT method[6], F_u is an undersampled DFT, y is *k*-space data, and 2) an "echo-by-echo CS" reconstruction of in- and out-of-phase echoes x via minimization of $\|y - F_u S\, x\|_2^2 + \lambda\|\Psi x\|_1$, followed by two-point Dixon processing. Bilateral breast DCE-MRI acquisitions were performed on patients with suspected breast cancer on a GE 3.0T MRI scanner (MR750, GE Healthcare) with a 3D SPGR DISCO sequence.[1] Scan parameters: TE1/TE2/TR = 2.2/3.3/6 ms, 512×386×192 matrix, 0.8 mm slice thickness. The central part of *k*-space (A) was acquired with 13s temporal resolution, and the inner annulus of peripheral *k*-space was divided into 4 non-overlapping Poisson-disc sampling patterns (B_1-B_4) fully covering an annular region B. The outermost annular region of *k*-space (C) was acquired only pre-contrast. Following contrast injection, A B_i was repeatedly acquired (Fig. 1). A 2.5×2 autocalibrating parallel imaging (ARC) factor was used and composites were reconstructed after VS. To achieve a compromise between VS and CS, CS reconstructions were performed with C A B_1 samples for the first dynamic phase and C B_i A B_{i+1} for all others. Signal intensity-time courses from within a 2D ROI over the lesion in the axial plane were compared.

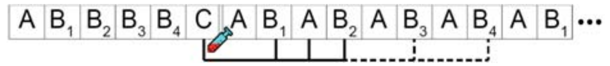

Figure 1: DISCO acquisition consisted of a high-resolution pre-contrast phase followed by repeated acquisition of a central region A and complementary Poisson-disc sampling B_i of an outer annular region. As indicated in the second dynamic phase, the temporal footprint for VS images (solid and dashed lines) was 2.6x longer than for CS reconstructions (solid line).

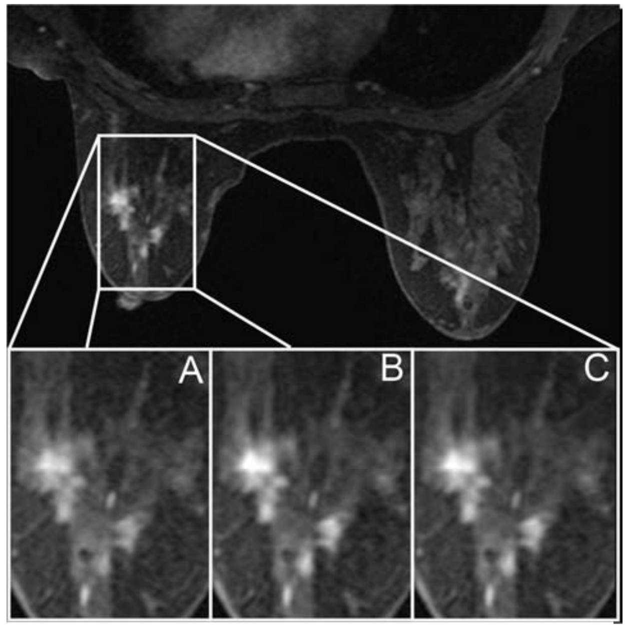

Figure 2: Composite VS (A), echo-by-echo CS (B), and water CS (C) reconstructions show comparable in-plane spatial resolution.

Results and Discussion: Both CS reconstructions show similar apparent spatial resolution and SNR to the composites but with a 2.6-fold reduction in temporal footprint enabled by a two-fold reduction in sampling density. Differences in temporal behavior could be observed from signal intensity-time courses (Fig. 3), and the maximum slope of signal intensity was 23% higher for water CS than for the composites, suggesting better ability to discriminate rapidly enhancing lesions. While the reduction in temporal footprint is desirable for water images, the composites more accurately recovered non-enhancing fat, which motivated the water CS reconstruction. By reconstructing a sparse water image consistent with a composite fat image, errors in the fat image and corresponding errors in the water image seen in the first dynamic phase were mitigated (Fig. 4). Note that the first phase used only C A B_1 data and showed CS artifacts not seen in the later phases reconstructed from C B_i A B_{i+1} data.

By restricting the use of full VS to fat, the image phase, and the coil sensitivities, "leakage" of composite data in the water image is eliminated. Computation is simplified by using *a priori* information about the temporal behavior with VS instead of sparsity constraints and allowing phase-by-phase reconstruction. The joint CS parallel imaging model further reduces computation relative to coil-by-coil CS and takes full advantage of the Poisson-disc sampling pattern.

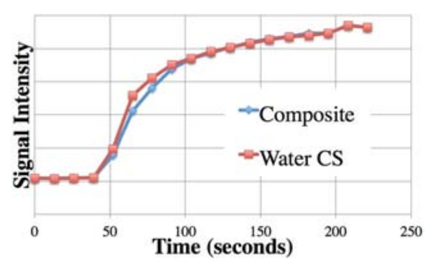

Figure 3: Signal intensity-time curves for composite images and water CS reconstruction show different temporal behavior.

Conclusion: The use of VS, CS, and parallel imaging in DCE-MRI requires a judicious combination of all techniques. CS appears to suppress noticeable artifacts and reduces temporal footprint. In two-point Dixon acquisitions, the measurement model can use a phase map to directly reconstruct water and fat images, allowing each to strike a different balance of VS and CS.

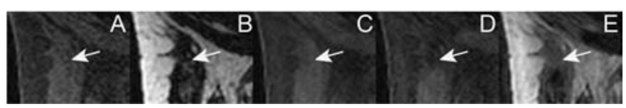

Figure 4: Composite water and fat images from the first dynamic phase (A-B) show features obscured in echo-by-echo CS (D-E) due to errors in the fat image. Using CS for water and VS for fat (C) suppresses these artifacts.

References: [1] Saranathan et al. JMRI 2012; 35:1484-92 [2] Song et al. MRM 2009;61:1242–48 [3] Trzasko et al. MRM 2011;66:1019-32 [4] Rapacchi et al. MRM 2013; [5] Ma et al. MRM. 52:415-419 [6] Uecker et al. MRM 2013

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