Improved Temporal Resolution for Human Breast DCE-MRI Data Using Compressed Sensing

D. S. SMITH[1], X. LI[1], L. ARLINGHAUS[1], E. B. WELCH[1], J. C. GORE[1], AND T. E. YANKEELOV[1]
[1]RADIOLOGY AND RADIOLOGICAL SCIENCES, INSTITUTE OF IMAGING SCIENCE, VANDERBILT UNIVERSITY, NASHVILLE, TN, UNITED STATES

INTRODUCTION Dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) provides information related to tumor perfusion and permeability (K^{trans}), extravascular extracellular volume fraction (v_e), and vascular volume (v_p). DCE-MRI involves the rapid acquisition of images before, during, and after the injection of a contrast agent (CA), so a compromise between temporal and spatial resolution must be reached. The rapid acquisition of images, and the associated low spatial resolution data, confines quantitative DCE-MRI in at least two ways: it limits 1) the ability to scan large sections of tissue at high resolution; and 2) clinical adoption of the technique because high resolution scans are required for standard-of-care. One approach that may allow for decreasing the acquisition time of an individual image without introducing artifacts is to use a compressed sensing (CS) reconstruction (1-3) coupled with a partial Fourier acquisition for dynamically acquired MRI data, which allows extra time to be "spent" on increasing spatial resolution (or SNR). In this study, we demonstrate the accuracy of extracted pharmacokinetic parameters from dynamic breast data that has been incompletely sampled by a range of factors in Fourier space and then reconstructed with CS.

METHODS *Data Acquisition* A patient with Stage II/III breast cancer was enrolled in an IRB-approved study. Imaging was performed on a 3.0 T Achieva MR scanner (Philips Healthcare, Best, The Netherlands) equipped with a 4-channel receive double-breast coil (Invivo Inc., Gainesville, FL). The DCE-MRI acquisition employed a 3D spoiled gradient echo sequence with TR\TE\α =7.9ms\1.3ms\20°. The acquisition matrix was 192×192×20 over a sagittal (22 cm)^2 FOV with a slice thickness of 5 mm. Each 20-slice set was collected in 16 seconds at 25 time points and 0.1 mmol/kg of Magnevist was injected over 20 seconds after the third scan. *Data Processing* Simulated CS scan were generated by randomly discarding 50%, 67%, and 75% of the phase encode lines; we refer to these as 2x, 3x, and 4x accelerated. The same phase encode lines were discarded on each slice. The partial Fourier data for each slice were then reconstructed independently using a TV-regularized, non-convex CS reconstruction. Standard CS reconstruction uses the L_1 norm of the sparse representation, but non-convex norms are known to produce more accurate signal reconstructions for a given number of samples (4). In this work, we use the $L_{1/2}$ norm, defined as the square of the sum of the square roots of a vector. The standard and extended model for analyzing the DCE data were used to extract K^{trans}, v_e, and v_p (extended model only) from the fully sampled and 2x, 3x, and 4x accelerated CS reconstructions. The results were then compared using the concordance correlation coefficient (CCC).

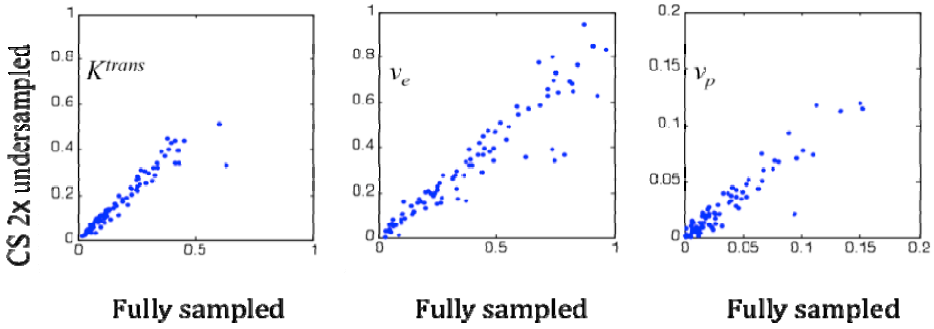

Figure 1: Comparison of K^{trans} (left panel), v_e (middle), and v_p (right) values returned from fully sampled data and those returned from 2x undersampled data. For this data set the values very nearly lie on the line of unity; see the Table below for CCC values.

RESULTS Figure 1 shows the parameters derived from both the fully sampled data set and the 2x accelerated scan. Visually, one can see excellent agreement between the two image sets, with no obvious systematic difference in parameter values. This suggests that undersampling Fourier space does not introduce a bias into the DCE parameter estimates. Table 1 summarizes all results for this study. There is excellent agreement between the undersampled and fully sampled reconstructions for the 2x accelerated scan for all parameters. The agreement is moderately good at 3x, but becomes quite poor at 4x. The agreement should improve for a given undersampling fraction with increasing spatial resolution.

CONCLUSION We find that undersampling a 192x192 DCE-MRI data set by a factor of two does not substantially alter the derived DCE parameters. When only average parameter values in a region of interest are required, rather than voxel-level values, a larger undersampling might suffice, because no obvious systematic bias is introduced by the CS reconstruction. These gains in imaging time could be used to increase spatial resolution, temporal resolution, or signal-to-noise. While one published effort discusses the utility of CS for standard-of-care breast DCE (5), to the best of our knowledge, this is the first effort to apply CS for the extraction of pharmacokinetic parameters in breast cancer. Future studies will seek to validate these findings in a much larger patient set.

	Standard		Extended		
	K^{trans}	v_e	K^{trans}	v_e	v_p
2x	0.90	0.96	0.98	0.96	0.94
3x	0.79	0.86	0.75	0.82	0.76
4x	0.39	0.72	0.48	0.69	0.58

Table 1: CCC values for both DCE-MRI models and three acceleration factors.

ACKNOWLEDGMENTS: NCI 1R01CA129961, NIBIB T32 EB001628, NCI 1U01CA142565, and NCI P30 CA68485

REFERENCES: (1) Lustig et al., Mag Reson Med 2007;58,1182-95. (2) Candes et al., IEEE Trans Inf Theory 2006;52:489-509. (3) Donoho, IEEE Trans Inf Theory 2006;52:1289-1306. (4) Chartrand, IEEE Sig Proc Lett 2007;14:707-10. (5) Wang et al, Med Phys 2010;37:4971-81.