Feasibility of high temporal resolution compressed sensing based DCE-MRI

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Introduction

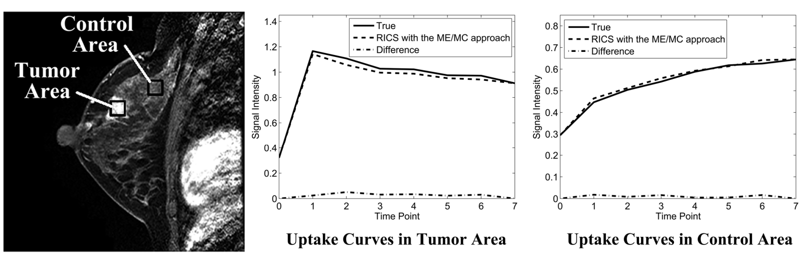
Dynamic contrast-enhanced (DCE) MRI has been widely used to characterize tumor vasculature. Because of the dynamic nature of DCE-MRI, higher temporal resolution translates into more accurate data for kinetic analysis. On the other hand, the heterogeneous nature of tumors requires high spatial resolution for accurate characterization. Because of their mutual importance, consistent efforts have been aimed at accomplishing both high temporal and spatial resolution DCE-MRI. Several applications of compressed sensing (CS) theory to dynamic MRI have been successfully demonstrated such as k-t SPARSE and k-t FOCUSS [1-2]. But only a few studies focus on CS-based DCE-MRI, and none on the breast. A number of practical issues have to be investigated before implementing CS-based DCE-MRI in a typical clinical setting, such as the reliability of uptake curves reconstructed from undersampled data with CS theory, and the potential impact of subject motion. The purpose of this study is to investigate the feasibility of applying CS theory to breast DCE-MRI to improve the temporal resolution while faithfully reconstructing uptake curves and minimizing potential motion related artifacts.

Methods

3D breast DCE-MRI data were acquired using T1-weighted 3D SPGR with fat suppression on a whole-body 1.5T scanner (Signa Excite, GE Medical Systems, USA). The experimental parameters were: TR/TE = 6.931/2.72ms, Flip Angle = 15°, slice thickness = 5mm, and matrix size = 512×512×21. One pre-contrast and seven post-contrast frames were obtained. Gd-DTPA (0.2mmol/kg; Magnevist, Bayer Schering Pharma AG, Berlin, Germany) contrast agent was injected into the antecubital vein with flow rate of 2 ml/s. Administration of contrast agent was followed by a 20 ml saline flush at flow rate of 2 ml/ s. Undersampled 3D data were extracted from the fully sampled 3D breast DCE-MRI data (a 2D Gaussian random undersampling in k_y and k_z directions with full sampling in k_x direction). Final DCE images $f(t)$ were reconstructed using Reference Image based Compressed Sensing technique (RICS) [3] with the average and motion estimation and motion compensation (ME/MC) [2] approaches, respectively. SFD was used as the spatial sparse transformation in l_1-norm minimization.

Results and Discussion

The uptake curve reconstruction experiment shows a high correlation between uptake curves reconstructed from fully sampled data by Fourier transform and from undersampled data by RICS, indicating high similarity between them (see Fig.1). The mean Pearson correlation coefficients for RICS with the ME/MC approach was 0.977±0.023. The comparisons of final reconstruction results between RICS with the average approach and RICS with the ME/MC approach suggested that the latter was superior to the former in reducing motion related effects as shown in Fig. 2 (indicated by the arrows). In conclusion, our preliminary results demonstrate the feasibility of RICS for faithfully reconstructing uptake curves for DCE-MRI and improving temporal resolution.



(a) (b) (c)

Fig. 1 Uptake curves reconstructed by RICS with the ME/MC approaches. (a) A representative image showing the tumor and control area (indicated by the black squares) from which uptake curves were calculated. Each of these two areas contained 900 pixels. (b) and (c) The "true" uptake curves (solid line), uptake curves reconstructed by RICS with the average approach (dashed line), and the absolute difference between them (dot-dashed line) from the tumor and control area, respectively.

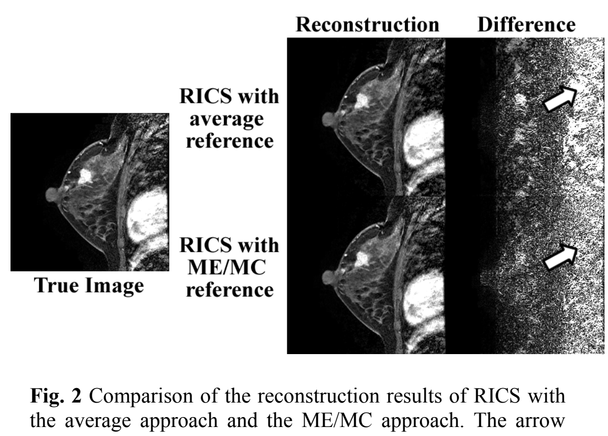


Fig. 2 Comparison of the reconstruction results of RICS with the average approach and the ME/MC approach. The arrow shows the region where the motion artifact is severer.

Reference

[1] M. Lustig et al, presented in Meeting of the ISMRM 14th scientific meeting and exhibition, Seattle, Washington, USA, 2006.

[2] H. Jung et al,"k-t FOCUSS: A General Compressed Sensing Framework for High Resolution Dynamic MRI," Magn. Reson. Med. **61** (1), 103-116 (2009).

[3] J. Ji et al,"Dynamic MRI with compressed sensing imaging using temporal correlations," presented at the 5th IEEE International Symposium on Biomedical Imaging: From Nano to Macro, Paris, France, May 14-17, 2008.