Fast Three-Dimensional Black-Blood MRI Based on Compressed Sensing

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Purpose:

High-resolution 3D-MERGE technique based black-blood imaging has been reported to quantitatively measure carotid atherosclerotic plaque morphology and tissue composition (1), and receive more and more clincial concerns. However, it brings about relative long time consuming due to the use of motion-sensitized preparation, which can increase the probability of motion artifacts due to swallowing, respiration or neck movements (2). Nevertheless, compressed sensing (CS) can improve temporal resolution by reconstructing images from a dramatically small number of data without introducing severe image artifacts (3-7). The purpose of this study was to investigate the feasibility of the fast 3D-MERGE imaging using CS reconstruction. Moreover, compared to the fully k-space sampling approach, we verified whether or not the CS based 3D MERGE images could provide appropriate blood signal suppression and comparable delineation of outer vessel wall, lumen-wall interface and surrounding tissue structure.

Materials and Methods :

After institutional review board approval and written informed consent, one healthy volunteer (male, age: 25) was recruited for this study. MR images of the carotid arteries were acquired on a clinical 3T scanner (Signa TM; GE Medical Systems, Milwaukee, WI) with an eight-channel phased-array bilateral carotid coil. In this study, both of the conventional 3D MERGE and CS based 3D MERGE sequence were implemented to conduct the black-blood imaging. The matrix size was 256 × 256, and number of slices is 32. Scan time for the full, 50, 40, 30, and 20% of the k-space sampling took 65, 33, 26, 22 and 17s, respectively. Similar with conventional fully k-space sampling, the centric order was also employed in compressive sampling (see Fig. 1). After 1-D inverse-Fourier transformation along $\mathbf{k_x}$ to the subsampled data sets, two-dimension CS reconstruction was performed for each coronal slice.

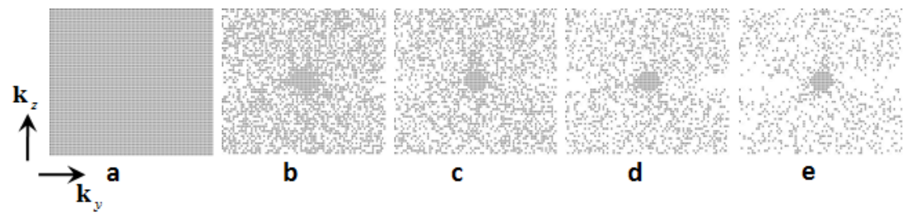

FIG. 1. The k-space sampling patterns of 3D MERGE used in the in-vivo experiment. a–e: Relative a subset of 100 (a), 50 (b), 40 (c), 30 (d), and 20% (e) of the k-space sampling. Note that an ellipse with radii 15% of the overall k-space radii was fully sampled in all cases. To maximum blood signal suppression, the centric acquisition strategy was used to the randomly choosing samples.

Results:

Figure 2 shows representative images at multiple axial locations acquired by subsampling. The different slices of right carotid artery are shown in Fig. 2a. It is observed that the images acquired using 30-50% of the k-space set exhibit comparable blood suppression and image details to the full k-space sampling images, demonstrated in Fig. 2b. But images at 20% of the k-space set show blurred both outer vessel wall and lumen-wall interface.

Figure 3 shows oblique reformatted images from 3D maximum intensity projection (MIP) at different persentage of k-space domain. It is observed that the delineation of the vessel wall, lumen and surrounding details at 30-50% of the k-space set is acceptable (see Fig. 3b-d), comparing with the fully sampling. But it is also demonstrated that the boundaries between vessel wall and surrounding tissue are not clear at 20% of the k-space set, and the outer vessel wall is blurred (see Fig. 3e). The image obtained at 20% of the k-space set is unacceptable in clinical use.

In full Nyquist sampling, the white arrows in Fig. 2 and Fig. 3 show the presence of residual blood signal in lumen. But the observed reduction of the residual blood signal appears in the corresponding positions at 30-50% of the k-space set. It indicates that the blood signal suppression of CS approach at 30-50% of the k-space set exhibits more efficient blood signal suppression than that of the full k-space sampling.

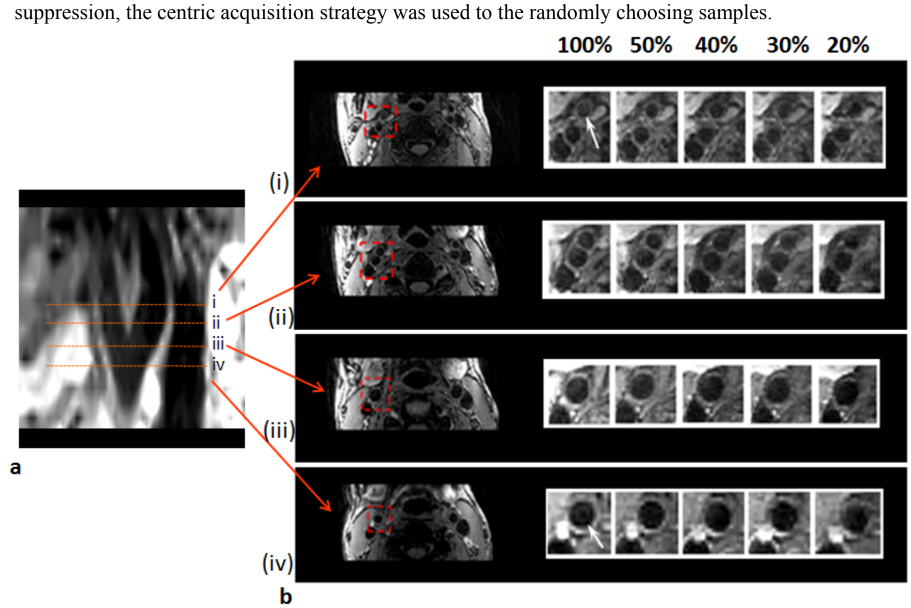

FIG. 2. Images reconstructed at the four axial slices around the right carotid artery using the full, 50, 40, 30, and 20% of the k-space domain. a) A 3D MIP image from the 3D volume, on which the orange dashed lines represent the locations of the four axial slices i, ii, iii and iv. b) The left column images were obtained by full k-space sampling, and the images zoomed in view from the corresponding part of the left column images (highlighted by red box) were shown on the right column.

Conclusions:

In the study, we have demonstrated the feasibility of applying CS in 3D carotid artery black-blood fast imaging. Imaging results suggested that with subsampled data sets at 30-50% of the full sampling, the CS strategy based 3D-MERGE black-blood imaging can achieve acceptable blood suppression and provide a comparable delineation of vessel wall for rapid plaque burden measurement.

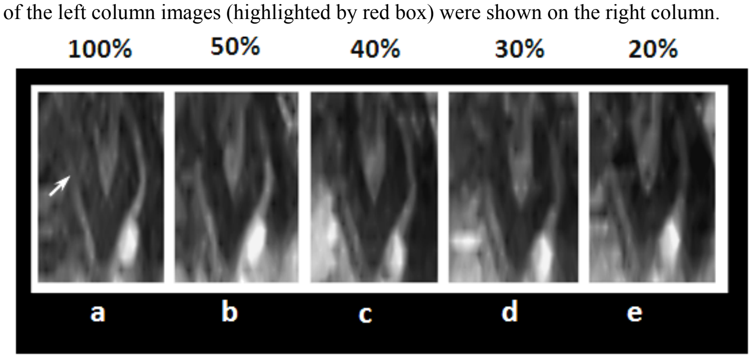

FIG. 3. Images reformatted obliquely from 3D MIP. a–e: Images reformatted from a subset of 100 (a), 50 (b), 40 (c), 30 (d), and 20% (e) of the full sampling.

References:

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