CoSMo: Compressed Sensing Motion Correction for Coronary MRI

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Introduction: In cardiac imaging, respiratory motion causes image artifacts and ghosting. Over the past two decades, several approaches have been proposed to minimize motion artifacts such as breath-holding, respiratory navigators or self-gating [1]. In high resolution imaging, respiratory navigators using a 2D selective RF excitation typically positioned on the right hemi-diaphragm, have been used to track and gate the respiratory motion. In this technique, the k-space lines acquired immediately after the navigator signal are used for image reconstruction only if the navigator signal is within a pre-defined gating window. The lines acquired outside the gating window are rejected and reacquired in the subsequent cardiac phase. The percentage of the accepted lines is reported as the navigator efficiency, which is commonly between 30% and 60% for 5mm gating windows. Furthermore, toward the end of data acquisition, the long acquisition time and patient movement may cause navigator drifting where the majority of navigator signals fall out of the acceptance window resulting in unsuccessful completion of the imaging. The rejected k-space lines depend on the patient's respiratory pattern and change during the data acquisition. Image reconstruction without re-acquiring these k-space lines results in incoherent aliasing artifacts. In this study, we investigate the utility of compressed sensing (CS) reconstruction [2,3] in estimating the rejected k-space lines instead of re-acquiring the data, and thus reducing the total acquisition time in coronary MRI.

Material and Methods: Images were acquired on a 1.5T Philips Achieva magnet using a 5-channel cardiac coil array. A coronary MRI acquisition was performed to image the right coronary artery (RCA) in healthy subjects. A free breathing ECG triggered SSFP sequence (TE/TR/α=4.3/2.1/90°, spatial resolution=1.3×1.3×3 mm^3) with T_2 Prep and fat saturation was used. A two-dimensional pencil beam navigator was placed on the dome of the right hemi-diaphragm to measure the respiratory motion without gating the acquisition, i.e. a navigator efficiency of 100%. To assure a fully sampled center of k-space, with all lines within an acceptance window, data acquisition was repeated multiple times. All data were transferred to Matlab (The MathWorks, Natick, MA) for reconstruction. A 5mm acceptance gating window was determined from the measured navigator data and placed at the mode of the navigator signal toward end-expiration, similar to the implementation on our clinical scanner. The gating window was used to determine and discard the k-space lines corrupted by the respiratory motion during the first acquisition. However, the center of k-space, a 5×5 box of slice and phase encode lines, was fully sampled by using data from subsequent averages when necessary.

Figure 1: *k_y-k_z under-sampling pattern created by discarding the k-space lines outside the acceptance gating window.*

We implemented a CS image reconstruction method, based on distributed l_1 minimization in wavelet domain using a reweighting scheme [4]. The CS algorithm simultaneously reconstructed the images in each coil and these were then combined using root-sum-squares. The reference image was created using retrospective gating with a 5mm acceptance window. For comparison, the coronary images were also constructed using the zero-filled under-sampled k-space, as well as without gating (nav. efficiency 100%).

Results and Discussions: Figure 1 shows the under-sampling pattern caused by discarding the k-space data outside the acceptance window in one subject. The navigator efficiency was calculated to be 41% for a gating window of 5 mm. Figure 2 displays example 2D slices from a 3D dataset reconstructed by retrospectively gating with (a) 5mm gating window, (b) CS, (c) zero-filling, and (d) no gating. As shown, images reconstructed by CS are comparable with the ones that are retrospectively gated. In contrast to the conventional gating method, which requires acquiring the whole k-space, in our study, the CS algorithm uses only 41% of the k-space to reconstruct the whole image with comparable quality. Furthermore, this reconstruction is based on an acquisition with a pre-defined duration.

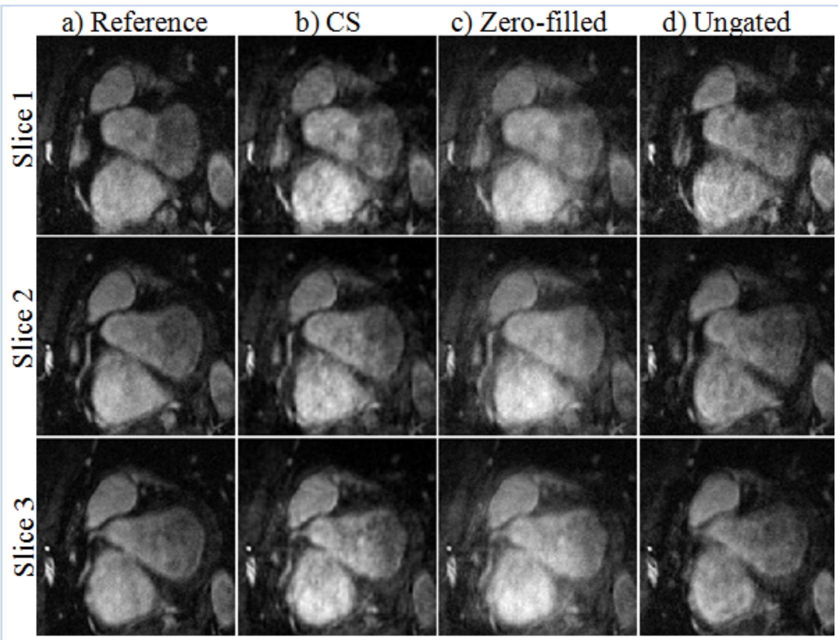

Figure 2: *Example slices of the right coronary artery reconstructed using four different techniques: a) retrospective gating b) CS (c) zero-fillling (d), no respiratory gating. CS yields images with similar quality to a fully sampled k-space but with a reduced acquisition time.*

Conclusions: We demonstrated the feasibility of employing CS in reconstruction of coronary artery MRI using a subset of the k-space retrospectively specified by the respiratory navigator signal, resulting in reduced image acquisition time compared to prospective gating.

References: [1]Scott, Radiology, 2009; [2] Donoho, TIT, 2006; [3] Barral, ISMRM, 2009; [4] Tropp, SP, 2006.

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