Free-breathing perfusion imaging with SW-CG-HYPR and motion correction

L. Ge[1], A. Kino[1], M. Griswold[2], J. Carr[1], and D. Li[1]
[1]Departments of Radiology and Biomedical Engineering, Northwestern University, Chicago, IL, United States, [2]Departments of Radiology and Biomedical Engineering, Case Western Reserve University, Ohio, United States

Introduction:

The diagnostic value of first-pass perfusion MRI is limited by low spatial coverage, resolution, SNR, and cardiac motion related image artifacts. Parallel imaging is limited by SNR in myocardial perfusion MRI. Time-resolved data acquisition with Sliding-Window Conjugate-Gradient HighlY constrained back PRojection (1, 2) (SW-CG-HYPR) has been used to acquire myocardial perfusion images with increased spatial coverage, better spatial resolution, and improved SNR (3). However, this method is sensitive to respiratory motion; therefore, breath-hold is required during data acquisition. In this work, we developed a motion correction method for SW-CG-HYPR which allows free-breathing myocardial perfusion MRI.

Methods:

An ECG-triggered, multi-slice FLASH (fast low angle shot) sequence with radial sampling was used in this study. The k-space was acquired in a segmented interleaved fashion. Three saturation pre-pulses were applied in each cardiac cycle and 2 slices were acquired after each saturation pulse. The "composite images" were reconstructed by a sliding window method, and the CG-HYPR method was used to reconstruct time-resolved images with a temporal resolution of one cardiac cycle.

For motion correction, both in-plane translation and rotation of the heart between different cardiac cycles were detected in the image domain by calculating the cross-correlation coefficients between low resolution images reconstructed from central undersampled k-space in each heartbeat. Motion correction was performed in k-space by rotating the undersampled k-space and shifting the phase by a factor of $e^{-2\pi i(\delta_x/N_{read}+\delta_y/N_{pe})}$, where δ_x and δ_y are the number of pixels to shift in x and y directions, respectively, and N_{read} and N_{pe} are the total number of pixels along readout and phase encoding directions, respectively.

Six healthy volunteers were scanned using a 1.5T system (Espree, Siemens, Erlangen, Germany) with and without breath hold. Images were acquired during the first-pass of 0.075 mmol/kg of contrast material, chased by 15 ml of saline solution injected intravenously at a rate of 4 ml/s. Imaging parameters included: TR/TE/flip-angle = 3.2/1.6 ms/10º, FOV = 270×270 mm^2, spatial resolution = 1.3×1.3×10 mm^3, and number of slices = 6. The images were qualitatively graded by a reviewer using a score of 1-4 (1: worse; 4: best), and signal vs. time curves were calculated. The image quality and the dynamic signal changes from the breath-holding SW-CG-HYPR images were used as a reference to compare with those from the free-breathing, motion-corrected SW-CG-HYPR images. A paired two-tailed t-test was used to determine significant differences of the image quality (α=0.05 level).

Results:

The average image quality score of the free-breathing images with motion correction (3.09±0.37) is significantly higher than that without motion correction (2.26±0.40), and is comparable to the successful breath-holding images (3.10±0.41) (Fig. 1) (Fig. 2: Case 1). The image quality of the free breathing SW-CG-HYPR images with motion correction is better than the failed breath-holding image (Fig. 2: Case 2). The signal changes in motion corrected free-breathing images were closely correlated to the breath-holding images, with a correlation coefficient of 0.9764 for myocardial signals (Fig. 3).

Conclusions:

This work demonstrated the feasibility of a motion correction method for SW-CG-HYPR myocardial perfusion MR imaging. The image quality was substantially improved with motion correction. This technique may allow myocardial perfusion MRI during free breathing, which is important for patients with coronary disease who may not be able to hold their breath adequately.

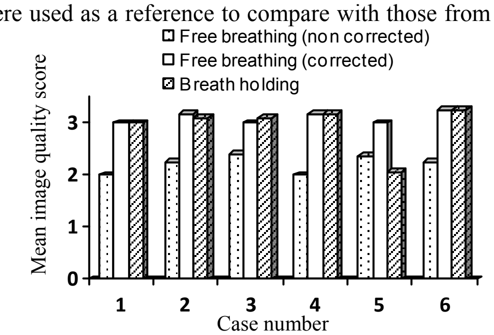

Figure 1. Mean image quality score of free-breathing images with motion correction and without motion correction and breath-holding images from six healthy volunteers.

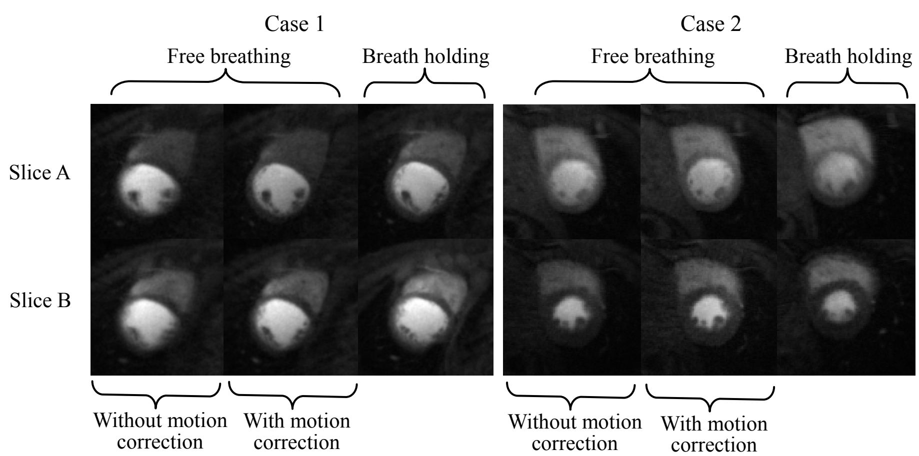

Figure 2. Comparison of the free-breathing images with and without motion correction and the breath-holding images. The breath-hold was successful in Case 1 and failed in Case 2.

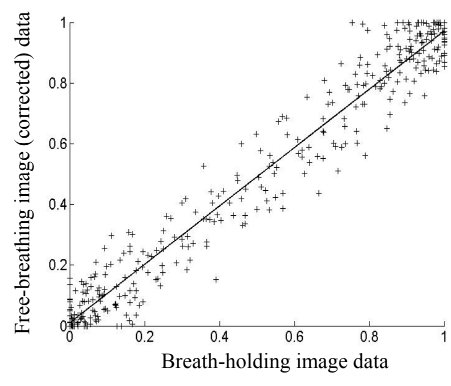

Figure 3. Correlation between signal intensities of free-breathing images with motion correction and those of breath-holding images.

References:

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