Myocardial Perfusion MRI with sliding window and CG-HYPR

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Introduction:

Perfusion MRI is a promising technique to detect ischemic heart disease. Single-shot imaging is currently used to acquire 3-4 slices with a temporal resolution of one time frame per cardiac cycle. Image quality is limited by cardiac motion and signal intensity changes after the saturation pulse. Reduced imaging time per slice will allow greater coverage of the heart and reduced motion artifacts, especially during stress imaging with high heart rates. Parallel imaging methods have been applied in myocardial perfusion MRI, but the acceleration factors are limited to 2-3 because of SNR considerations. Time-resolved data acquisition with Highly Constrained Backprojection reconstruction (HYPR) has been proposed to permit vast undersampling in the image time series (1). Conjugate-gradient (CG) methods can further improve the accuracy of the signal change for closely spaced pixels with different time courses (2). A combination of sliding composite images and CG-HYPR method will allow vast undersampling (reduced acquisition time per slice) and increased number of slices while preserving the temporal resolution of one frame per heartbeat and dynamic blood and myocardial signal intensity changes. In this work, we compared this new method with the conventional clinical protocol for myocardial perfusion in healthy volunteers.

Methods:

An ECG-triggered, 2D multi-slice FLASH (fast low angle shot) sequence with radial *k*-space sampling was used in this study. As shown in Figure 1, the *k*-space was acquired in a segmented interleaved fashion. The "composite images" were reconstructed by a sliding window method with full *k*-space data. Conjugate-gradient HYPR method was used to reconstruct time-resolved images (one image per cardiac cycle) combining signal intensity information from the undersampled radial projections, and the structural information from the sliding composite images whose center corresponds to the current cardiac cycle.

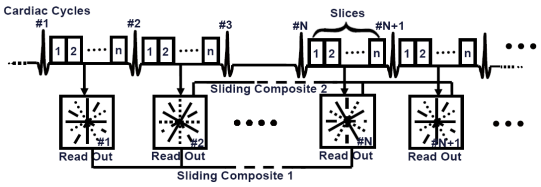

Figure 1. Schematic of the 2D-multislice radial k-space acquisition using interleaved sliding window.

Simulations: Fully sampled myocardial perfusion data were acquired in a healthy volunteer as the reference. The datasets were undersampled by a factor of 5 to simulate a shorter scan time, and post-processed by the sliding-composite CG-HYPR method. Left ventricle and myocardium signal changes after contrast injection were compared between the sliding CG-HYPR images and the full *k*-space reference images.

In vivo Studies: Six healthy volunteers were scanned using a 3T system (Trio, Siemens, Erlangen, Germany) during a breath-hold. Images were acquired during the first-pass of the contrast agent. 10 ml of contrast material, chased by 15 ml of saline solution, was injected intravenously at a rate of 4 ml/s. Imaging parameters included: TR/TE/flip-angle = 3.6/1.8 ms/10º, FOV = 260×260 mm^2, matrix = 160×192, slice thickness = 8 mm, saturation prepulse delay = 50 ms, number of slices = 6. One 2D *k*-space dataset was acquired in an interleaved fashion with 16 projections per heartbeat over 10 cardiac cycles, and six datasets were collected over 60 heartbeats. Sliding composite images were reconstructed from *k*-space lines over 10 cardiac cycles. To verify the signal changes after contrast administration, a conventional scan was performed with the same contrast injection scheme and the following parameters: TR/TE/flip-angle = 2.06/1.03/10º, FOV = 350×270 mm^2, matrix = 106×192 (sampled lines/heartbeat = 63), GRAPPA factor = 2, slice thickness = 8 mm, saturation prepulse delay = 40 ms, number of slices = 3. The dynamic signal changes from the conventional scan were used as a reference to compare those obtained from sliding CG-HYPR images.

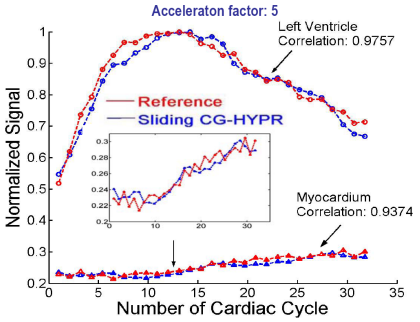

Figure 2. Comparison of the simulation results between the fully-sampled reference images and the sliding CG-HYPR images with an acceleration factor of 5.

Results:

Simulations: The signal intensity curves of sliding CG-HYPR are highly correlated with those of the reference (Figure 2, correlation coefficients: 0.9757, 0.9374 for blood and myocardial signals, respectively).

In vivo Studies: As shown in Figures 3 and 4, left ventricle and myocardium signal changes in CG-HYPR images were closely related to those observed in images obtained using the conventional protocol. The mean correlation coefficients between sliding CG-HYPR and reference images are 0.9672, 0.9423 for blood and myocardial signals, respectively. With sliding CG-HYPR, 16 radial views were required for each cardiac cycle, while the conventional protocol requires 64 lines.

Conclusions:

This work demonstrated the feasibility of sliding CG-HYPR for accelerated myocardial perfusion imaging with a temporal resolution of one time frame per cardiac cycle. Using this method, the acquisition time per cardiac cycle can be reduced dramatically, which allows an increased number of slices and reduced motion artifacts during myocardial perfusion imaging, improving diagnostic accuracy for ischemic heart disease.

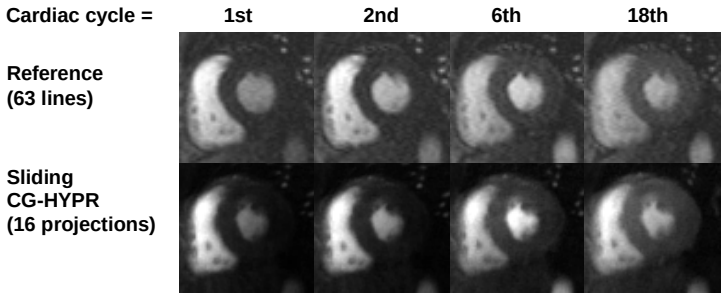

Figure 3. Comparison of conventional method and sliding CG-HYPR. Blood signal change is observed in sliding CG-HYPR perfusion images, and comparable to the reference.

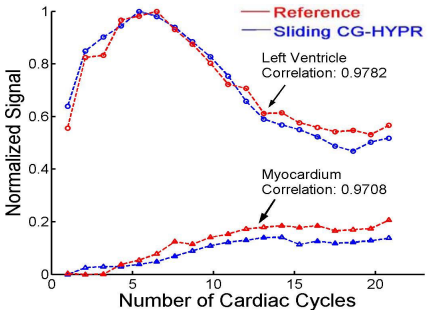

Figure 4. Comparison of the left ventricle and myocardium signal changes vs. time (same datasets as Figure 3).

References:

1. Mistretta CA, et. al. MRM, 55: 30-40, 2006
2. Griswold MA, et. al. Proc ISMRM, Berlin, 2007: 834