Myocardial Perfusion MRI Using SW-CG-HYPR in Canines with Improved Spatial Coverage, Resolution and SNR

L. Ge[1], A. Kino[1], D. Lee[1], R. Dharmakumar[1], M. Griswold[2], C. Mistretta[3], J. Carr[1], and D. Li[1]

[1]Northwestern University, Chicago, IL, United States, [2]Western Reserve University, Ohio, United States, [3]University of Wisconsin-Madison, WI, United States

Introduction:

First-pass perfusion MRI is a promising technique for detecting ischemic heart disease. However, the diagnostic value of the method is limited by the low spatial coverage, resolution, SNR, and cardiac motion related image artifacts. 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 and echo-planar imaging (EPI) methods have been applied in myocardial perfusion MRI, but the spatial coverage is still limited to 3-4 slices with relatively low resolution and SNR. A combination of sliding window and CG-HYPR (1, 2) methods (SW-CG-HYPR) have been proposed to reduce the acquisition window for each slice while maintaining the temporal resolution of one frame per heartbeat in myocardial perfusion MR imaging (3). This method allows increased number of slices, reduced motion artifacts, and preserves the relatively high SNR and spatial resolution of the "composite images". In this work, using a controlled animal model, we compare this new method with conventional clinical protocols (both turbo-FLASH and EPI) for myocardial perfusion and test whether the myocardial territory supplied by a stenotic coronary artery can be detected accurately.

Methods:

Five dogs with LCX occlusion were scanned using a 1.5T system during the first-pass of the contrast agent. The images were acquired within a breath-hold, first at resting condition, then during stress condition induced by continuous intra-arterial adenosine injection (14 μg/kg/min). 0.05mmol/kg of contrast material, chased by 12 ml of saline solution, was injected intravenously at a rate of 4 ml/s. An ECG-triggered, turbo-FLASH sequence with radial *k*-space sampling and saturation recovery (SR) preparation was used in this study. The *k*-space was acquired in a segmented interleaved fashion with 16 projections per heartbeat, and the "composite images" were reconstructed by a sliding window method with *k*-space data from 10 consecutive cardiac cycles. CG-HYPR method was used to reconstruct the time-resolved images (2). The reduced data acquisition window (about 1/4 compared to the conventional protocol) by SW-CG-HYPR makes it possible to acquire multiple slices after each SR pre-pulse (Fig. 1). Imaging parameters included: TR/flip-angle = 2.5 ms/12º, FOV = 240×240 mm^2, matrix = 192×192, number of slices = 6 and spatial resolution = 1.2×1.2×8 mm^3. The position and TI time (100 ms) of slice 2, 4 and 6 were matched to the slices acquired by conventional protocols for comparison purpose. Slices 1, 3 and 5 were acquired with a shorter TI time (60 ms) but were within the range of acceptable TI times commonly used. To compare the image quality and verify the signal changes after contrast administration, a conventional scan with either turbo-FLASH (2 dogs) or EPI (3 dogs) was performed with the same contrast injection scheme. The parameters for turbo-FLASH included: TR/flip-angle = 2.0/12º, FOV = 140×280 mm^2, matrix = 80×192, GRAPPA factor = 2, TI = 100 ms, number of slices = 3, spatial resolution = 1.8×1.8×8 mm^3. The parameters for EPI include: TR/flip-angle = 1.8/25º, FOV = 140×343 mm^2, matrix = 70×192, TI = 100 ms, number of slices = 3, spatial resolution = 2.0×1.8×8 mm. The dynamic signal changes from the conventional scan were used as a reference to compare to those obtained from SW-CG-HYPR images. The signals from the left ventricle, healthy myocardium, and ischemic myocardium for all of the three methods were measured and compared.

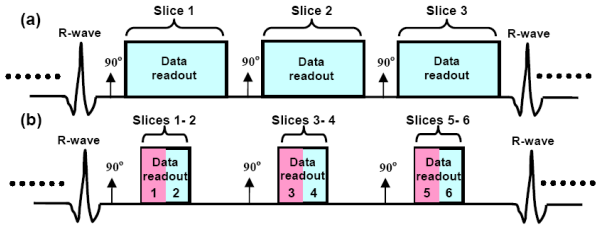

Figure 1. Schematic of the perfusion data acquisition structure: (a) Conventional SR prepared FLASH sequence. (b)Multi-slice/SR sequence for SW-CG-HYPR.

Results:

The SNR of the left ventricle at peak enhancement with SW-CG-HYPR (32.1±2.32) is significantly higher than turbo-FLASH (20.6±2.62) and EPI (12.9±1.95). Figure 2 shows examples of conventional and SW-CG-HYPR perfusion images. The signal changes of the left ventricle and healthy myocardium in SW-CG-HYPR images (Figure 2, bottom row) closely follow those observed in images obtained using the conventional protocols (Figure 2, top row). The defects caused by LCX occlusion can be clearly delineated in SW-CG-HYPR images with improved SNR and resolution. The signal intensity changes of the left ventricle, healthy and ischemic myocardium are highly correlated (Figure 3). For all five dog studies, the mean correlation coefficients between SW-CG-HYPR and reference images are 0.99, 0.96 for blood and healthy myocardial signals, respectively. The paired two-tailed t-test detected no significant time-to-peak differences between the SW-CG-HYPR and reference methods (p<0.05).

Conclusions:

This work demonstrated the feasibility of SW-CG-HYPR for detecting the myocardial territory supplied by a stenotic coronary artery. Using this method, the acquisition time per slice was reduced by a factor of 4, which should substantially reduce cardiac motion artifacts. In particular, the number of slices was doubled, the spatial resolution was improved by a factor of 2 and the SNR by >50% as compared to conventional methods. All these improvements have helped delineation of the myocardial defects. This technique needs to be evaluated in patients to determine its clinical value.

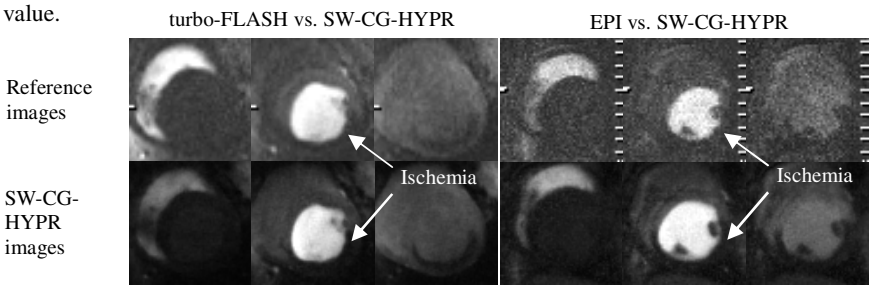

Figure 2. Similar signal changes in the left ventricle and myocardium are observed between the SW-CG-HYPR and the conventional methods. The delineation of the myocardial territories supplied by LCX stenoses in SW-CG-HYPR images is clearly improved as compared to the reference images.

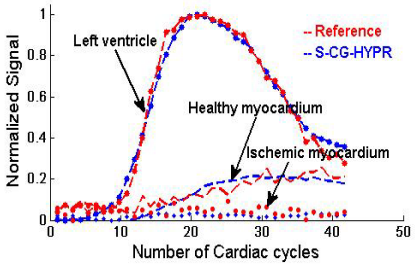

Figure 3. Comparison of the signal changes vs. time curves between SW-CG-HYPR and reference methods in a dog study.

References:

1. Mistretta CA, et. al. MRM, 55: 30-40, 2006
2. Griswold MA, et. al. Proc ISMRM, Berlin, 2007: 834
3. Ge L, et al. Proc ISMRM, Toronto, 2008: 43