RAPID UNGATED CMR PERFUSION IMAGING TO EVALUATE CORONARY ARTERY DISEASE IN PATIENTS WITH ARRHYTHMIA

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Purpose: Cardiac Magnetic Resonance (CMR) perfusion imaging is a well-established non-invasive tool for detection of coronary artery disease (CAD) in intermediate risk patients. Conventional gated imaging relies on regular cardiac rhythm to acquire quality images without motion artifact. However, ECG gating problems in patients can degrade diagnostic information, and when the cardiac cycle length is variable there may be misregistration of images at different time frames. This is a problem especially with CMR perfusion imaging, which has a short window for image acquisition during first pass of contrast. As a result, patients with significant arrhythmias have been excluded from some clinical perfusion CMR trials. Here we investigate a previously proposed ungated, rapid image acquisition and post processing method for first pass perfusion CMR in patients with arrhythmia, to determine how informative ungated and self-gated images are for assessing coronary disease.

Methods: Eight patients who were scheduled for X-ray angiography or had it within 2 weeks of the study, had adenosine stress and rest CMR perfusion imaging performed using a saturation recovery radial turbo FLASH sequence with TR/TE=2.2/1.2msec, 2.3x2.3x10mm pixel size on a 3T magnet. Four to five slices were acquired after each saturation pulse, with each image acquired in 42-53 msec, using no gating and during free-breathing. This was repeated without pause, approximately four times per second for a minute. The images were reconstructed from undersampled radial data with an iterative compressed sensing method using spatial and temporal total variation constraints. The ungated images were then processed to self-gate the images into near-systole and near-diastole image sets. A region of interest around the heart in each time frame of the cardiac cycle was summed for each slice, which generated a plot (Figure 1).The peaks of this plot were considered as near-diastolic phase and the nadirs as near-systolic phase for that slice. Model-based deformable image registration was then used on each of the self-gated datasets to reduce residual cardiac and respiratory motion. The ungated, systolic, and diastolic images, each having 4-5 slices at both stress and rest, were read as normal or with disease in a random order by three independent blinded readers. Image quality was also rated (5-1, highest quality to lowest quality).

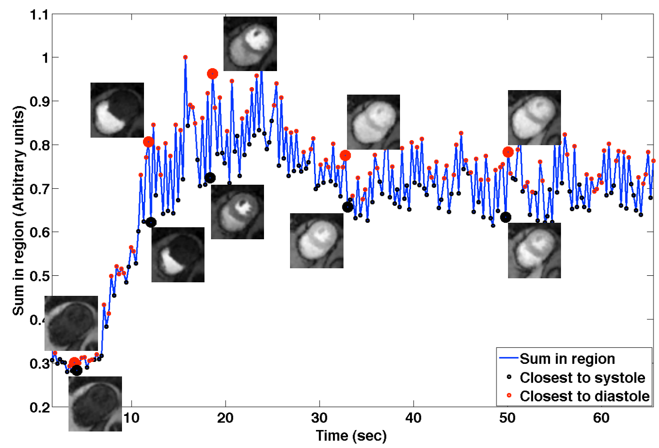

Figure 1: Illustration of selected ungated time frames and the self-gating process in one slice. The sum of a region around the heart (found automatically) in each time frame was used to generate a 1D self-gating signal, plotted in blue. The ungated images were then binned (self-gated) into near-diastole or near-systole if the 1D signal was a peak or a trough, respectively. The images above the plotted blue line are all near-diastole and their time points correspond to the large red circles. Near-systole images are shown below the plotted blue line and were acquired at the times marked by the large black circles.

Results: All 8 patients successfully completed the perfusion MRI protocol and 7 out of 8 underwent coronary angiography. Three patients were in atrial fibrillation and five were in sinus rhythm during MRI scanning. There was no significant difference in image quality or artifact between the three image sets (1. ungated, 2. self-gated to near-diastole, 3. self-gated to near-systole) both at stress and rest. No significant difference in image quality was noted in AF and normal sinus rhythm patients (3.6 ± 0.7 vs. 3.3 ± 0.5). Of the 8 patients, four had normal perfusion, two had fixed perfusion defects correlating with late gadolinium enhancement findings and two had reversible perfusion defects (Figure 2). Analysis of the pooled scores from the 3 independent readers showed a sensitivity of 0.92(CI 0.65-0.99) and specificity of 1(CI 0.76-1) for the detection of CAD compared to X-ray angiography, both with ungated and self-gated images. If the diagnosis had been determined based on majority (diagnosis of CAD made if 2 out of 3 readers called the images positive for perfusion defect) then the sensitivity would have been 1.

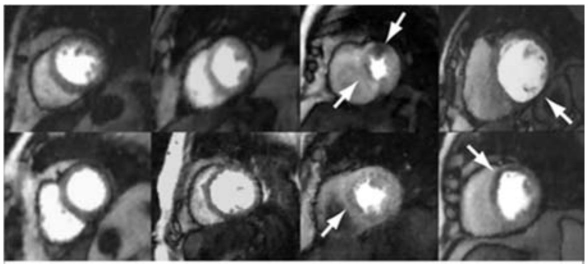

Figure 2: Ungated stress perfusion images- One time frame of one slice from each of the 8 patients. The four images on the left are from patients with normal x-ray angiography. The four images on the right depict reversible ischemia in two images and fixed perfusion defects consistent with infarction in the far right two images.

Discussion: These initial results show that a rapid radial perfusion imaging method obviates the need for ECG gating due to improved temporal resolution while maintaining diagnostic accuracy in patients with CAD. The perfusion images can be interpreted from the raw ungated image data or from the retrospectively sorted self-gated datasets in near-diastole and near-systole. The results show comparable image quality and accuracy with ungated and self-gated approaches, in both sinus rhythm and atrial fibrillation. This has potential in being a reliable non-invasive method of diagnosing CAD especially in patients with arrhythmia and gating problems. The main limitation of this study is the sample size, and a larger study to confirm the diagnostic accuracy and image quality of this approach is needed.

Conclusion: Ungated radial perfusion CMR can be performed with high quality imaging in patients in sinus rhythm and atrial fibrillation. Fast CMR perfusion imaging without the need for ECG gating simplifies the acquisition and could expand the role of stress perfusion CMR to include patients with significant arrhythmias and those with gating problems.