Artifact-free Non-ECG-Gated First-Pass Myocardial Perfusion MRI: Continuous Acquisition for All-Systolic Imaging

Behzad Sharif[1], Reza Arsanjani[1], Rohan Dharmakumar[1], Noel Bairey Merz[1], Daniel S Berman[1], and Debiao Li[1]

[1]Biomedical Imaging Research Institute, Dept. of Biomedical Sciences, Cedars-Sinai Medical Center, Los Angeles, California, United States

INTRODUCTION: First-pass perfusion (FPP) cardiac MR (CMR) imaging has been shown to have a high performance for diagnosis of coronary artery disease (CAD). Reliability of FPP imaging, however, is hindered by dark-rim artifacts (DRAs) and the need for near-perfect ECG gating. The latter can be challenging in the presence of arrhythmias or heart-rate variations during stress. Moreover, end-systolic (ES) imaging has recently been shown to provide improved visualization of subendocardial defects [1].

PURPOSE: We developed an innovative ungated FPP technique capable of simultaneously eliminating DRAs [2,3] and enabling reconstruction of all slices at ES. We hypothesized that the developed method achieves DRA-free imaging and high accuracy in patients with suspected CAD, using nuclear myocardial perfusion imaging (MPI) as the non-invasive reference.

METHODS: Based on a previously developed "Ungated Cine FPP" approach [3], a multi-slice magnetization-driven [5-7] method was developed for ungated FPP imaging. Fig. 1 highlights the main differences of the proposed pulse sequence compared with the conventional FPP method. All scans were performed on a 3T clinical scanner using an ungated RF-spoiled GRE sequence with continuous golden-angle radial acquisition as in Fig. 1b (flip angle =21°, resolution: 1.7x1.7x10 mm). The reconstruction method used automatic self-gating and optimally apodized [3] compressed sensing for accelerated reconstruction. Normal subjects (n=6) were studied using both the proposed and conventional method. Patients (n=9) with suspected CAD on the basis of recent abnormal SPECT/PET MPI underwent adenosine stress/rest FFP CMR. Three patients returned for a second study using the conventional method.

RESULTS: The cine FPP studies in normal subjects were all of high quality and demonstrated normal perfusion. A representative patient study is shown in Fig. 2. Stress-induced hypoperfusion (arrows) was observed in the ES *Ungated Cine FPP* images, corresponding to a stress-induced defect on PET MPI (Fig. 2b). Fig. 2c shows the mid ventricular slice for the conventional FPP scan (separate study) with the red arrow point to a DRA. Based on nuclear MPI results, the sensitivity and specificity of the developed method were 93% and 95%, respectively. The minor disagreements can be explained by the presence of subendocardial defects and possible artifacts on SPECT. All images were reviewed and no DRAs was detected on the Ungated Cine FPP images (2 readers, consensus). However, for the 3 studies using the conventional method, mild-moderate DRA was observed in 21% of the segments.

DISCUSSION: Conventional FPP methods are prone to DRAs, require accurate ECG gating, and do not provide the freedom to image all slices at ES. The developed method overcomes these challenges and is an attractive alternative with the advantage of simplicity (no gating), higher accuracy in the subendocardium (no DRAs, ES imaging), and thereby potentially improved reliability. Preliminary results in healthy volunteers and patients with suspected CAD were of high quality and showed high accuracy compared to nuclear MPI.

References: [1] Motwani and Plein et al., Radiology 2012;; 262. [2] Sharif and Li et al., JCMR 2013, 15(Suppl 1): O3. [3] Sharif and Li et al., MRM 2013, doi: 10.1002/mrm.24913 [4] Sharif and Li et al., JCMR 2013, 15(Suppl 1): O1. [5] Judd et al., MRM 1995; 34. [6] DiBella et al., MRM 2012; 67. [7] Giri and Simonetti: MRM 2013.
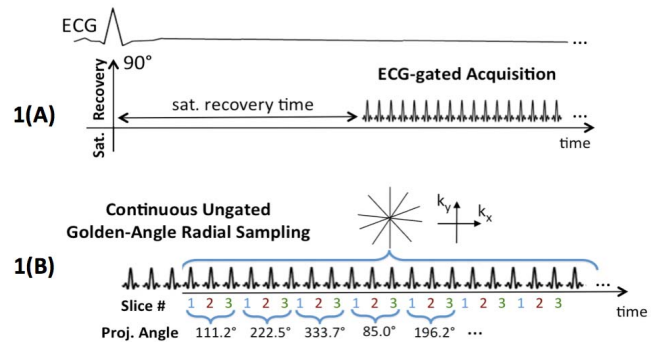
Fig. 1. (A) Schematic for a conventional magnetization prepared (Saturation Recovery) pulse sequence; (B) the proposed "magnetization driven" T1-weighted pulse sequence with golden-angle radial sampling; 3 slices are acquired without ECG gating and continuously with the projections acquired in a slice-interleaved order.
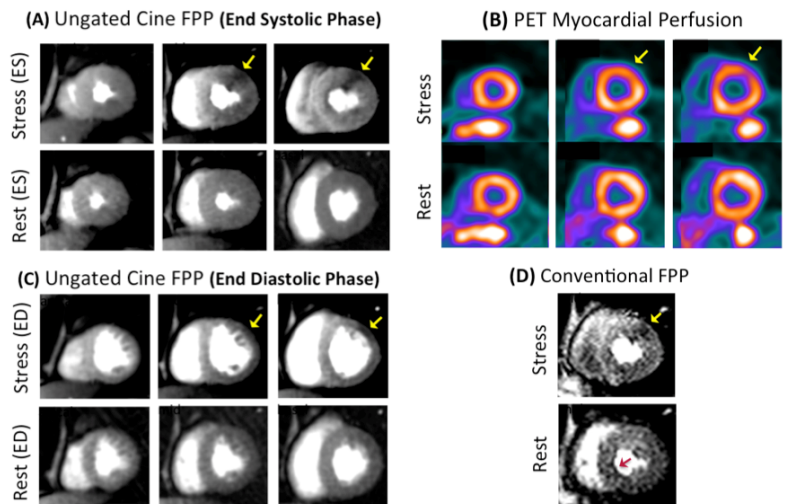
Fig. 2. Results for a representative patient showing stress-induced hypoperfusion. (A) end-systolic reconstruction of all 3 short-axis slices for the adenosine stress and rest scans, showing stress-induced hypoperfusion in the anterolateral wall at mid and basal slices. (B) results of the PET myocardial perfusion study done on the same subject (prior week) showing stress-induced defect in the same region as the one captured in (A). (C) reconstruction of the same dataset at the end-diastolic phase, also showing the perfusion defect but with poor visualization of the transmural gradients. (D) The stress and rest mid ventricular images for the conventional FPP scan; the red arrow points to a subendocardial dark-rim artifact.