Rapid ungated free-breathing cardiac MRI protocol

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Introduction/Purpose: Cardiac MRI is useful for characterizing coronary artery disease and deciding on the need for catheter-based X-ray angiography. However, use is limited in part due to complexity. ECG gating, the need for an expert technologist and an additional IV for adenosine infusion make the protocol challenging. New methods are opening the possibility of an ungated free breathing protocol that would be nearly pushbutton. Here we propose such a protocol with ungated cine imaging, perfusion, T1 mapping and LGE. This approach could have several benefits such as making cardiac MRI more widely available, improving studies where ECG-gating is poor, and enabling robust use in patients with arrhythmias. Here we describe methods for an ungated free breathing approach and demonstrate its use.

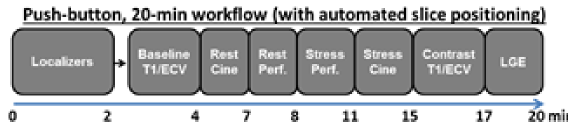

Figure 1: Ungated free-breathing acquisition protocol.

Methods: The protocol in Fig. 1 is proposed to obtain the information critical for evaluating coronary artery disease. The stress cine is not required but fills a delay that is needed after all contrast has been injected.

ECV mapping: The arrhythmia insensitive method (AIR) [1] was used for T1 mapping, but with modifications to handle an ungated free-breathing acquisition. The proton density frame was acquired followed by 30 T1-weighted frames. The closest matching frame was used to give the T1 map. This was done in 3 slices pre-contrast and post-contrast to calculate ECV.

Cine: Cine acquisitions used golden ratio radial sampling with image reconstruction size = 160 x 160, spatial resolution = 2.0mm x 2.0mm, TR = 2.96 ms, and 14 rays per cardiac phase. At 41 ms per image, two heartbeats per slice, and 14 short axis slices the entire sequence required less than a minute to acquire. A block-wise low rank with temporal TV reconstruction was used [2]. EF was calculated by manual selection of end systolic and end diastolic frames. Two, three, and four chamber views were also acquired.

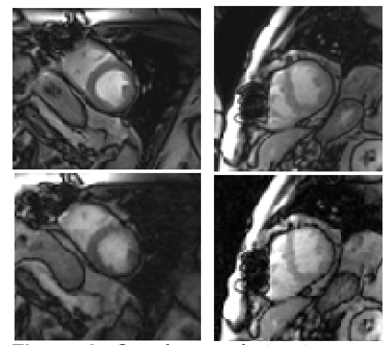

Figure 2: One frame of cine images. Left: subject #1, right: subject #2. Top left: Breath-hold gated, Top right: real-time TGRAPPA. Bottom: free-breathing ungated.

Perfusion: A saturation recovery radial turboFLASH sequence was used for ungated free breathing cardiac perfusion imaging as in [3]. TR/TE=2.2/1.2msec, FOV=260mm, 2x2x8mm pixel size. 20-24 rays with golden angle ratio were acquired for each slice. Four slices were acquired after a single saturation pulse and a ~30 msec delay. The first slice has low SNR and was not used in this study. Each image was acquired in 42-53msec and repeated every ~250msec with no gating and during shallow breathing. Gadoteridol 0.06mmol/kg was injected and ~230 sets of slices were acquired over a total of a minute. Thus each slice was acquired at various cardiac phases in each heartbeat. The images were reconstructed with an iterative TV-regularized method [3]. Instead of stress perfusion, a standard ECG-gated rest perfusion was acquired for comparison.

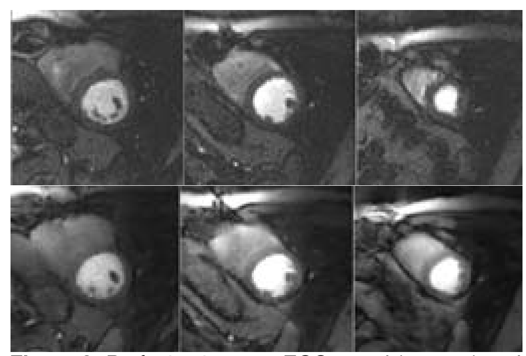

Figure 3: Perfusion images: ECG-gated (top row) and ungated (bottom row).

LGE: A standard single-shot phase-sensitive acquisition was used, with no gating signal. The slice stack was re-acquired multiple times to provide different cardiac phases. The cardiac phase nearest to diastole was selected for use for each slice. This gave a stack of slices for comparison to the standard gated LGE method.

MRI protocol: Two subjects with infarct were imaged with the above methods. Standard gated techniques were inserted into the protocol and performed adjacent in time to the corresponding ungated methods for comparison.

Results/Discussion: Fig. 2 shows a cine results in the two subjects, subject #1 had EF=56% (gated breath-hold), EF=54% (ungated free-breathing). Subject #2 had arrhythmias so the commercial real-time TGRAPPA acquisition was used for comparison: EF=43% TGRAPPA and 39% ungated free-breathing. Fig. 3 shows an example frame from a perfusion study in one of the two subjects, with similar image quality of the gated and ungated images. Fig. 4 shows ECV maps for subject #1. LGE images are not shown, since the images are equivalent to standard single-shot methods but with cardiac phase of the slice varying. These initial results imply that the ungated free-breathing protocol may have diagnostic capabilities similar to gated breath-hold methods. This would provide a much simpler acquisition workflow, increasing the impact of cardiac MRI for healthcare. In addition to the two subjects reported here, we have acquired a number of ungated perfusion studies, and, separately, cine studies. Still, further studies are needed to better determine the accuracy and the advantages of this exciting rapid ungated free-breathing protocol.

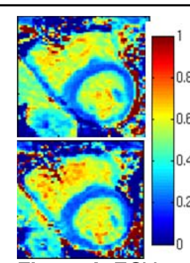

Figure 4: ECV maps: ECG-gated (top) and ungated (bottom).

References: **[1]** Fitts M, et al. Magn Reson Med. 2013 70:1274-82. **[2]** Chen X, et al. Magn Reson Med. 2014 72:1028-38. **[3]** DiBella et al., ISMRM, 222, 2011.