Direct Coronary Artery Motion Tracking from Cartesian 2D Fat Image Navigator for Motion Corrected Coronary MRA

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INTRODUCTION: 2D image based cardiac navigators [1-3] have been recognized for effective motion tracking in coronary magnetic resonance angiography (CMRA). Navigators with spectrally selective fat excitation of epicardial fat surrounding the coronary arteries directly track coronary motion [2-5]. Retrospective motion correction (MC) has been established with a 3D spiral navigator [5], but its long reconstruction time of acquired spiral data is not well-suited for the prospective motion compensation that can be more efficient and effective than the retrospective approach [6-8]. A Cartesian 2D fat image navigator approach, on the other hand, can be used in a prospective manner [3]. In this study, we demonstrate the proof-of-concept of using a 2D fat image navigator to acquire a coronal image of the epicardial fat, from which coronary artery motion in both the SI and LR directions was extracted for MC (on all acquired data) in 3D SSFP CMRA.

METHODS: The 2D fat image navigator acquires a 6cm thick coronal slice with FOV 32cm (RL) by 20cm (SI) capturing the epicardial fat excited by a spectral-spatial excitation [9] (1-3-3-1 binomial pulse train, flip angle=20°), each followed by a single phase encode readout and a spoiler (TR_{nav}=12.8ms and rBW_{nav} ±62.5kHz). Repeated phase encodes (24-32 echoes) were acquired in a total of 260-350ms, using a reverse centric view order. This 2D navigator was incorporated into a 3D SSFP CMRA sequence with the following parameters: TR=4.6ms, TE=1.8ms, FA=90^o, 256x256x12, rBW=±62.5 kHz, FOV=26.0x26.0cm, VPS=32 with a centric view order, slice thickness=3.0mm. The SSFP imaging train was preceded by a spectrally selective fat saturation and 6 Kaiser-Bessel ramp-up pulses.

Experimental Setup: A total of 8 healthy volunteers (age=39±12) were scanned on a 1.5T GE HDx scanner under an IRB approved protocol. The CMRA sequence acquired the 3D k-space data with no oversampling (128 heartbeats (HB); total scan time = 2 minutes for a nominal heart rate of 60 BPM). The protocol additionally included an 8-second breath-held high resolution scan of the 2D fat image navigator.

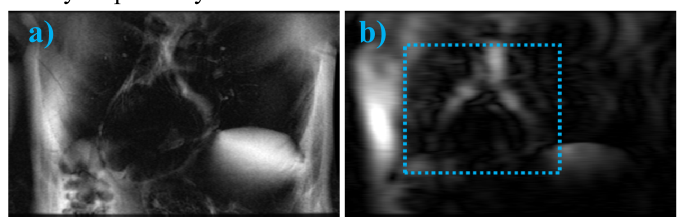

Fig. 1: a) High resolution 2D fat image acquired over 8 heartbeats b) 2D fat image from one heartbeat used for motion tracking. The ROI, which was used for template matching, includes the epicardial fat from two branches.

Data Analysis: Coronary motion extraction from the 2D fat image navigator (2D cross-correlation), motion correction (using the Fourier shift theorem), and 3D reconstructions were all performed offline in MATLAB (Mathworks, Nattick, MA). 2D fat images were reconstructed at 128x512 (RLxSI) at every heartbeat, and the ROI was selected manually. The volumes were each generated with and without *MC*. All volumes were assessed by an experienced radiologist in a blinded manner, and an RCA visualization score was given on a 5-point scale (0=non-diagnostic; 1=poor; 2=fair; 3= good; 4=excellent).

RESULTS: All scans were completed successfully. Fig. 1 shows the high-resolution image from the 2D navigator in a breath hold over 8 HBs, as well as a low resolution 2D fat image acquired in one HB. The epicardial fat surrounding two artery branches can be clearly seen in the low-resolution image. Fig. 2 shows the coronary artery images from two volunteers, where image quality improved substantially after applying *MC*; this is particularly notable in Case 2, which suffered from severe motion artifacts. The RCA score was significantly higher (P=0.02) with *MC* (2.8±0.6) than without *MC* (1.9±0.7).

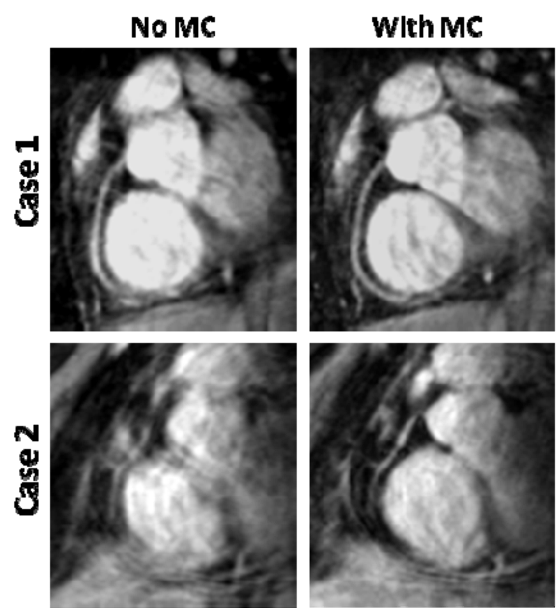

Fig. 2: Reformatted CMRAs from two volunteers.

DISCUSSIONS: We have demonstrated the feasibility of a fast, 2-minute CMRA scan with retrospective motion correction using epicardial fat displacements from a 2D fat image navigator. The substantial improvements in CMRA image quality after applying *MC* suggests that the coronary artery motion measured by the 2D fat image navigator is accurate. This accuracy of estimating the respiratory motion of coronary arteries may be explained by the fact that it primarily depends on the center of mass of the 2D fat image navigator, which is fairly immune to its low native spatial resolution and motion blurring by cardiac motion.

Further improvements in overall CMRA image quality are expected by combining this approach with a prospective navigator gating using a very large bin size. This is an area for further investigation.

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