High-Resolution Whole-Heart Contrast-Enhanced Coronary MRA in 5 Minutes with Self-Navigation and 100% Gating Efficiency

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Target Audience: Researchers and clinicians interested in contrast-enhanced coronary imaging.

Purpose: Contrast-enhanced (CE) whole-heart coronary MRA is a promising technique for CAD detection [1]. However, the current imaging time is relatively long at around 10 min, and the spatial resolution is limited at around (1.1×1.1×1.3 mm)^3. The aim of this work is to develop and evaluate a 3D projection reconstruction (3DPR) based CE coronary MRA technique that achieves (1.0 mm)^3 spatial resolution in 5 minutes of scan time. The short and fixed scan time would make it easier to integrate the proposed method into a comprehensive contrast-enhanced cardiac MRI protocol at 3T, which may include perfusion (rest and stress) and viability scans. As an initial evaluation, we compare the apparent signal-to-noise ratio (aSNR) and the apparent contrast-to-noise ratio (aCNR) of two undersampling levels with 10,000 and 20,000 radial projections to explore the impact of undersampling on image quality in the context of CE imaging.

Methods: To simulate the contrast dynamics in a comprehensive protocol, a 3-bolus injection scheme was employed for Gd-BOPTA: the first two boluses were in the dose of 0.05 mmol/kg and injected at 4 ml/s (intended for the stress and rest perfusion; actual scans not performed), and the remaining 0.10 mmol/kg was injected right before the coronary MRA at the same rate. An ECG-gated, fat-saturated, inversion-recovery prepared spoiled gradient-echo sequence was used with 3DPR k-space trajectory for free-breathing data acquisition. A self-navigated respiratory motion correction scheme was implemented to achieve 100% gating efficiency [2]. Non-Cartesian sensitivity encoding acceleration was used to suppress the streaking artifacts from undersampling [3]. Healthy volunteer studies (N=10) were conducted to compare the image quality at two undersampling levels: 20,000 projections that were acquired prospectively, and the first 10,000 projections from the same acquisition. The aSNR was measured as the ratio between the average signal within a blood ROI and the standard deviation within a background ROI. The aCNR was measured as the ratio between the blood-myocardium signal difference and the standard deviation in the background ROI. The two were used as quantitative indicators of the perceived image quality.

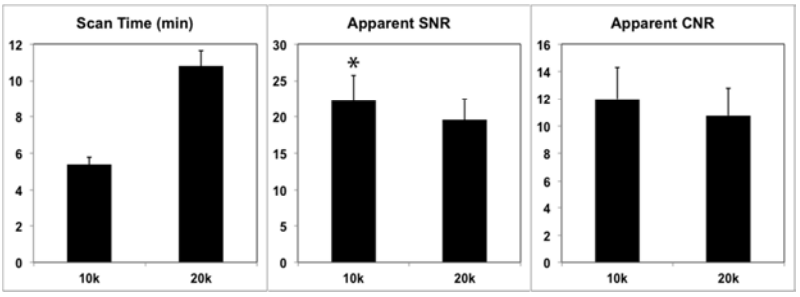

Fig. 1: (Left) The average scan time for the 10,000 projections images was 5.4 minutes, half of that used to acquire 20,000 projections. (Middle) The 10,000 projection images show significantly higher aSNR than the 20,000 projection images (P=0.02); (Right) The 10,000 projection images show non-significantly higher aCNR than the 20,000 images (P=0.07).

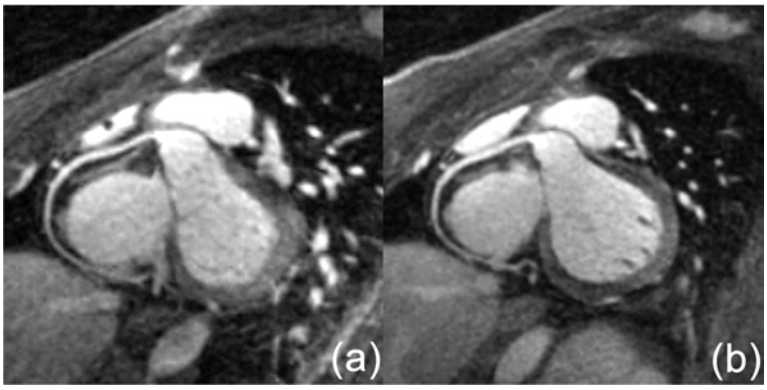

Fig. 2: Example RCA visualizations. (a) 10,000 projections; (b) 20,000 projections

Results: As shown in Fig. 1, the average scan times of the 10,000 and 20,000 projection images were 5.4±0.4 and 10.8±0.8 minutes, the average aSNR values were 22.20±3.51 and 19.61±2.81, respectively, and the average aCNR values were 12.00±2.32 and 10.76±2.04, respectively. The 10,000 projection images showed significantly higher average aSNR in the blood pool (P=0.02) due to the higher contrast agent concentration in the earlier stage of the acquisition. Additionally, the non-Cartesian parallel imaging acceleration used in this work suppressed the streaking artifacts, therefore maintained the aSNR of the undersampled image despite the two-fold acceleration. The average aCNR for the 10,000 projections images were higher than that of the 20,000 images as well, albeit non-significantly (P=0.07). Example right coronary artery (RCA) reformats are shown in Fig. 2.

Discussion and Conclusion: We have developed a CE coronary MRA technique that delivers good image quality at (1.0 mm)^3 spatial resolution with a free-breathing scan time of 5 minutes. The short scan time allows the imaging to be finished before the contrast agent is washed out, therefore improving the aSNR of the blood pool and aCNR. Further investigations are warranted on subjective image quality evaluation, protocol optimization, and tests on patients with suspected CAD.

References: [1] Yang Q. et al. Circ Cardiovasc Imaging. 2012; [2] Pang J. et al. MRM 2013 doi:10.1002/mrm.24628. [3] Pang J. et al. ISMRM 2013 pg. 1295