TIME-EFFICIENT WHOLE-HEART CORONARY PLAQUE CHARACTERIZATION WITH SIMULTANEOUSLY ACQUIRED MRA

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Target audience: MR scientists and physicians interested in coronary vessel wall imaging.

Purpose: Plaque rupture is the most common type of coronary plaque complication, accounting for ≈70% of fatal acute myocardial infarctions and/or sudden coronary deaths[1]. Recently T1-weighted (T1w) MRI with[2] or without[3] contrast enhancement (CE) has been used for characterizing coronary plaques showing promising prognostic capability for coronary events[4]. However the drawbacks of current protocols using conventional Cartesian acquisition and respiratory gating may hinder the clinical application of this technique: a) the anatomical coverage is limited to proximal coronary segments; b) the spatial resolution is low and anisotropic; c) a separate bright-blood MRA acquisition is needed as anatomical reference due to highly suppressed background tissue in T1w images. **The purpose of this work is to develop a time-efficient protocol using 3DPR for coronary artery plaque characterization that provides 1) 3D whole-heart coverage, 2) isotropic high spatial resolution (1.1^{3}mm^3), and 3) simultaneously acquired MRA for luminal assessment and anatomical reference.**

Methods:

Pulse sequence: The proposed sequence consisted of ECG-gated, inversion recovery (IR) prepared spoiled gradient echo (FLASH) acquisition with golden-angle 3DPR trajectory (**Figure 1**). The IR pulse was played out every other heartbeat, enabling interleaved dark-blood and bright-blood imaging. Slab-selective excitation pulses were used to suppress outer-volume. Spectral Adiabatic Inversion Recovery (SPAIR) was used together with water-only excitation pulses to suppress the signal of epicardial fat. Respiratory navigator was used in 'monitor-only' mode with 100% gating efficiency.

Image reconstruction: Retrospective motion correction was performed with an integrated self-calibrating iterative SENSE scheme. Both dark-blood and bright-blood k-space data were segmented into six respiratory bins using the navigator signal as a uniform reference. An image-based affine motion correction algorithm[5] was used to correct for respiratory motion between different bins using the higher SNR bright-*blood* data. Identical motion transformation matrices were then shared by both dark-blood and bright-blood images.

In vivo imaging: Healthy volunteers (n=12) and stable CAD patients with noncalcified plaques found on CT angiography (n=11) were scanned on a 3T scanner (Siemens Magnetom Trio) pre- and post-CE (Dotarem@0.1mmol/kg, 30mins delay) with the following parameters: whole-heart 3D sagittal slab with FOV = 330^{3}mm^3; matrix size = 288^3; spatial resolution = 1.1^{3}mm^3; FA = 12°; TR/TE = 4.6/2.3ms; BW = 721 Hz/pixel; total projections = 8500; scan time ≈ 10mins depending on heart rate. After completing MRI patients underwent interventional X-ray angiography and intracoronary optical coherence tomography (OCT) for coronary plaque evaluation.

Results:

All 23 subjects successful completed the pre-CE MRI. Six eligible patients also completed the post-CE imaging. None of the healthy subjects showed hyper-intensive plaques (HIPs) whereas 2 and 3 patients showed HIPs on pre-CE and post-CE MRI, respectively.

Figure 2: Pre-CE T1w image showed a HIP localized on MRA at mid-LAD (yellow arrows). CTA and X-ray showed significant stenosis and the plaque appeared to be low-density (red arrows). OCT image showed signal-poor area (blue arrow) suggestive of possible lipid core/intra-plaque hemorrhage.

Figure 3: Delayed post-CE T1w image showed diffused wall enhancement localized on MRA at mid-LCX (yellow arrows). CTA and X-ray showed only moderate stenosis (red arrows). OCT image showed strong multi-focal back reflections and signal heterogeneity within the overlying tissue suggestive of high macrophage density (blue arrows).

Discussion:

The proposed 3DPR method allows, for the first time, whole-heart coronary plaque characterization with simultaneously acquired bright-blood MRA. The MRA images are inherently co-registered to the T1w images therefore may be used for localizing lesions and evaluating luminal stenosis. With the help from advanced motion correction (100% respiratory gating efficiency) and parallel imaging (SENSE), isotropic high resolution coronary imaging was possible within clinically feasible scan time (10mins). Preliminary comparison with OCT suggested that the HIPs on the pre- and post-CE images may be associated with lipid core/hemorrhage and neovascularization/inflammation, respectively. Further clinical validation of this technique with OCT in a larger population and correlation to histology are warranted and currently underway.

Conclusion:

Time-efficient T1w whole-heart coronary plaque imaging with isotropic high resolution and simultaneously acquired MRA was feasible. The proposed method showed the potential to characterize different plaque components in the coronary wall.

References: [1] Naghavi M. et al., Circ.; 2003:108. [2] Maintz D. et al., Eur Heart J; 2006:27. [3] Kawasaki T., et al., JACC Imaging; 2009:2. [4] Noguchi T. et al., JACC; 2014:18. [5] Pang J. et al., MRM; 2014:71.

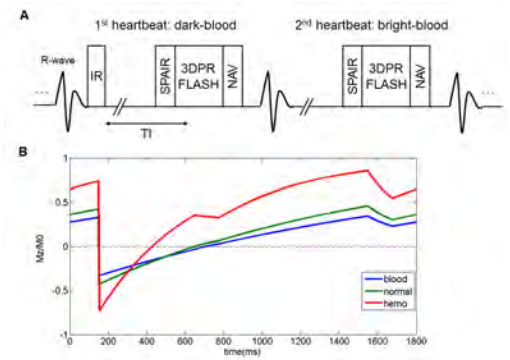

Figure 1. ***A:*** *Sequence diagram of 3DPR interleaved dark-blood (T1w) and bright-blood coronary imaging.*
B: *Simulated steady-state signal behavior of different tissue types.*

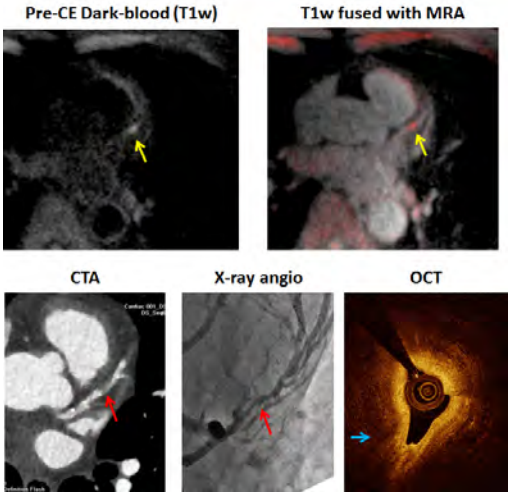

Figure 2. A CAD patient with possible intra-plaque hemorrhage.

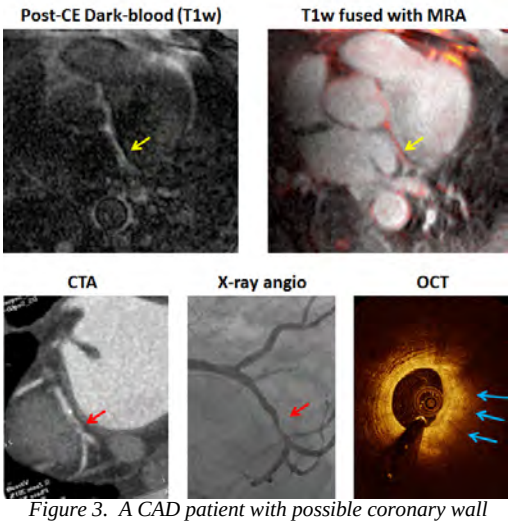

Figure 3. A CAD patient with possible coronary wall inflammation.