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Coronary Atherosclerosis T1-weighed Characterization with integrated anatomical reference (CATCH)

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Background

The detection of high-risk coronary atherosclerotic lesions before severe plaque complications is the "holy grail" in cardiology. Recently T1-weighted (T1w) MRI with [2] or without [3] contrast enhancement (CE) has been used for characterizing coronary plaques showing promising prognostic value [4]. However the drawbacks of current protocols based on conventional Cartesian acquisition and navigator gating hinder the clinical application of this technique: a) coverage is limited to proximal coronary segments; b) spatial resolution is low and often anisotropic; c) because normal tissue in T1w images is highly suppressed, a separate MRA acquisition is needed to provide anatomical reference. **The purpose of this work is to develop a highly accelerated MR technique for coronary plaque characterization with 1) whole-heart coverage, 2) fine isotropic spatial resolution, and 3) simultaneously acquired bright-blood anatomical reference.**

Methods

CATCH consists of ECG-gated, inversion recovery (IR) prepared spoiled gradient echo sequence with golden angle 3D radial trajectory to acquire dark-blood T1w images and bright-blood reference images in an interleaved fashion (Fig. 1). Retrospective motion correction with 100% respiratory gating efficiency was performed as described previously [5]. Healthy volunteers (n = 12) and CAD patients with stable and unstable angina (n = 26) were scanned on a 3T scanner (Siemens Magnetom Trio) before and after CE. Scan parameters: whole-heart 3D slab with FOV = 330^3 mm^3; spatial resolution = 1.1^3 mm^3; TR/TE = 4.6/2.3 ms; number of radial projections = 8500; scan time = ~10 minutes depending on heart rate. After completing MRI, 21 CAD patients further underwent interventional X-ray angiography (XA) and intracoronary optical coherence tomography (OCT) for coronary plaque evaluation. OCT images were graded for high-risk coronary plaque features (lipid-richness, macrophages, microvessels, cholesterol crystals) by two experienced cardiologists without the knowledge of MR results.

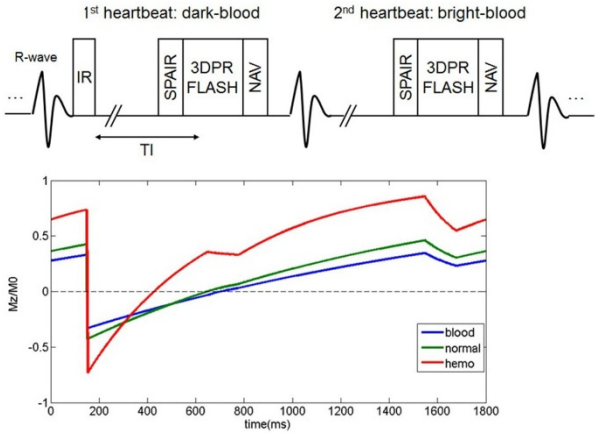

Figure 1 Upper panel: Sequence diagram of CATCH. Lower panel: Simulated steady-state signal behavior of blood, normal vessel wall, and intra-plaque hemorrhage.

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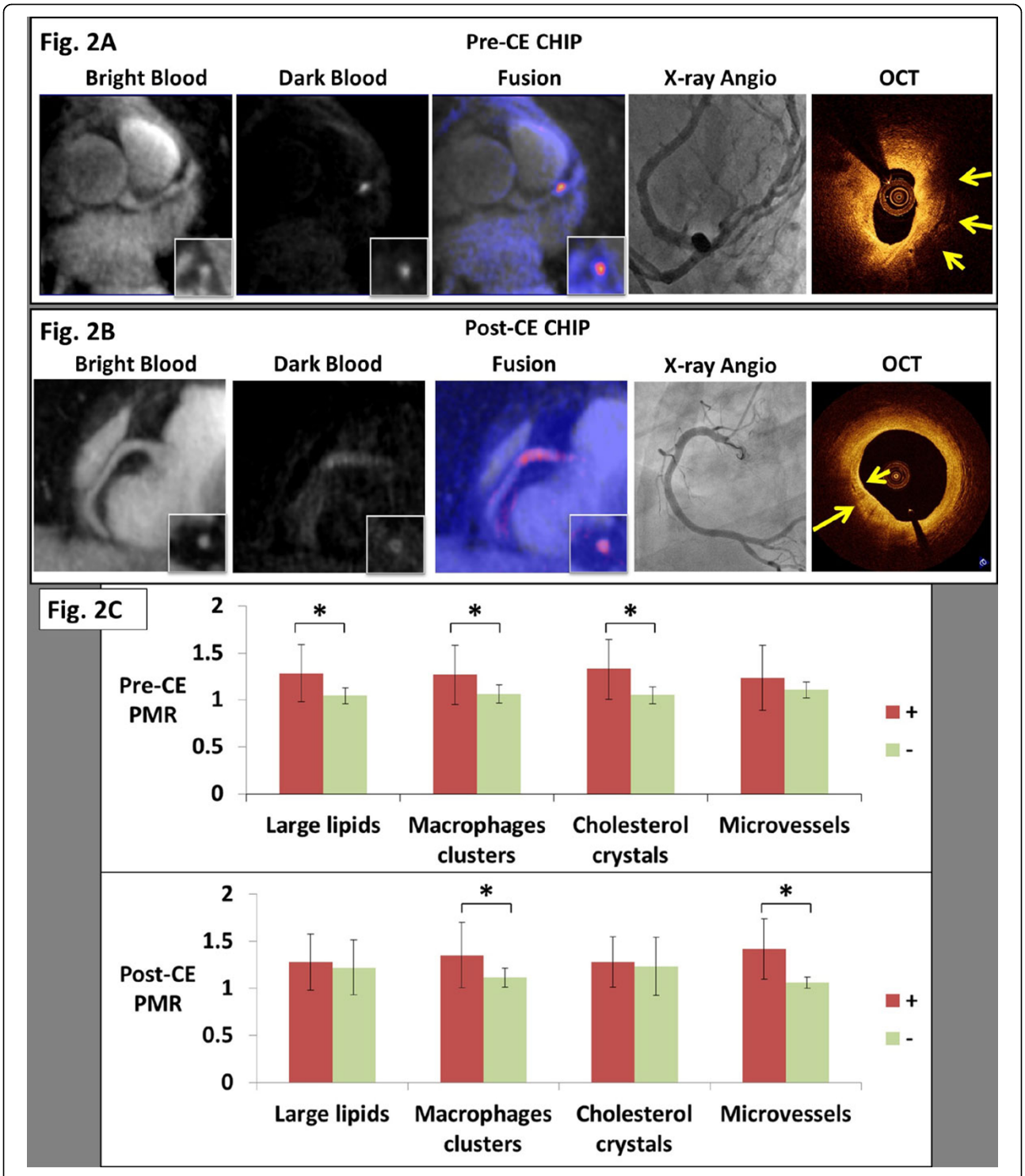

Figure 2 A: An example of pre-CE CHIP was found at middle LAD as localized on the bright-blood images. XA showed significant stenosis (70%) at that location. OCT showed large signal-poor area suggestive of possible lipid core and/or intra-plaque hemorrhage (yellow arrow). **B**: An example of post-CE CHIP with diffuse wall enhancement at proximal RCA as localized on the bright-blood images. XA showed only mild stenosis (30%) at that location. OCT showed strong multi-focal back reflections and signal heterogeneity within the overlaying tissue suggestive of high macrophage density (yellow arrows). **C**: Coronary plaques with high-risk features as classified by OCT tended to be hyper-intensive on CATCH images. Star signs (*) denote statistical significance ($p < 0.05$). Positive sign (+) and negative sign (-) denote lesion groups with corresponding OCT grading. Plaque hyper-intensity is presented in terms of plaque to myocardium ratio (PMR) as described previously [4].

Results

All 38 subjects successful completed the pre-CE exams. All 12 healthy volunteers and 23 eligible patients also completed the post-CE exams. None of the healthy subjects showed coronary hyper-intensive plaques (CHIPs) in either pre-CE or post-CE T1w MRI. In total 3 patients showed CHIPs on pre-CE exams and 4 patients showed CHIPs on post-CE exams, respectively. Fig. 2A and Fig. 2B are two representative patient cases with a pre-CE CHIP and a post-CE CHIP, respectively, with corresponding imaging evidences from other modalities. Fig. 2C is the lesion-based statistics showing elevated plaque hyper-intensity in the advanced lesions as classified by OCT.

Conclusions

The proposed MR technique of accelerated T1w whole heart coronary plaque characterization with simultaneously acquired anatomical reference was feasible. Coronary plaque hyper-intensity showed positive association with certain high-risk plaque features on OCT.

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