Black-blood dynamic contrast-enhanced coronary artery wall MRI: A potential tool for kinetic-modeling-based wall inflammation assessment

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Introduction: Inflammation plays a major role in atherosclerotic plaque progression and regression [1]. Dynamic gadolinium contrast-enhanced (DCE) vessel wall MRI has recently been used to compute a set of model-based contrast kinetic parameters (e.g. K^{trans} and V_p) that can well characterize the extent of inflammation in carotid plaques [2,3]. However, no studies have shown its feasibility in coronary artery wall. This is presumably due to the technical challenges in imaging such a constantly-moving and ultra-small structure and potential difficulty in visually distinguishing the wall from the hyperintense lumen with conventional DCE techniques. **The present work aimed to develop a black-blood navigator-gated ECG-triggered T1-weighted sequence for DCE MRI of coronary vessel wall. The sequence allows acquisition of high-spatial-resolution bright blood and black blood images in an interleaved fashion, regardless of time-varying T1 of blood, and signal changes in the vessel wall and blood measured from the image series can be utilized in kinetic modeling [4].**

Methods: ***-Pulse sequence*** An SR-DIR (saturation recovery combined with double inversion recovery) preparation is combined with an RF spoiled GRE sequence to achieve two aims: 1) To create T1-weighting for vessel wall; 2) To consistently null the blood with a fixed inversion time combination (TI1 and TI2) (**Fig. 1**). This SR-IR preparation has been previously shown to suppress the background tissues over a wide range of T1's in coronary MRA [5]. Bright-blood acquisition is interleaved with black-blood acquisition to enable arterial blood signal measurement as needed in kinetic modeling. Note that the dual non-selective IR, used in the second interleaf acquisition, is to mimic the effect that the dual-IR pulse exerts on the vessel wall, which guarantees the vessel wall and blood signal have the exactly same T1-weighting.

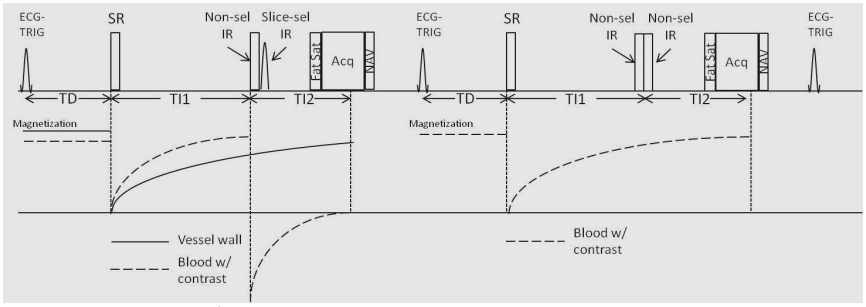

Fig. 1 *Sequence diagram of the ECG-triggered and navigator-gated SR-DIR prepared RF spoiled GRE sequence. Black-blood and bright-blood images data are collected in an interleaved fashion. Blood signal is suppressed by a combination of SR and dual-IR. SR: saturation recovery; IR: inversion recovery.*

-Imaging Ten healthy volunteers (1 F, 9 M; age 22-45 years) were scanned at 3T (Siemens Magnetom Verio) using a 6-channel body matrix coil and spine coil. Proximal coronary arteries were first localized using a 3D navigator-gated, ECG-triggered segmented GRE sequence with data collected in the mid-diastolic quiescent window. DCE imaging was then performed using the developed technique at one single slice selected from one of major coronary arteries, i.e. left main, left anterior descending coronary artery, and right coronary artery. Imaging parameters included: resolution = 0.8 × 0.8 × 4.0 mm^3, flip angle = 15°, 20 lines/R-R, TI1/TI2 = 350/40 ms based on computer simulations. One-frame pre-contrast scan was followed by repetitive contrast-enhanced scans (1-2 min/frame, > 15 min), along with intravenous contrast (0.2 mmol/kg gadopentetate dimeglumine) injection and saline flush (30 ml) both at 0.2 ml/s. Through ROI analysis on the black-blood and bright-blood image series, respectively, the changes in signal intensity of coronary vessel wall and lumen were obtained and used to compute the kinetic parameters using non-linear least-square fitting based on Toft's two compartmental model [5].

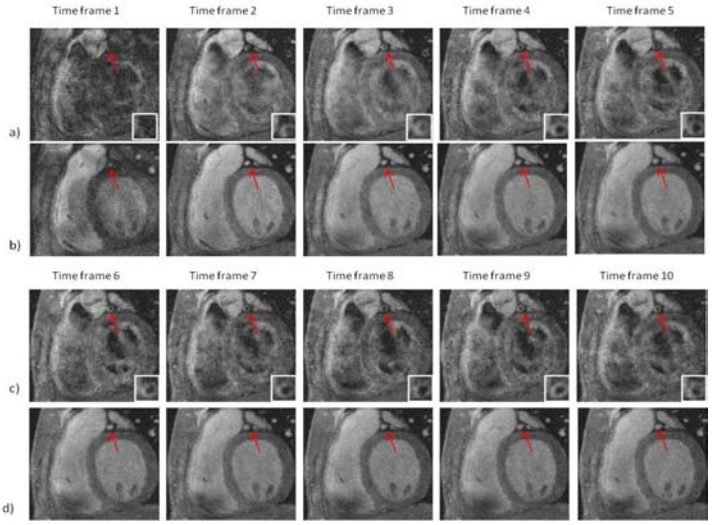

Fig. 2 *Representative dynamic black-blood (a, c) and bright-blood (b, d) images throughout the contrast injection process.*

Results: DCE coronary wall images were successfully obtained in all 10 volunteers. Representative images from one volunteer at left main are shown in **Fig. 2**, where the lumen signal is consistently nulled in the black-blood acquisition (a, c) and vessel wall is clearly differentiated from the lumen. The sharp wash-in and slow wash-out process of the blood signal was observed in all the volunteers (**Fig. 3a**), and the enhancement peak of the blood was sufficiently captured by dynamic scan, with a high-temporal-resolution (low-spatial resolution) scan using the same sequence as the reference (**Fig. 3b**) From the 10 subjects, K^{trans} = 0.031±0.020 min^{-1}, K_{ep} = 0.226±0.105 min^{-1}, and V_p = 38.37±23.34%. The kinetic model fit the acquired data reasonably well (R^2 = 0.80±0.07, ANOVA analysis).

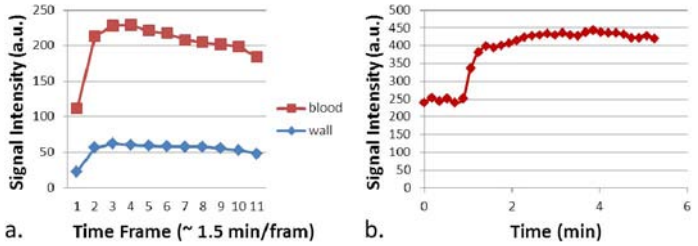

Fig. 3 a.*Typical signal intensity curve of coronary vessel wall and the nearby aorta.* ***b.****From the same subject, blood signal intensity was measured with a high-temporal-resolution (low-spatial resolution) scan using the same sequence.*

Discussion: Despite previous works on carotid inflammation, there have been limited studies performed in coronary arteries. **To our knowledge, this is the first dynamic study investigating coronary wall characteristics related to inflammation. With SRDIR preparation, black blood imaging can be fulfilled consistently regardless of blood T1 value. This could improve the accuracy of vessel wall signal measurement and make this technique feasible for coronary vessel wall that has much thinner vessel wall compared to carotid.** K^{trans} and V_p computed were in accordance with previous studies (4). A feasibility study applying this technique to clinical patients with stable angina is underway. Further improvements are warranted, particularly the temporal resolution and spatial coverage.

References: [1] Libby P, Nature 2002;420:868. [2] Kerwin, *et al.* Circulation 2003;107:851. [3]. Kerwin WS, *et al.* Radiology 2006;241:459. [4] Tofts PS, *et al.* J Magn Reson Imaging 1999;10:223. [5] Deshpande VS, *et al.* Magn Res Med 2003;50:570.