Robust and time-efficient black blood coronary vessel wall imaging at 3T using iMSDE

J. Wang[1], S. Gerretsen[2], J. H. Maki[1], D. Herzka[3], B. Chu[1], V. L. Yarnykh[1], C. Yuan[1], and T. Leiner[2]

[1]University of Washington, Seattle, WA, United States, [2]Maastricht University, Maastricht, Netherlands, [3]School of Medicine, Johns Hopkins University, Baltimore, MD, United States

Introduction

The coronary arteries are a frequent site for atherosclerotic disease. However, unlike other vascular beds such as carotid and femoral arteries, very limited studies have been conducted to study the coronary vessel wall using non-invasive imaging techniques [1, 2]. The primary challenge lies in the lack of a proper black-blood technique that can sufficiently suppress the blood signal while acquiring high-resolution images in a timely fashion. Both in-flow suppression (IS) and double inversion recovery (DIR) techniques are limited by the recirculating flow and/or prolonged imaging time. This study sought to examine the feasibility of a recently proposed black-blood technique, improved motion-sensitized driven equilibrium (iMSDE) sequence [3], for time-efficient *in vivo* human coronary vessel wall imaging.

Methods

Study population 8 healthy volunteers (five males, three female, ages 28-63 years) and one subject with coronary atherosclerosis diagnosed by computed tomography were recruited for coronary artery MRI. Informed consent was obtained from all participants. The study was performed in compliance with the guidelines of the local Institutional Review Board.

Pulse sequence and MR imaging All MR images were acquired on a clinical 3T system (Philips Achieva R2.5.3, Best, the Netherlands). The manufacturer-provided 6-channel cardiac coil was used for image acquisition. The location of the targeted coronary artery (RCA and/or LAD) was determined with the 3-point planning scheme based on a whole heart scout. Based on the location, bright-blood and black-blood longitudinal, as well as black-blood cross-sectional images of the targeted coronary artery were acquired.

The scheme of the iMSDE sequence was constructed as discussed in the previous study [3] (Fig. 1(a)). The parameters for coronary imaging were optimized to possess a first gradient moment of 155 mT•ms^2/m in a separate study. The turbo field echo (TFE) acquisition window had a total duration of < 120 ms. The trigger delay time ranged from 550-750 ms (Fig. 1(b)). Due to the short duration of the iMSDE sequence, only 1 R-R interval was required for imaging. Other scanning parameters for the optimized iMSDE-prepared black-blood coronary vessel wall imaging protocol include: 3D TFE sequence, TR/TE 10/2.3 ms, flip angle 20, TFE factor 19, FOV 300×264×30mm, pixel size 0.9×0.9×1.5mm, reconstruction matrix 512×512, fat saturation, and two averages. The total scan time is 4 min 6 sec without navigator efficiency (Calculated for heart rate of 60 beats/min).

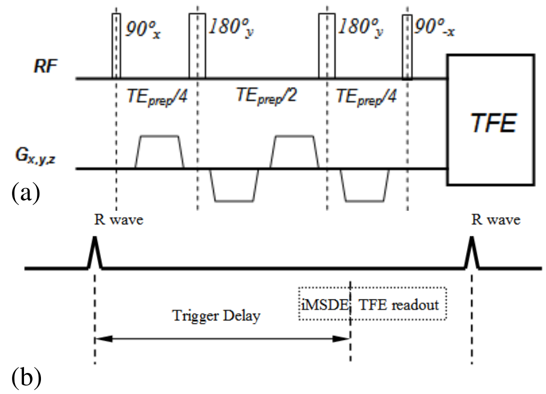

Fig. 1 Image acquisition scheme of the iMSDE sequence with TFE readout. (a) is the iMSDE pulse sequence; (b) shows the image acquisition scheme. Due to the short preparation time of iMSDE sequence, the repetition time used in this study is 1R-R.

Comparison with bright blood luminography To evaluate the vessel characterization capability of the black blood imaging technique, the lumen diameter and visible artery extent of the images was compared with that from the bright blood images. To measure lumen diameter, three locations close to the root of the longitudinal view artery were chosen from each artery and the averaged result was used. To measure visible extent, the center line of the arteries on the longitudinal view was carefully drawn and measured with dedicated image analysis software, CASCADE [4]. Both measurements were then compared with Bland-Altman plot and regression study.

Reproducibility To validate the reproducibility of the iMSDE coronary wall imaging technique, two of the eight healthy volunteers were scanned at two time points (TP) each using the optimized protocol with an interval of no more than 3 days. Lumen diameter and visible artery extent were then measured on images from both scans.

Results

Images with diagnostic values of the coronary artery were successfully obtained from 7 out of 9 subjects. In Fig.2, panel (a) demonstrates right coronary artery vessel wall thickening on a longitudinal view (arrow heads); panels (b) and (c) (cross-sectional views) clearly demonstrate the normal (b) and thickened (c) coronary vessel walls with excellent suppression of luminal blood. The artery characterization capability of the technique was found to be similar to that of the bright blood imaging technique. Excellent lumen diameter correlation was found between bright and black blood images (r=0.90, p=0.005). The Bland-Altman plot of the lumen diameter measurements was shown in Fig.3. As for the visible artery extent, although the black blood technique presents slightly shorter visible extent (mean 79.7mm vs. 84.2mm) than the bright blood technique, very high correlation (r=0.989, p<0.001) was still found. The excellent reproducibility of this coronary artery imaging protocol can be observed in panels (a) and (b) in Fig. 4. The lumen measurements between the two scans were 2.90 (TP1) and 2.91 (TP2) mm; the visible extent measurements were 88.73 (TP1) and 89.32mm (TP2), respectively.

Discussion and Conclusions

Compared to traditional DIR based sequences which require a TR of 2 R-R interval, iMSDE-prepared coronary vessel wall imaging can inherently reduce the scan time by half as the TR can be reduced to a single RR-interval. iMSDE also removes flow artifact more effectively since it is not limited by the flow direction.

In conclusion, the feasibility of using iMSDE sequence of coronary wall imaging was well demonstrated in this study. Quantitative measurements also reveals that the black blood imaging technique can visualize the same extent of the arteries as the bright blood luminography does.

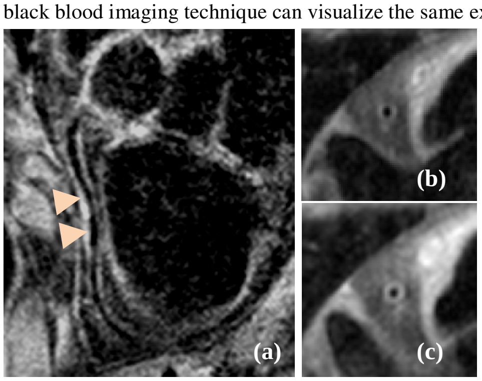

Fig. 2 (a) iMSDE revealed coronary vessel wall thickening identified on the longitudinal view of right coronary artery of a patient (arrows). Increased vessel wall thickness was also identified on the cross-sectional images (b) and (c).

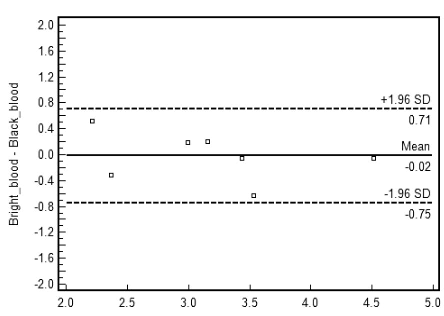

Fig. 3 Bland-Altman plot of the lumen diameter measured on bright blood images and black blood images. The consistency between the two measurements can also be demonstrated by the high correlation coefficients between them (r=0.90, p=0.005).

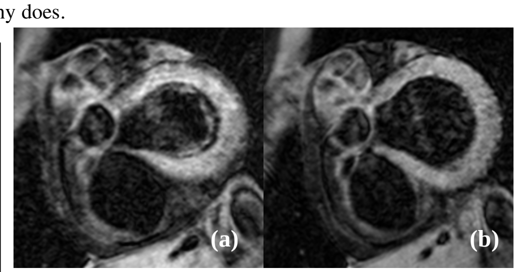

Fig. 4 Excellent reproducibility of the coronary artery vessel wall imaging protocol demonstrated on panels (a) and (b) which show images acquired 3 days apart in the same volunteer.

References:

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3. Wang J et al. 16th ISMRM annual meeting, #961.
4. Kerwin B et al. Top MRI 2007; 18:371-8.