3D coronary dark-blood interleaved with gray-blood (cDIG) MRI

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Introduction: 3D dark-blood MRI techniques have shown great potential in coronary plaque burden assessment [1]. However, substantial variability in quantification could result from superficial calcification that often mimics part of lumen because of its low signal. Recent work shows that gray-blood contrast can help separate superficial calcification from lumen [2]. Thus, the purpose of this work was to develop a 3D coronary dark-blood interleaved with gray-blood (cDIG) MRI technique to improve the visualization and quantification of coronary plaque.

Methods:

Sequence: cDIG is based on balanced SSFP combined with local reinversion (LocReInv) preparation [3]. Double inversion pulses are applied every two heartbeats and dark-blood images are collected in the first heartbeat (Fig. 1). The novelty of cDIG is the acquisition of gray-blood images by utilizing the second heartbeat during which blood magnetizations have partially recovered. To improve gating efficiency, two independent respiratory navigators are used in two successive heartbeats, for dark-blood and grey-blood imaging, respectively.

Imaging: 8 healthy volunteers (age 29±9) with informed consent were scanned on a 3T MR scanner (MAGNETOM Verio, Siemens, Germany). Imaging parameters included: TE/TR = 1.7/3.9 ms, flip angle = 70°, in-plane resolution = 0.81×0.81 mm^2 (interpolated to 0.41×0.41 mm^2); slice thickness = 2.0 mm for 3D cross-sectional imaging and it was interpolated to 1.0 mm for 3D in-plane imaging; 7/8 partial Fourier in phase direction; 822 Hz/pixel receiver bandwidth; 11~25 segments/heartbeat; SPAIR with a delay time of 180 ms for fat suppression. Cross-sectional imaging using LocReInv with the same scan parameters was performed for both image quality and signal intensity comparison. Quantitative measurement of SNR, CNR, wall thickness and lumen area were performed to compare cDIG dark-blood images to those of the LocReInv method. Wilcoxon signed rank test was conducted with $p<0.05$ considered as significant.

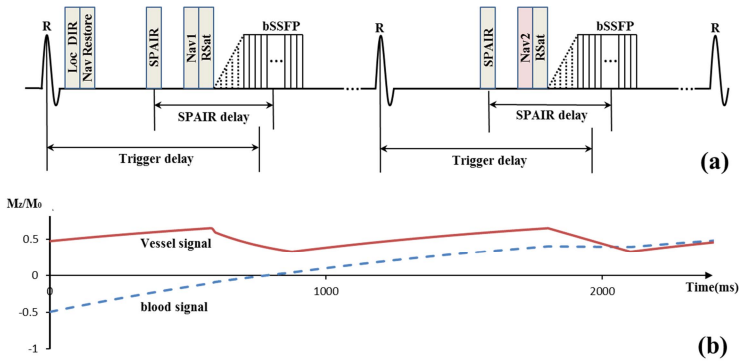

Fig. 1. (a) Schematic sequence diagram of the proposed cDIG technique and (b) simulated coronary wall and blood signal intensities.

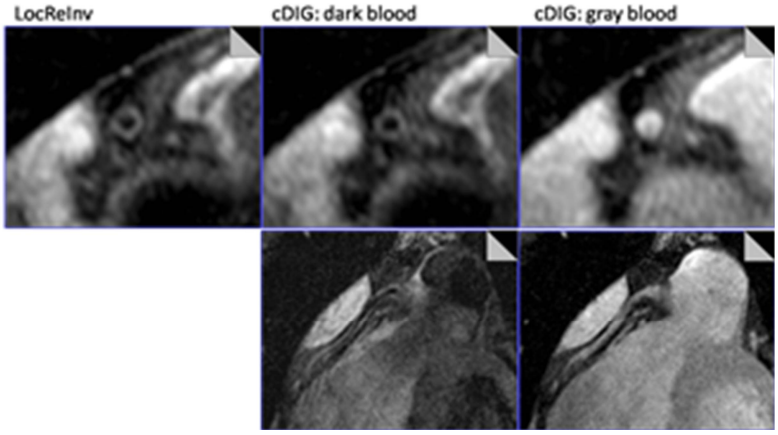

Fig.2 Representative images of right coronary artery using the cDIG and LocReInv methods.

Results: All scans were successfully completed using the proposed cDIG technique and single-contrast LocReInv method. Representative images are shown in Fig. 2. Both vessel wall and lumen are clearly visualized in dark-blood images. The values of SNR, CNR, wall thickness, lumen area as well as scan time are not statistically different between cDIG and LocReInv methods (Table 1). The cDIG method provides more information (gray-blood images), potentially facilitating the identification of calcified plaques and thus improving the accuracy of plaque burden assessment.

Conclusion: A novel method for simultaneously obtaining coronary vessel wall and gray lumen images was proposed. Dual contrasts were simultaneously acquired using the proposed method without compromising dark-blood contrast and scan time. Patient studies are required to evaluate the accuracy of cDIG to measure the coronary plaque burden.

Table 1. Quantitative analysis results for image quality comparison between cDIG and LocReInv methods

Method	wall SNR	Lumen SNR	Fat SNR	Myocardium SNR	Wall/blood CNR	Wall/fat CNR	Wall thickness (mm)	Lumen area(mm^2)	Acquisition Time (min)
cDIG mean±std	19.4±4.9	6.6±3.0	9.6±2.1	21.7±6.6	12.8±6.5	9.8±3.8	1.4±0.2	5.4±1.6	8.1 ± 3.4
LocReInv mean±std	20.2±4.4	6.9±2.8	10.8±2.4	25.1±8.2	13.3±5.9	9.4±2.9	1.4±0.1	5.3±1.9	7.0 ± 1.9
Wilcoxon test	ns	ns	ns	<0.05	ns	ns	ns	ns	ns

Note: ns – not significant

References: [1] WY Kim, et al. Circulation 2007, 115: 228-235. [2] I Koktzoglou, et al. MRM 2013, 75(1):75-85. [3] RM Botnar, et al. MRM 2001,46(5): 848-854.