Coronary Artery Wall Imaging at 3 Tesla: A Feasibility Study

I. Koktzoglou[1], O. Simonetti[2], D. Li[1]

[1]Northwestern University, Evanston, Illinois, United States, [2]Siemens Medical Solutions, Chicago, Illinois, United States

Introduction: Promising results have been obtained in MR imaging of coronary artery wall at 1.5T systems using a black-blood TSE sequence [1,2]. Because of the small size of coronary arteries, relatively high resolution is required to define the boundary of the coronary artery wall, resulting in low SNR or long imaging time because of the need for ECG triggering and respiratory motion compensation. 3T whole body MR imaging systems have recently become available for clinical studies. In theory, the higher field strength of 3T could improve SNR, allowing for higher resolution imaging of the coronary vessel wall or shorter imaging times. 3T imaging of the heart and in particular coronary artery wall imaging, however, confront several potential problems including B1 inhomogeneity, amplified ECG artifacts, and higher SAR levels. The goal of the study was to assess whether vessel wall imaging using a black-blood TSE sequence is feasible at 3T.

Methods: Breath-hold and free-breathing ECG-gated 2D double inversion recovery (DIR) TSE sequences were run on healthy volunteers (n = 8) in a whole body 3T Siemens Trio MR scanner. An eight-channel cardiac phased array coil consisting of four posterior and four anterior channels was used for signal reception. MR localization of the left anterior descending (LAD) coronary artery was performed using an ECG-gated 3D FLASH sequence (TR/TE = 4.1 ms/2.0 ms, flip angle = 15^o, bandwidth = 550 Hz per pixel, 1.4 mm $\times$ 0.7 mm in-plane resolution, slab thickness = 18 mm, 6 slices per slab interpolated to 12). An ECG-gated 2D DIR TSE sequence was subsequently used to image a slice perpendicular to a proximal portion of the LAD. Care was taken to ensure the accuracy of the imaging slice.

Black-blood preparation was achieved through application of a double IR pulse immediately after every other R wave. Data was acquired during mid-diastole at an inversion time (TI) dependent on the RR interval [3]. At 3T, the longer blood T1 relaxation time (1550 vs. 1300 ms) required slightly longer TI as compared with 1.5T. Inversion times between 775 ms and 575 ms corresponded to heart rates between 50 bpm and 80 bpm, respectively. Fat suppression was achieved through application of a chemical shift selective (CHESS) pulse before data acquisition.

The imaging parameters were TR = 2 $\times$ RR intervals, TE = 7~50 ms, echo spacing (ES) = 7 ms, slice thickness = 3~5 mm, field-of-view (FOV) = 21 cm $\times$ 35 cm, and in-plane resolution = 0.7~1.6 mm. Breath-hold scans (between 15~25 s) employed echo train lengths (ETL) of 15~17, and radiofrequency (RF) refocusing flip angles of 130^o~180^o. Lower refocusing angles were used as needed for adherence to specific absorption rate (SAR) limits. Respiratory-gated scans acquired navigator echoes before and after data acquisition, had an ETL of 7, and an RF refocusing flip angle of 180^o**.** No reductions in refocusing flip angle were required for respiratory-gated acquisitions.

Results: Proton density weighted (PDW) images of ECG-gated 2D double IR TSE at 3T are shown in Fig. 1. The image on the left was acquired during free-breathing and the one on the right during a 24-s breath-hold. The images demonstrate that non-invasive in-vivo coronary wall imaging is feasible at 3T. A bright ring corresponding to the LAD coronary wall can be seen in both images. The image on the left was acquired during free-breathing and the one on the right during a 24s breath-hold.

In three out of the eight volunteers, ECG-gating was corrupted by artifacts induced by the DIR preparation or the TSE RF pulses. In the remaining five volunteers, images (n = 12) perpendicular to the proximal LAD coronary were analyzed. After proper windowing, an MR-host distance measurement tool was used to estimate coronary vessel thickness and diameter. Eight measurements of vessel thickness and lumen diameter around the circle were averaged to estimate thickness and diameter for each vessel, respectively. Mean coronary wall thickness was 0.91 ± 0.10 mm and mean lumen diameter was 3.60 ± 0.29 mm, consistent with previous MR measurements [1,2]. Assuming a circular vessel shape, mean lumen area was 10.2 ± 1.6 mm^2.

B1 inhomogeneity affected signal uniformity as previously described [4], but did not appear to significantly affect signal from the coronary wall. Fat suppression in regions around the coronary wall, as can be seen from the images, was sub-optimal. In some subjects, frequency shifting of the CHESS pulse improved fat suppression around the coronary wall. Images from breath-hold scans with reduced refocusing flip angles did not suffer from appreciable artifacts.

Discussion: Initial volunteer studies indicate that it is feasible to visualize coronary artery wall at 3T using black-blood TSE. Nonetheless, several aspects of the 2D DIR TSE sequence must be improved for consistent acquisition of high quality, high resolution images. First, amplified hydrodynamic ECG artifacts at 3T must be adequately filtered to ensure reliable ECG gating. The consistency and robustness of fat suppression should also be improved without compromising black-blood. This may be achieved through improved field shimming or imaging frequency adjustment. SAR limitations may hinder the efficiency of breath-hold TSE imaging by necessitating the use of longer echo spacings, reduced echo trains, and reduced RF refocusing flip angles. Lower refocusing flip angles may be used, however, without substantial SNR loss [5,6] and artifacts. In summary, coronary artery wall imaging is feasible at 3T, but requires technical improvements before high resolution imaging is possible. Patient studies are needed to evaluate the clinical utility of 3T coronary wall imaging.

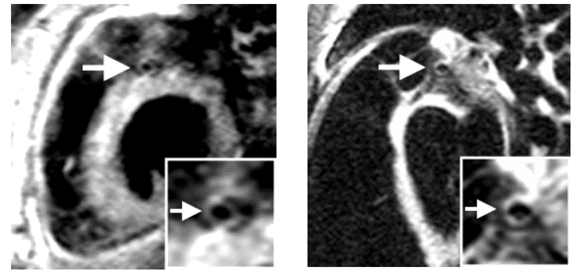

Figure 1. PDW images of the proximal LAD coronary artery wall (arrows) on two subjects under navigator-gated (left) and breath-hold (right) conditions. Insets show the close-up of the LAD wall.

References:

[1] Fayad ZA. et al. Circulation 2000; 102:506-510
[2] Botnar RM. et al. Circulation 2000; 102:2582-2587
[3] Luk-Pat GT. et al. Magn Reson Med 1999; 42:762-771
[4] Greenman RL. et al. J Magn Reson Imaging 2003; 17:648-655
[5] Alsop DC. Magn Reson Med 1997; 37:176-184
[6] Henning J. et al. Magn Reson Med 2000; 44:983-985