Optimization of Coronary Wall Imaging

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Introduction:

High interest exists for imaging the coronary wall with MRI, since atherosclerotic wall remodeling often begins long before lumen size decreases. Various papers have been published on MR coronary wall imaging[1,2], but yet it is not done clinically because the procedure and setup have remained very challenging. The recent advent of free-breathing, whole heart coronary magnetic resonance angiography[3] (MRA) and the determination of subject-specific periods of diastasis[4] have made coronary MRA much simpler and clinically feasible. By using these advances, we propose an optimized method for clinically feasible imaging of the coronary arterial wall.

Methods and Materials:

Several steps were taken to improve the coronary wall imaging sequence. First, an asymmetric, adiabatic spectral inversion pulse (AASPIR)[3] was used for fat suppression to maximize contrast with the vessel wall. The advantage of an asymmetric pulse is that a sharp transition band (50Hz) can be set between the fat and water peaks while a long inversion band (223 Hz) is used to suppress the entire fat signal that slopes away from the water peak. The adiabatic condition ensures that the same flip angle is applied over the entire FOV. Second, for navigator (NAV) gating, prospective slice following with a correction factor of 0.6 was used and the center position of the NAV acceptance window adapted to diaphragm drift by immediately changing to higher diaphragm positions (upward drift) and changing to lower diaphragm positions only if the maximum diaphragm position over the last 20 heartbeats was below the acceptance window (downward drift). Finally, pre-acquired cine images of the coronary wall slice orientation were processed inline using a cross-correlation (CC) algorithm to look at bulk motion between phases. The algorithm determined the period of diastasis and generated an optimal data acquisition window (DACQ), which is crucial for high-quality coronary wall imaging.

5 volunteers were imaged on a 1.5T scanner (Magnetom Avanto, Siemens, Erlangen, Germany). Several preliminary steps were required before imaging the coronary wall. First, a cine 4-chamber view of the heart was acquired using a 2D breath-held, retrospectively ECG-gated steady-state free precession (SSFP) sequence with a temporal resolution of 30 ms and a spatial resolution of 1.6x1.6x5.0 mm^3. As mentioned above, these images were processed to generate a DACQ for coronary artery imaging. Next, a 3D whole-heart, NAV and ECG-gated, fat suppressed, T2-prepared, SSFP sequence was used to image the coronary tree. Motion adapted gating (MAG) was used for NAV gating as described above. Sequence parameters were as follows: TR/TE = 3.8/1.7 ms; bandwidth = 975 Hz/pixel; flip = 90º; 1.1x1.1x1.5 mm^3; 100-120 mm slab thickness; T2-prep time = 40 ms; NAV acceptance window = 4 mm. Multi-planar reformats were done on the coronary MRA images to generate cross-sectional orientations for coronary wall imaging. Before each coronary wall was imaged, another 2D cine image was acquired in the cross-sectional orientation to determine the DACQ again as described above. A 2D, black-blood, NAV and ECG-gated, fat suppressed, turbo spin-echo (TSE) sequence acquired coronary wall images with the following parameters: TR = 2 R-R intervals, TE = 33 ms, echo-spacing = 6.6 ms, bandwidth = 305 Hz/pixel; FOV = 420 mm; Matrix = 384x384; slice thickness = 5 mm; NAV acceptance window = 4 mm; and the dark-blood re-inversion thickness = 15 mm.

Total scan times, NAV efficiencies, and DACQ were compiled for all coronary MRA and coronary wall images. The SNR and CNR were calculated for coronary wall images.

Results:

Coronary MRA's and coronary wall images were obtained in all subjects. For coronary MRA, the DACQ ranged from 56 ms to 155 ms, with a mean of 100 ms. Mean NAV efficiency was 38±10% and mean scan time was 9.1±1.1 min. Cross-sections of the proximal right coronary artery (RCA) and proximal left anterior descending coronary artery (LAD) were done in all subjects; the left main (LM) and left circumflex (LCX) coronary arteries were also imaged in 4 and 2 subjects, respectively. Example images are shown in Figures 1 and 2. For coronary wall images, the mean DACQ was 80±22 ms. Mean NAV efficiency was 33±10% and mean scan time was 4.2±1.4 min. SNR and CNR for the LAD were 70.0±33.2 and 42.7±29.4, respectively. SNR and CNR for the RCA were 57.2±14. and 29.5±8.2, respectively.

Conclusions:

Several cross-sections of different coronary wall locations were obtained in each subject. Scan times were reasonable and the MAG algorithm ensured that diaphragm drift would not cause scan failure. Fat suppression was excellent in all images, as reflected by high CNR numbers. Overall, this optimized method demonstrates a means by which coronary wall imaging can be clinically feasible.

References:

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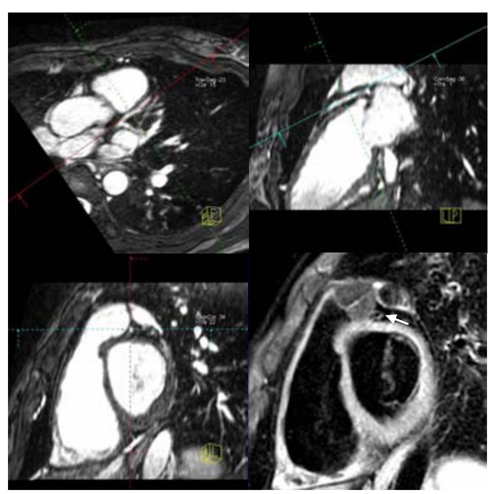

Figure 1: MPR's from whole-heart coronary MRA used to determine coronary wall cross-section. Resulting coronary wall image is shown in bottom right corner (arrow).

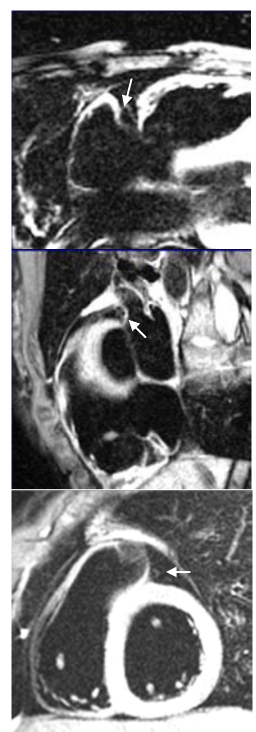

Figure 2: Coronary wall images of RCA (left), LCX (middle), and LAD (right).