High-resolution 3D Coronary Vessel Wall Imaging Using Spiral Image Acquisition at 3T

M. W. Lagemaat[1], M. Henningsson[2], M. Stuber[3], A. J. Wiethoff[2,4], and R. M. Botnar[2]

[1]Dep. of Biomedical Engineering, Eindhoven University of Technology, Eindhoven, Netherlands, [2]NIHR Biomedical Research Centre at Guy's & St Thomas' Hospital and King's College London, London, United Kingdom, [3]Dep. of Radiology, Johns Hopkins University, Baltimore, MD, United States, [4]Philips Healthcare, Reigate, United Kingdom

Introduction: X-ray coronary angiography is the gold standard for the assessment of lumen encroaching coronary stenoses, but provides little information on the presence or magnitude of atherosclerotic plaque. From interventional studies it is known that approximately 60-70% of acute coronary syndromes are caused by < 50% luminal diameter stenoses (1). Thus, a non-invasive approach for coronary plaque imaging would be desirable. MR coronary vessel wall and plaque imaging techniques at 1.5 T using dual inversion (Dual-IR) 2D fast spin echo or local inversion 3D spiral imaging techniques have been reported previously (2,3,4) and were successful in imaging the RCA and LAD vessel walls. With the wider spread availability of high field 3T clinical scanners and the advent of commercially available 32-channel coils, higher resolution coronary vessel wall imaging has become feasible.

Purpose: In this study we sought to implement and optimize the local inversion pre-pulse technique on a 3T system and to obtain higher-resolution (0.5mm) 3D black blood cross-sectional coronary vessel wall images.

Method: Free-breathing 3D coronary vessel wall imaging using a local inversion technique and spiral image acquisition was implemented on a 3T Achieva clinical scanner (Philips Healthcare, Best, the Netherlands). Four healthy adult subjects without clinical history of cardiovascular disease were examined in supine position using a 32-element cardiac coil. The local inversion prepulse was applied immediately after the R-wave and imaging data were acquired in mid-diastole. This allowed taking advantage of rapid early systolic right coronary artery (RCA) flow providing maximum blood exchange while maintaining black blood properties. A coronary angiogram of the RCA was used to plan the local inversion black blood 3D vessel wall scan. A non-selective 180° inversion pre-pulse was immediately followed by a 2D selective 180° pencil beam local inversion pre-pulse (diameter=35mm), which was planned along the path of the RCA, approximately perpendicular to the 3D imaging volume. To facilitate navigator detection on the right hemi-diaphragm, a 2D selective 180° navigator restore pulse was applied. The inversion time of approximately 600-700ms was sufficient to allow for complete blood exchange in the imaging volume and was followed by a 3D spiral imaging sequence, which was preceded by a right hemidiaphragmatic navigator (5mm gating window) and a chemical shift selective (SPIR) fat suppression prepulse. The imaging sequence consisted of 1 spiral interleave (flip angle=45°) every other heart beat with a very short acquisition window of 21ms to minimize cardiac motion artifacts. For a 100% navigator efficiency, 304 heart beats are required to acquire 6 cross-sectional slices with a slice thickness of 3mm and an in-plane spatial resolution of 0.5x0.5mm (FOV=220mm, TR=26ms, TE=1.45ms, 38 interleaves/slice) and 176 heart beats to obtain a resolution of 0.6x0.6mm (FOV=120mm, TR=28ms, TE=2.1ms, 22 interleaves/slice). Total imaging time was approximately between 6 (small FOV) and 10 (large FOV) minutes for a navigator efficiency of 50% and a heart rate of 60bpm.

Results and discussion:
In three out of four subjects, we obtained well-defined 3D vessel wall images, both with a large FOV (Fig. 1a-c) as with a small FOV (Fig. 1d-f). The wall thickness (1.12±0.12mm) and lumen diameter (2.56±0.48mm) found in this study were in good agreement with previous studies. As spiral imaging is sensitive to off-resonances e.g. inaccurate f0 determination or shimming, imaging failure in one of the subjects was likely related to these properties. Off-resonance effects are larger at higher fields strengths due to larger intrinsic field inhomogeneities. Furthermore, f0 may vary throughout the cardiac and respiratory cycle. ECG triggered f0 determination and shimming, performed during quiescent phase of the cardiac cycle therefore seems advantageous to obtain images of good quality.

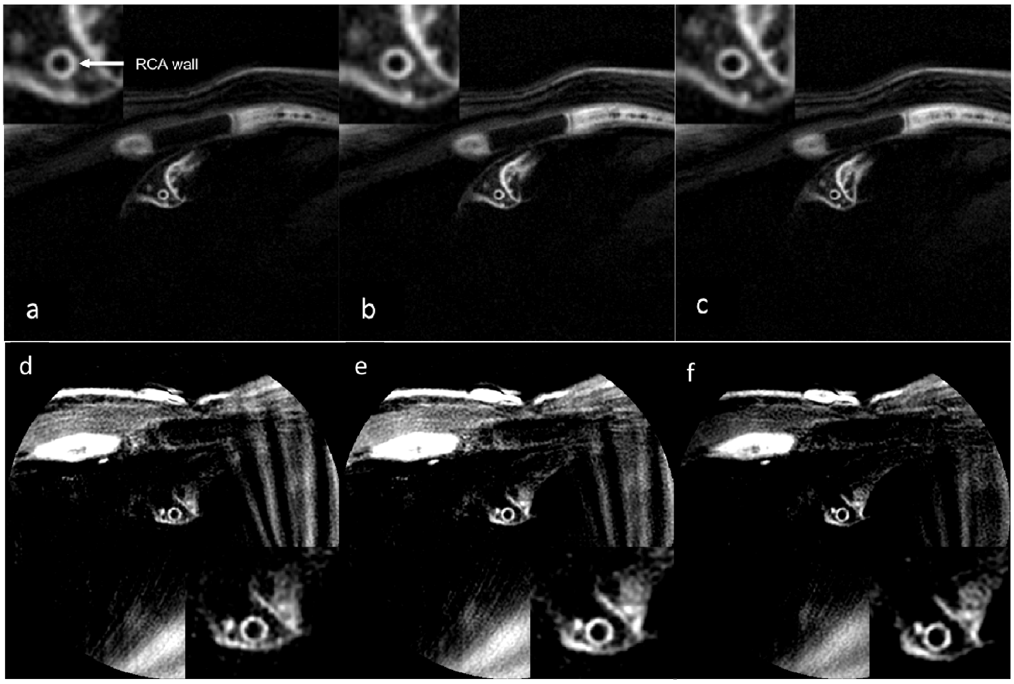

Figure 1: (a-c) 3D dataset (in-plane resolution of 0.50x0.50 mm) and (d-f) (in-plane resolution of 0.60x0.60 mm) of a cross-sectional coronary vessel wall scan. All slices clearly show the wall of the RCA with a good contrast between the wall, blood and epicardial fat. Myocardial tissue inside the local inversion been is visible as the bright structure surrounding the wall. Signal outside the beam area is strongly suppressed apart from cartilage rich regions in the chest (short T1). The reconstructed slice thickness was for both resolutions1.5mm.

References: (1) Little WC. Circulation 1988;78:1157-66, (2) Fayad ZA et al. Circulation 2000; 102:506-510, (3) Botnar RM et al. Circulation 2000; 102:2582-2587, (4) Botnar RM et al. MRM 2001; 46:848-854