High resolution 3D coronary vessel wall imaging with near 100% respiratory efficiency using epicardial fat tracking: Reproducibility and comparison with standard methods

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Introduction

Coronary artery vessel wall thickness measurements must be highly reproducible for use in longitudinal studies of disease progression or regression. While 2D turbo-spin-echo (TSE) and spiral techniques are commonly used for MR imaging of the coronary artery wall, 3D techniques reduce partial-volume effects and allow greater coverage of the vessel. However the efficiency of navigator based respiratory gating which is typically used with 3D coronary vessel wall imaging is low and highly variable. Recently, 3D coronary artery vessel wall imaging was demonstrated with 100% respiratory efficiency using beat-to-beat respiratory motion correction (B2B-RMC) [1] which uses motion information obtained from low resolution 3D images of the fat around the vessel to retrospectively correct the vessel wall images. Here we assess the reproducibility of this technique together with that of navigator-gated 2D TSE and navigator-gated 2D spiral acquisitions.

Methods

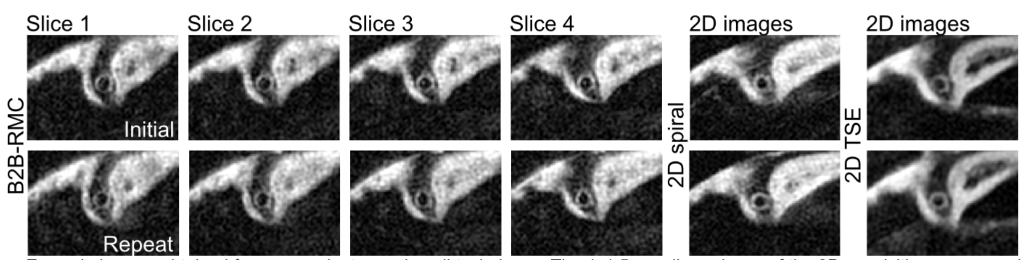
Cross-sectional right coronary artery wall images were obtained in 10 healthy subjects on a Siemens 1.5T Avanto MR scanner using dark-blood prepared B2B-RMC 3D spiral imaging, navigator-gated 2D TSE imaging and navigator-gated 2D spiral imaging. Acquisition order was randomized and subjects were imaged on two separate occasions to assess inter-study reproducibility using the intra-class correlation-coefficient (ICC) and Bland Altman analysis. All acquisitions were triggered on alternate ECG R-waves and used 0.7x0.7mm in-plane resolution. B2B-RMC 3D spiral acquisitions acquired 8x3.0mm slices (16x1.5mm slices reconstructed) and 2D techniques acquired 1x6.0mm slice. Both spiral techniques acquired two 10ms spiral interleaves in the subject specific rest period with 45° and 90° binomial water selective excitations and slab selective dark blood preparation [2]. The 2D and 3D spiral trajectories were identical, requiring 75 interleaves to fill a k_x-k_y plane of 570mm. The 2D TSE technique used a subject specific echo train length, limited to a maximum of 15, to fill a matrix of 576x576 (with 77% phase over-sampling prescribed to improve SNR) over a 403x403mm field of view, asymmetric adiabatic short TI spectral inversion recovery fat suppression [3] and standard dark blood preparation. Navigator-gated techniques used a 5mm gating window while B2B-RMC excluded data acquired at only very extreme respiratory positions (>10mm outside the normal tidal range). For B2B-RMC, 3D low resolution fat selective spiral data (4.8x4.8x3.0mm resolution, 8 slices) were acquired immediately before each high resolution segment of the 3D high resolution acquisition. Off-line normalised sub-pixel cross-correlation of a 3D region of fat around the right coronary artery was used to determine the 3D beat-to-beat respiratory translations which were then used to retrospectively correct the corresponding high resolution data. Durations, assuming 100% respiratory efficiency, were 600 cardiac cycles for the B2B-RMC 3D spiral, 76 cardiac cycles for the 2D spiral and 202-576 cardiac cycles for the 2D TSE acquisitions (depending on echo train length).

Analysis: A single central slice was selected from each 3D acquisition for comparison with the 2D acquisitions. For all acquisitions, average coronary wall thickness was obtained from circular regions of interest drawn around the inner and outer edges of the vessel wall. The intra- and inter-observer reproducibility of this measurement technique was analysed in a subset of 20 images.

Results

Example images from one subject are shown in the figure. 92% of acquisitions (55 of 60) were successful. The five rejected datasets failed due to cardiac motion during the acquisition window. Respiratory efficiency, wall thickness and acquisition durations are presented in Table 1. The respiratory efficiency of B2B-RMC was less variable and significantly greater than for navigator gating (99.6±1.2% vs. 39.0±7.5%, $p<0.0001$) and there was no significant difference in vessel wall thickness between techniques (p=ns).

Reproducibility data are presented in Table 2. Mean intra- and inter-observer wall thickness difference was 0.04±0.09mm and 0.05±0.08mm respectively. The B2B-RMC technique was most reproducible (ICC 0.84, mean difference between initial and repeat studies 0.01±0.10mm).



Example images obtained from one volunteer using all techniques. The 4x1.5mm slices shown of the 3D acquisition correspond to the single 6mm slices of the 2D acquisitions. There is a high degree of visual similarity between the initial (upper) and repeat images (below) acquired 29 days apart. Respiratory efficiency in the initial studies was 100% B2B-RMC, 40% 2D spiral and 38% TSE. In the repeat studies respiratory efficiency was 100% B2B-RMC, 55% 2D spiral and 40% 2D TSE.

Table 1: Comparison between the three coronary wall imaging techniques.

Method	3D spiral B2B-RMC	2D spiral navigator	2D TSE Navigator
Respiratory efficiency (%)	99.5±1.6	39.0±9.4	39.3±4.6
Total duration (Cardiac cycles)	603±10	209±59	479±74
Acquisition duration/reconstructed slice (Cardiac cycles)	37.7±0.6	209±59	479±74
Wall thickness (mm)	1.10±0.14	1.14±0.15	1.21±0.17
N	9	10	8

Table 2: Reproducibility of the three coronary wall imaging techniques.

Method	3D spiral B2B-RMC	2D spiral navigator	2D TSE Navigator
Mean wall thickness difference (initial-repeat acquisition) (mm)	0.01±0.10	-0.01±0.14	0.06±0.14
Intra-class correlation coefficient	0.86	0.70	0.72
N	9	10	6

Discussion

Reproducibility is good for the 2D techniques and excellent for the 3D technique. B2B-RMC enables the acquisition of high resolution 3D images of the coronary vessel wall with near 100% respiratory efficiency. The efficient and reproducible nature of coronary artery vessel wall imaging with B2B-RMC will permit future studies of disease progression and/or regression within a clinically feasible timescale in a patient cohort.

References

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