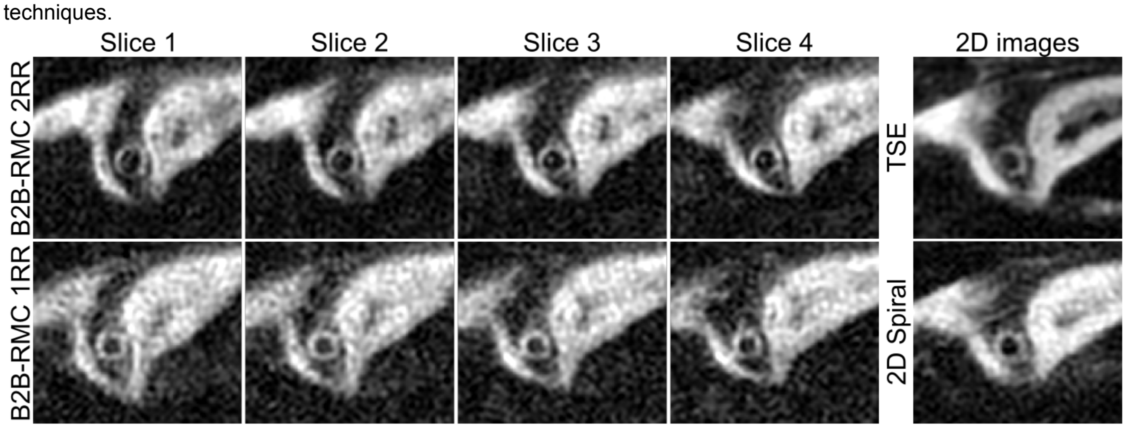
High resolution 3D spiral coronary vessel wall imaging with >99% respiratory efficiency using beat to beat respiratory motion correction: quantitative comparison with navigator gated 2D spiral and turbo spin echo imaging

A. D. Scott[1,2], J. Keegan[1,2], and D. N. Firmin[1,2]

[1]National Heart and Lung Institute, Imperial College, London, Greater London, United Kingdom, [2]Cardiovascular Magnetic Resonance Unit, The Royal Brompton Hospital, London, Greater London, United Kingdom

Introduction: Dark blood coronary artery wall imaging has demonstrated the ability to detect vessel wall thickening in subjects with non-significant coronary heart disease [1]. For high resolution imaging, studies are generally performed with diaphragmatic navigator gating which has an inherently low respiratory efficiency (RE) and is further compromised by respiratory drift through the long acquisition. Recently, 3D spiral dark blood right coronary artery wall imaging was demonstrated with 100% RE using a beat to beat respiratory motion correction (B2B-RMC) technique [2] which uses motion information determined from low resolution images of the fat around the vessel as a surrogate for vessel motion. 3D techniques are advantageous as they reduce through-plane partial volume effects and have the potential to image the full 3D extent of a plaque. We propose that that the vessel wall thicknesses measured with this technique at nearly 100% RE are equivalent to those measured with conventional navigator-gated 2D turbo spin echo (TSE) and spiral imaging which have poorer and highly variable RE.

Method: Cross-sectional right coronary artery wall images were obtained in 10 healthy subjects on a Siemens 1.5T Avanto scanner using B2B-RMC 3D spiral imaging, 2D navigator gated TSE imaging and 2D navigator gated spiral imaging. The acquisition order was randomized. For B2B-RMC, a 3D low resolution spiral dataset (8 slices, 4.8x4.8x3mm resolution, reconstructed to 0.5x0.5x1.5mm) with fat selective excitation was acquired every cardiac cycle (CC) immediately before 2 interleaves of a 3D high-resolution spiral dataset (8 slices, 0.7x0.7x3mm resolution, reconstructed to 16 slices x1.5mm) with water selective excitation. A following navigator was used to reject data acquired at very extreme respiratory positions (>10mm outside normal range). B2B-RMC acquisitions were performed with both single (1RR) and alternate (2RR) R-wave gating. Beat-to-beat respiratory displacement of the coronary artery was determined from the low resolution images using localized 3D normalized sub-pixel cross-correlation of a region of fat around the coronary artery (relative to an end-expiratory reference image) and used to retrospectively correct the corresponding high-resolution interleaves. For comparison a 2D navigator gated spiral acquisition with identical k-space trajectories (0.7x0.7x6mm resolution) to the 3D technique was performed with 2 interleaves per cardiac cycle and water selective excitation. A navigator-gated TSE acquisition (ETL 8 – 13, depending on coronary rest period) with 0.7x0.7x6mm resolution and spectrally selective inversion recovery fat suppression was also performed. In these acquisitions, phase oversampling was implemented in subjects with small arteries and fast heart rates to boost signal-to-noise ratio. Both 2D spiral and TSE acquisitions used standard diaphragmatic navigator gating (5mm window) with end expiratory tracking and alternate R-wave ECG gating. All techniques used double inversion dark blood preparation with inversion times of 400ms (1RR) or 625ms (2RR) (less in subjects with an earlier rest period). The 2D and 3D spiral techniques used a selective reinversion band to reduce chest wall signal and prevent re-inversion of blood flowing into the artery from the left ventricle. Acquisition durations, assuming 100% RE were 300CC (1RR) or 600CC (2RR) for the 3D B2B-RMC technique, 75CC for the 2D spiral technique and 202-576CC for the TSE technique depending on the ETL and phase oversampling. ***Analysis:*** For each corrected 3D B2B-RMC dataset (1RR and 2RR), a single slice was selected from the 4x1.5mm slices corresponding to the 6mm slice imaged with the 2D techniques. The selected B2B-RMC images and the 2D spiral and TSE images were Fourier interpolated to 0.16mm in-plane resolution. Vessel wall thickness was measured as the difference in radius between circles drawn around the outer and inner edges of the vessel wall. The inter and intra observer variability of this method was assessed in a subset of 20 images. Repeated measures analysis of variance was used to assess the differences in measured vessel wall thickness between techniques.



Examples of images obtained from 1 volunteer. The 4x1.5mm slices shown of the 3D acquisitions correspond to the single 6mm slices of the 2D acquisitions. In both cases the B2B-RMC images were acquired with 100% RE, 2D spiral images with 40% RE and TSE images with 38% RE.

Results: Example images from each of the techniques are shown in the figure. TSE imaging failed in 2 subjects due to an incorrect acquisition window. Assessment of vessel wall thickness was also not possible in the 1RR B2B-RMC technique images of one subject due to poor blood/vessel contrast. The average respiratory efficiency and vessel wall thickness for each technique is given in the table. Respiratory efficiency was significantly higher for the B2B-RMC technique (mean ± SD 99.6±1.2%) compared to the navigator gated techniques (39.1±7.5%, p<0 .0001). The intra and inter observer variations in measured wall thicknesses were low (mean difference ± SD 0.02±0.09mm and 0.03±1.0mm respectively). Repeated measures ANOVA showed that there were no significant differences in vessel wall thickness between the techniques.

	Number Assessed	*Respiratory Efficiency (%)*	*Vessel Wall Thickness (mm)*
3D B2B-RMC 1RR (standard deviation)	9	99.8(0.3)	1.20(0.14)
3D B2B-RMC 2RR (standard deviation)	9	99.5(1.6)	1.11(0.17)
2D Spiral (standard deviation)	10	39.0(9.4)	1.14(0.15)
2D TSE (standard deviation)	8	39.3(4.6)	1.21(0.17)
p-value	-	<0.0001	ns

Conclusion: Right coronary artery wall images have been obtained in healthy subjects with nearly 100% respiratory efficiency using the B2B-RMC technique. Vessel wall thicknesses measured with this technique are not significantly different from those obtained with conventional navigator gating. The improved respiratory efficiency enables 3D acquisitions to be performed within a reasonable duration which will permit improved assessment of coronary plaque.

References: 1. Kim. Circ 2002. 2. Keegan. JMRI 2007.