High resolution, free-breathing coronary artery imaging with >99% respiratory efficiency: comparing beat to beat respiratory motion correction with navigator gating

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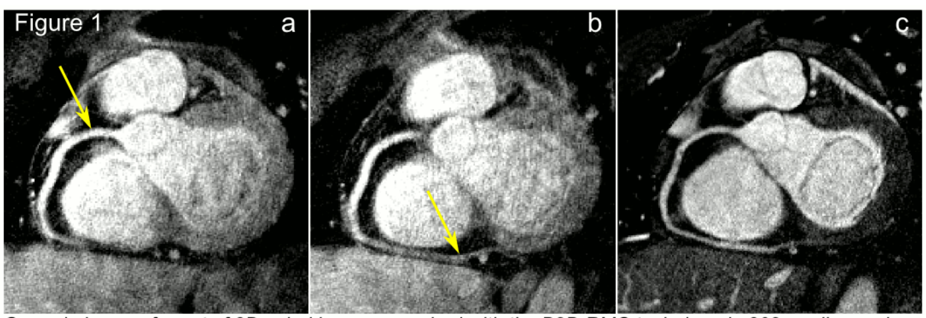
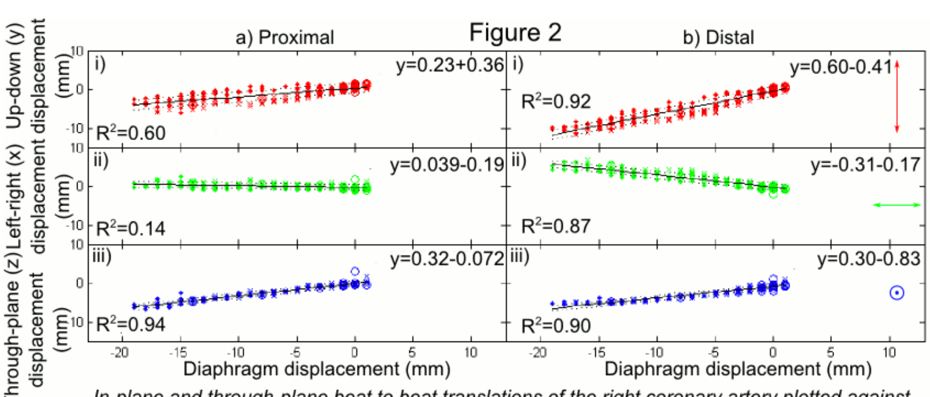
Introduction: High-resolution coronary artery imaging is commonly gated to end-expiration using diaphragmatic navigator echoes, resulting in inherently low respiratory efficiency (RE) which is further exacerbated by respiratory drift. Recently, it was demonstrated that epicardial fat can be used as a marker of coronary artery position in a 3D beat-to-beat non-model based subject-specific respiratory motion correction (B2B-RMC) technique [1]. We propose that this technique, which has a respiratory efficiency close to 100%, can compensate for respiratory motion in high resolution coronary artery imaging as effectively as a standard navigator gated technique which has much poorer and highly variable efficiency.

Methods: In-plane right coronary artery images were acquired in 10 healthy subjects on a Siemens 1.5T Avanto scanner. For the B2B-RMC technique, 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 immediately before 2 interleaves of a 3D high-resolution spiral dataset (8 slices, 0.7x0.7x3mm resolution, reconstructed to 0.7x0.7x1.5mm) with water selective excitation. A following navigator was used to reject data acquired at very extreme respiratory positions (>10mm outside normal range). Acquisition duration was 300 cardiac cycles assuming 100% RE. 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 origin (relative to an end-expiratory reference image) and used to retrospectively correct the corresponding high-resolution interleaves. Resulting images were compared to a navigator gated (5mm window) 3D T2-prepared balanced steady-state free-precession (nav-bSSFP) acquisition with identical spatial resolution (251 cardiac cycles assuming 100% RE). Acquisition order was randomised in the 10 subjects. ***Analysis:*** For each B2B-RMC and nav-bSSFP dataset, a maximum intensity projection (MIP) of the artery was generated with overlying anatomy zeroed to enable the whole vessel to be visualized in a single image. A line was manually traced along the centre line of the vessel in the MIP and perpendicular profiles obtained at each point along the centre line. Average vessel diameter (full-width at half maximum – minimum) and sharpness (inverse of 20-80% intensity distance [2]) were automatically measured in the proximal (0-20mm) and mid (20-40mm) arteries. Due to the intrinsic contrast differences between the techniques signal and contrast to noise ratios were not measured. Paired t-tests were used to compare the RE, vessel sharpness and vessel diameter between the two techniques.

Table	*Respiratory Efficiency (%)*	*Proximal sharpness (mm^{-1})*	*Mid sharpness (mm^{-1})*	*Proximal diameter (mm)*	*Mid diameter (mm)*
B2B-RMC (standard deviation)	99.3 (0.5)	1.00 (0.14)	1.01 (0.11)	2.85 (0.38)	2.85 (0.39)
nav-bSSFP (standard deviation)	44.0 (8.9)	1.08 (0.11)	1.05 (0.12)	2.70 (0.34)	2.80 (0.35)
p-value	<0.0001	ns	ns	<0.05	ns



Curved planar reformat of 3D spiral images acquired with the B2B-RMC technique in 302 cardiac cycles (99.3% efficient) corrected for optimal proximal (a) and distal (b) vessel quality (20mm diaphragm motion). Equivalent reformatted 3D nav-bSSFP image, acquired in 612 cardiac cycles (43.6% efficient) is shown in (c). The arrows in a) and b) highlight the improved proximal and worse distal vessel delineation in a) when compared to b) and vice versa.



In-plane and through-plane beat to beat translations of the right coronary artery plotted against the corresponding diaphragm displacement, optimized for (a) proximal and (b) distal motion.

Results: Good quality images were obtained using both techniques in all subjects. For the B2B-RMC technique, the RE was close to 100% (99.7%, range 98.4 – 100%) and significantly higher ($p<0.0001$) than for the nav-bSSFP technique (44.0%, range 33.0 – 62.8%). There were no significant differences in proximal or mid vessel sharpness between the two methods (table). There was no significant difference between methods for mid-vessel diameters and a significant but insubstantial (0.15mm or around 5%) difference in proximal diameter which is possibly due to reduced vessel wall signal in the T2-prepared nav-bSSFP technique. Figure 1 shows example B2B-RMC images optimally corrected for (a) proximal and (b) distal vessel motion (RE=99.3%) and the equivalent nav-bSSFP results (c) (RE=43.6%). Figure 2 plots the corresponding 3D beat-to-beat displacements obtained as a function of the diaphragm displacements measured with the following navigator. The linear least squares fit highlights the greater amplitude of motion of the distal artery, which is in close proximity to the diaphragm, when compared to the proximal section.

Conclusion: High-resolution coronary artery images were acquired with 99.7% RE using B2B-RMC in 10 healthy subjects. Diameter and sharpness in the proximal and mid vessel were not substantially different to values obtained with nav-bSSFP acquired with mean RE 44.0%. For optimal visualisation, the B2B-RMC method requires cross-correlation of a *local* region of fat, as demonstrated in Figure 1 (a) and (b). Further work will merge images corrected for both proximal and distal vessel motion to generate a single corrected dataset.

References:

1. Keegan J et al. J Magn Res Imag. 2007; 26:624.
2. Li D et al. Radiology 2001; 219:270.