Simultaneous left and right coronary artery wall imaging with highly efficient beat-to-beat respiratory motion correction

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Introduction

Vessel wall imaging is commonly gated to alternate ECG R-waves, in order to increase signal to noise ratio and minimise artefacts due to beat-to-beat variations in the RR-interval. However, this results in one redundant cardiac cycle in every two. In previous work with 2D carotid artery wall imaging, the resulting redundant RR-interval was used to acquire additional parallel vessel wall images [1]. We postulate that the redundant RR-interval can be used to image an additional volume in 3D coronary artery vessel wall imaging. Beat-to-beat respiratory motion correction (B2B-RMC) [2] tracks the epicardial fat surrounding the coronary artery in 3D low resolution fat images acquired immediately before each segment of the high resolution acquisition and uses these 3D respiratory translations to retrospectively correct the corresponding high resolution data with near 100% respiratory efficiency. We propose that acquiring left and right coronary artery vessel wall images on odd and even cardiac cycles respectively in conjunction with B2B-RMC could permit high resolution simultaneous 3D imaging of both arteries in ~10minutes.

Methods

A free-breathing 3D spiral coronary artery wall imaging sequence was modified in order to acquire two high resolution 3D volumes. Two spiral interleaves, both corresponding to the same imaging volume were acquired per cardiac cycle with water selective excitation and slab selective dark blood preparation [3]. Resolution was 0.7x0.7x3mm, with 8 slices/volume (reconstructed to 16 x 1.5mm slices)
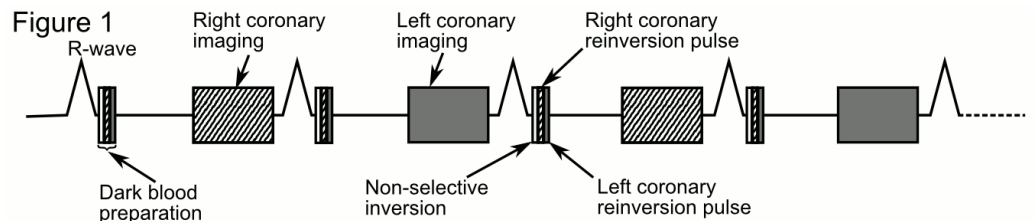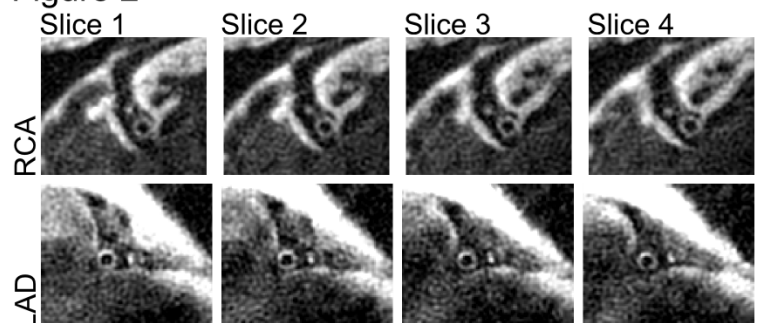

Figure 1

Schematic diagram of the simultaneous left and right 3D coronary vessel wall imaging sequence. In each cardiac cycle, the dark blood preparation non-selectively inverts all tissue and selectively reinverts tissue slabs covering the left and right coronary arteries. Left and right coronary artery wall data are acquired on odd and even cardiac cycles respectively. Each imaging block includes the acquisition of a low resolution 3D fat-excitation dataset which is used to track respiratory motion for B2B-RMC[2].

and an acquisition duration of 600 cardiac cycles assuming 100% respiratory efficiency. The first and second volumes were imaged on odd and even cardiac cycles respectively (figure 1). The slab selective dark blood preparation was modified to reinvert two slabs every cardiac cycle. For B2B-RMC a low resolution 3D volume was imaged in the same plane as the high resolution acquisition which immediately followed it in the same cardiac cycle. This low resolution acquisition used a 3D stack of spirals trajectory of 8 slices at 4.8x4.8x3mm resolution and fat selective excitation. Only data acquired at very extreme respiratory positions (>10mm outside the normal tidal range) was discarded using a following diaphragmatic navigator. In the remaining data, 3D respiratory translations were obtained independently for each imaging volume from the relevant low resolution 3D fat images using 3D local normalised sub-pixel cross-correlation. These respiratory translations were used to retrospectively correct the corresponding high resolution data, resulting in a respiratory efficiency of nearly 100% [2,4].

Acquisitions were performed in healthy subjects using a Siemens Avanto 1.5T MR scanner. The first and second volumes were positioned to obtain cross-sectional left anterior descending and right coronary images respectively. The first reinversion slab was positioned to selectively reinvert the right coronary artery whilst avoiding reinversion of aortic blood and minimising reinversion of the tissue imaged in the left coronary artery volume. The second reinversion slab was similarly positioned for the left coronary artery. Inversion time was 400ms which is optimal for dark blood imaging gated to every R-wave at a heart rate of 60 beats/minute.

Results

High resolution left and right coronary artery wall images obtained simultaneously in 629 cardiac cycles and corrected for respiratory motion using B2B-RMC are shown in figure 2. The respiratory efficiency in this case was 95%. Image quality, respiratory motion compensation and blood suppression is good in both arteries.

Discussion

We have demonstrated simultaneous left and right coronary artery wall imaging in the duration required to image a single artery. Used in conjunction with B2B-RMC, this has permitted high resolution 3D imaging of both the left and right coronary walls in approximately 10 minutes. Further improvements are expected with the use of 2D selective reinversion pulses for dark blood preparation [5]. Future work will include a direct comparison with conventional alternate R-wave gating acquisitions and an investigation into the robustness of the technique to changes in RR interval.

References

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Figure 2

Four contiguous slices from the right (top) and left (bottom) coronary artery volumes acquired simultaneously in 629 cardiac cycles using a dark blood 3D spiral acquisition with B2B-RMC. The respiratory efficiency was 95%.