Image-based respiratory motion compensation for CMRA in patients with coronary artery disease

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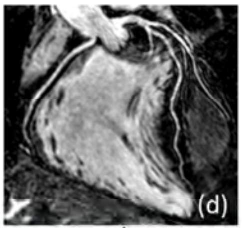
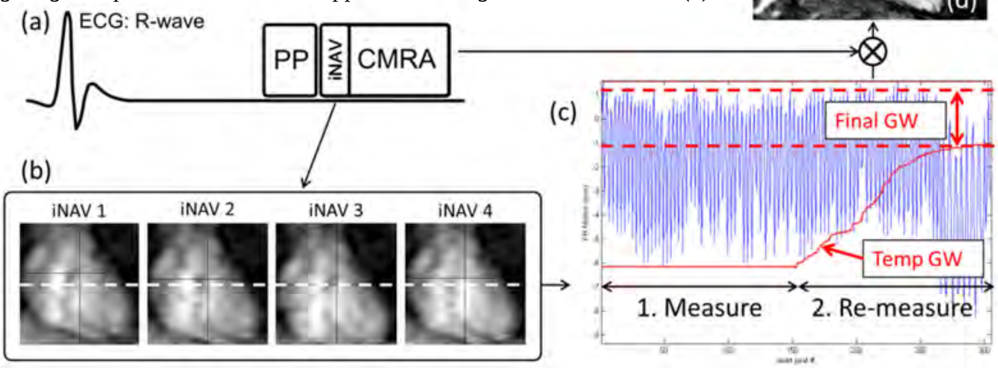
Background: Respiratory motion remains a major impediment in a substantial amount of patients undergoing coronary magnetic resonance angiography (CMRA). Recently, image-based respiratory navigation (iNAV) has emerged as a promising approach to address this issue [1]. However, it has primarily been evaluated in healthy volunteers and has been limited to offline reconstruction and motion correction. In this work, we show preliminary clinical results from an inline implementation of image-based respiratory motion correction and gating in 25 patients with coronary artery disease.

Methods: The iNAV allowed for direct tracking of translational respiratory motion of the heart in 2D (foot-head and left-right motion) and was generated using the startup echoes of a bSSFP sequence. To improve robustness of this method to non-rigid motion, respiratory gating was implemented using the diminishing variance algorithm (DVA) [2]. In this approach k-space was completely filled during the first phase of the scan, while in the second phase the most motion corrupted data was discarded and re-acquired. If N shots were needed to fill the entire k-space for an ungated scan then both DVA phases one and two each consisted of N shots, resulting in a 50% gating efficiency. The schematics of the motion correction and gating are shown in Figure 1. Motion correction and DVA gating with iNAV for CMRA was integrated into the software of a clinical 1.5T scanner (Philips Healthcare, Best, Netherlands) and no post-processing was required. The CMRA images were acquired with 1.3mm isotropic resolution and a SENSE factor of 2.5 in phase encoding direction. We compared the findings of the CMRA with iNAV against gold standard coronary X-ray or CT.

Results: In the 25 patients, 75 coronary vessels were analysed (right coronary artery, left anterior descending and left circumflex), and 14 vessels were found to be diseased (lumen diameter < 50%) in a total of 8 patients based on the reference X-ray or CT angiograms. CMRA scans with iNAV were successfully obtained in all patients with an average scan time of 7:51±0:32 min:sec. Representative images from four patients, two with no CAD and two with confirmed CAD, are shown in Figure 2. The final gating window using DVA gating was found to be 3.9±1.3 mm. The sensitivity and specificity of the proposed approach on a per vessel basis was 92% [confidence interval (CI): 66%-99%] and 98% (CI: 91%-99%) respectively, and on a per patient basis 86% (CI: 47%-98%) and 94% (CI: 71%-99%).

Figure 1. *Image-navigators (iNAV) are generated using the startup echoes of the CMRA sequence (a).The iNAVs are reconstructed and registered in real-time to enable FH and LR motion correction of the CMRA data (b). In addition, the iNAVs are used to gate the scan, where in the first (**Measure**) phase, all data is accepted to acquire 100% of k-space. In the second phase (**Re-measure**) the most motion corrupted data is discarded and re-acquired using a temporary gating window (**GW**) (c). Both iNAV correction and gating is implemented inline and applied to the high resolution CMRA (d).*





Discussion: The proposed iNAV method provides whole-heart CMRA in a short and predictable scan time while minimizing respiratory motion artifacts. Additionally, this method improves CMRA ease-of-use as the iNAV can be extracted directly from the CMRA field-of-view and no dedicated navigator scan planning is required. Preliminary results suggest that the proposed approach may provide diagnostic information approaching that of the gold standard methods for coronary angiography which utilize ionizing radiation. However, further work is required to validate the clinical usefulness of CMRA using iNAV motion correction for patients with coronary artery disease.

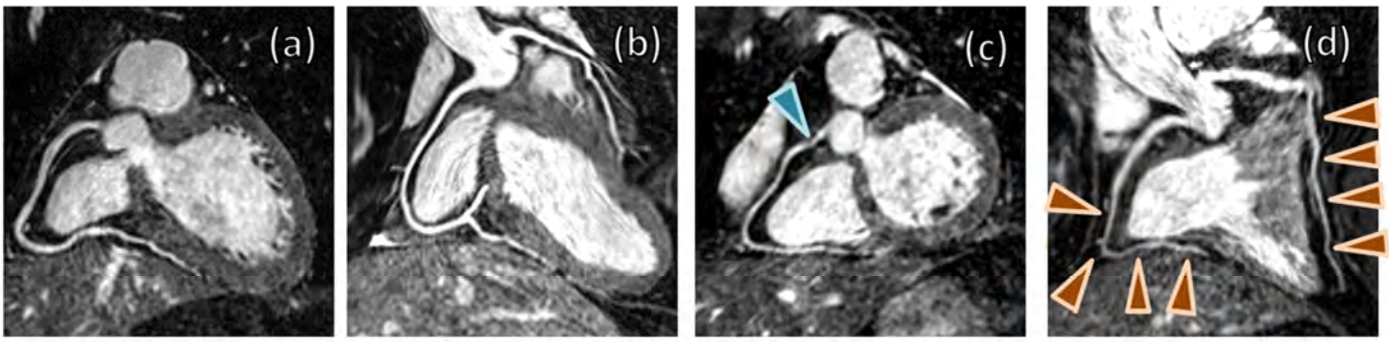


Figure 2. Reformatted CMRA of 2patient without CAD (a, b), one with a 75% stenosis of the RCA (c), and one with diffuse CAD (d).

References: [1] Henningsson, MRM 2012; [2] Sachs, MRM 1995.