Cartesian Whole-Heart Coronary MRA Using Interleaved Auxiliary Image Acquisition and 3D Affine Motion Correction

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Introduction: Extensive respiration induced motion of the coronary arteries during MRI acquisition often degrades image quality. The current standard approach for coronary MR angiography (CMRA) acquires image data only during a narrow window at end-expiration to reduce motion artifacts by correcting for feet-head (FH) translation. This approach leads to prolonged scan times (around 30-50% scan efficiency), as well as residual motion artifacts in some subjects. Accurately calculating and applying 3D affine motion correction to CMRA acquisitions could allow for image sampling throughout the whole respiratory cycle [1-3], and subsequently a reduced scan time. Here we propose a new motion correction strategy with 100% scan efficiency, which uses the startup echoes to generate 3D auxiliary images for affine motion estimation at different respiratory positions. The motion parameters estimated from these auxiliary images are applied to correct the CMRA data acquired simultaneously at the corresponding respiratory bins.

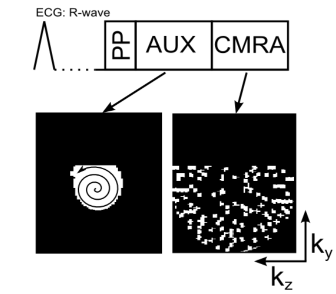

Figure 1. Phase encoding profile order for the low resolution, fully sampled auxiliary (AUX) and high resolution, undersampled coronary MRA (CMRA) acquisitions. PP = pre-pulses.

Methods: Four evenly spaced respiratory bins were defined, each comprising 5mm motion as measured by a diaphragmatic 1D navigator (1Dnav), from end-expiration (bin 1) to end-inspiration (bin 4). For each bin a fully sampled low resolution auxiliary (AUX) image and a high resolution but undersampled CMRA image was acquired, using Cartesian *k*-space sampling. AUX image data was generated from the startup profiles of an SSFP sequence [4]. The phase and slice encoding profile orders for both AUX and CMRA was centric, meaning that the centre of *k*-space was sampled during the first shot and successive shots traversed *k*-space outwards along a spiral like trajectory, illustrated in Fig. 1 (half scan with a factor of 0.6 was used in the phase encoding direction). The main difference between the AUX and CMRA acquisition was that for each bin AUX k_y-k_z encoding continues where the previous shot in that bin ended, creating fully sampled low resolution images, whereas CMRA k_y-k_z encoding increments regardless of respiratory position resulting in pseudorandom under-sampling at each bin. AUX and CMRA data was reconstructed and a region of interest selected encompassing the heart. The AUX images were used to calculate 3D affine parameters for each bin by registering bin 2-4 to the reference end-expiratory bin 1 (Fig. 2). These transformations were then applied to the corresponding CMRA acquisitions. Pixel-wise summation of all the CMRA bins after transformation yields the motion corrected image. Three healthy subjects were scanned on a Philips 1.5T clinical scanner using the proposed approach. A segmented (15 profiles/shot for both AUX and CMRA) SSFP whole-heart protocol was used for the experiments with the following imaging parameters: FOV = 280x280x100mm, 1x1x2mm resolution, α = 70˚, TR/TE = 4.6/2.3ms. For comparison, a CMRA dataset was acquired using a diaphragmatic 1Dnav with 7mm gating window and FH tracking factor of 0.6.

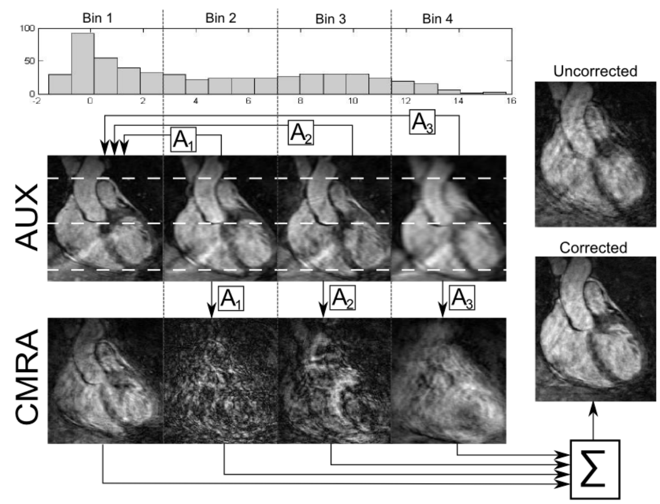

Figure 2. AUX and CMRA respiratory binned images from one scan. The distribution of the 1Dnav is shown in the histogram (top) indicating the amount of data in each bin. The AUX images are used to calculate 3D affine transformations $A_{1\text{-}3}$ for each bin to end-expiration (bin 1) which are then applied to the corresponding CMRA bins. Summing all transformed CMRA bins yields the motion corrected image.

Results: Representative reformatted images are shown in Figure 3, using a 7mm respiratory gating window and 1D FH tracking (a), no gating and 3D affine correction (b) and no gating and no correction (c). The average navigator efficiency for the gated scan was 55% ±12%, compared to 100% for the proposed approach.

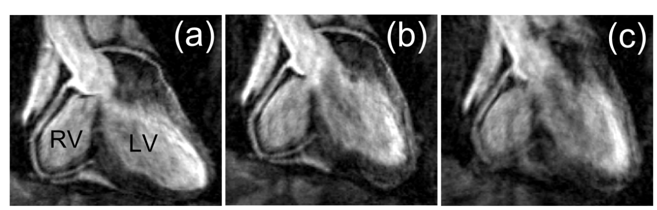

Figure 3. Images acquired with 7mm gating and 1D FH tracking (a), no gating and 3D affine correction (b) and no gating and no correction (c).

Conclusion: We have demonstrated the feasibility of the proposed approach to perform respiratory motion correction with 100% gating efficiency and image quality comparable to that of 1D FH correction with a 7mm gating window. A more extensive study in healthy subjects is currently underway to validate these findings.

References: [1] Manke et al. MRM 2003. [2] Shechter et al. TMI 2003. [3] Bhat et al. MRM 2011. [4] Henningsson et al. MRM 2011.