3T Coronary MRA with 100% Navigator Efficiency with 3D Self Navigation

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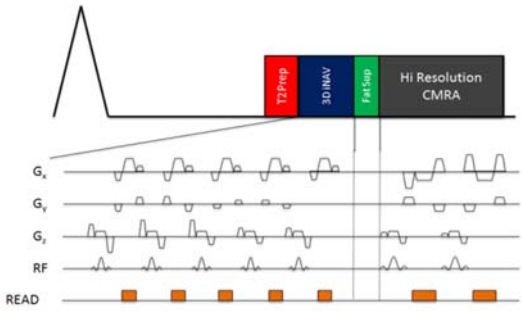
Introduction: Recently several methods have been proposed to obtain 2D and 3D cardiac motion data in order to perform motion correction [1-3] of 3D coronary MRA (CMRA). Compared to 1D navigators, these methods offer the possibility of more accurate correction and improvements in certain quality metrics. Using a novel interleaved scanning method (iSCAN), we obtained full 3D cardiac navigators enabling us to obtain full 3D beat-to-beat motion curves for motion correction. We compared the quality of 3D self navigator (3DSN) corrected images with 100% scan efficiency to 1D navigator gated images. Because data is corrected rather than rejected when outside a gating window, we hypothesise that we can significantly reduce scan times. We corrected the acquired k-space data by multiplying by the appropriate complex phase related to the translational motion measured in each heartbeat. In previous work, we have shown that correcting in FH and LR directions can provide equivalent image quality to traditional gated scans. [4]



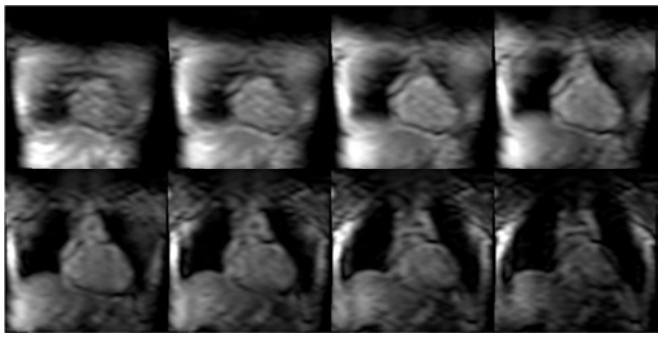


Figure 1 (Left): Interleaved scanning (iScan) was used to switch between the segmented high resolution GRE CMRA scan, and a single shot 3D GRE image navigator, acquired once per heartbeat.
Figure 2 (Right): Representative beat-to-beat dataset acquired with the 3D navigator. Resolution was 5x10x10mm and the acquisition time was 81ms. 3D iNAVs were acquired with a SENSE factor of 3.

Material and Methods: The proposed sequence is shown in Figure 1. The 3DSN was implemented in the interleaved scanning environment, iScan, that allows seamless switching between imaging sequences (Figure 1). During each heartbeat a complete 3D whole heart navigator was obtained. The navigator is low resolution and acquired using 3x SENSE with 24 profiles in 81ms. The high resolution imaging parameters included a FOV of 300x300mm, slab thickness of 80mm, a spatial resolution of 1x1x2mm, TR/TE = 4.1/1.4ms and FA = 20**°.** The navigator was acquired with identical FOV parameters, but with a spatial resolution of 5x10x10mm, TR/TE = 3.4/1.7ms and FA = 2**°.** For comparison, 1D navigator diaphragmatic gated whole heart datasets with identical high resolution imaging parameters were acquired with a gating window of 8mm. Four healthy volunteers were scanned on a Philips 3T Achieva scanner (Philips Healthcare, Best, NL). A 3D template matching algorithm was used to extract motion data from the navigator images and data correction and reconstruction were performed in the MATLAB environment using an iterative SENSE reconstruction. Analysis of the vessel sharpness and reformatting of the images was performed with the Soapbubble tool [5].

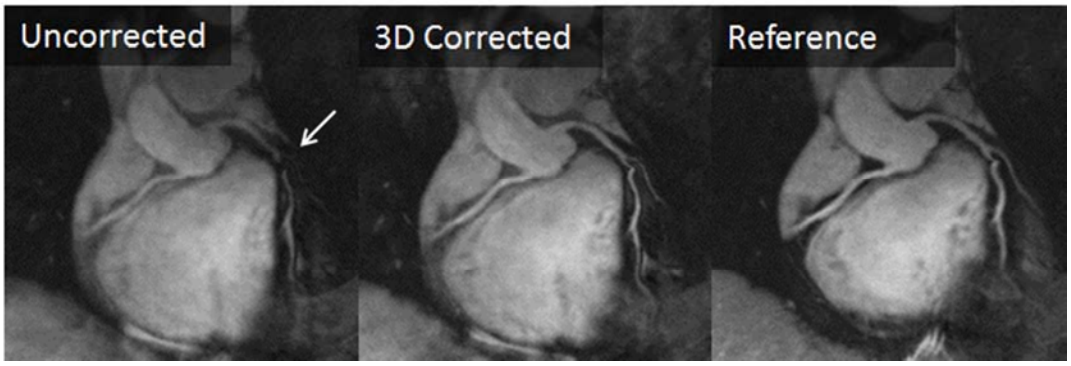


Figure 3: Representative reformatted images showing the coronary arteries. The image on the left is ungated and uncorrected, blurring is visible. The middle image is the same dataset, corrected using 3D motion data. The coronaries are sharper after correction, and correspond well with the reference image (right).

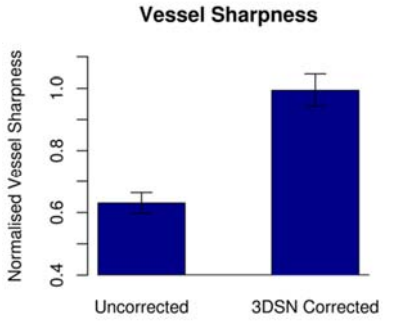


Figure 4: Vessel Sharpness is presented normalised to the reference gated scans. Uncorrected images display significantly worse image quality. 3DSN correction is able to restore vessel sharpness to an equivalent level as the reference images.

Results: We were able to obtain a whole heart 3D cardiac dataset every heartbeat and to derive beat-to-beat 3D motion data (Figure 2). The resolution was sufficient to visualise the important bulk anatomy of the heart, and can be used to obtain 3D cardiac motion data. Representative imaging examples of gated (8 mm), ungated 3DSN corrected (100% efficiency) and uncorrected whole heart scans are shown in Figure 3. It can be seen that the uncorrected image displays significant blurring, and the coronary arteries are not visible in parts (arrow). The corrected images however display increased vessel definition, and an equivalent amount of coronary artery is visible compared to the reference image. Figure 4 displays the results of the analysis of vessel sharpness. The vessel sharpness measures are calculated normalised to those of the reference gated vessel sharpness measures. We observe a significant decrease in vessel sharpness in the uncorrected images of 0.63 ± 0.03, but after correction we achieve similar vessel sharpness (0.99 ± 0.05) compared to the 1D navigator gated reference 3D CMRA. Scan efficiency with the 3DSN approach was improved to 100% compared to 61.0%± 0.5% with the gated 3D CMRA.

Discussion and Conclusion: The initial results of the proposed 3DSN method are very promising. We are able to obtain a real-time 3D cardiac image every heartbeat and obtain useful motion data from them. Once the 3D CMRA images are corrected, they display equivalent vessel sharpness to the gated. This method of correcting acquired data instead of rejecting it outside of a gating window leads to a significant improvement in scan time. In patients with significant motion in RL or AP directions, this method should lead to improved performance over 1D and 2D navigator corrected images. Future work will investigate extending the motion model and correction method to correct for affine motion and to further optimise the 3D navigator parameters.

References: [1] Stehning, C et al MRM 2005 54:2 476-480 [2] Li, D et al MRM 2008 59:6 1378-1385 [3] Henningsson, M et al MRM 2013 69:2 486-494 [4] Powell, J et al Proc ISMRM 2013 0545 [5] Etienne et al. MRM 2002 48:4 658–666