CMRA with 100% navigator efficiency with radial 2D self navigation

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Introduction: Traditional pencil beam navigators for Coronary Magnetic Resonance Angiography (CMRA) measure the displacement of the diaphragm and then assume bulk cardiac motion is proportional to this by a constant factor. Self navigation techniques have been proposed [1-3] in order to improve upon this estimate by directly measuring cardiac motion. We compared the performance of radial and Cartesian 2D self navigators (2DSN) with 100% scan efficiency to 1D navigators. 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. We then compared corrected radial and Cartesian 2DSN scans with traditional 1D gated CMRA with an 8 mm gating window.

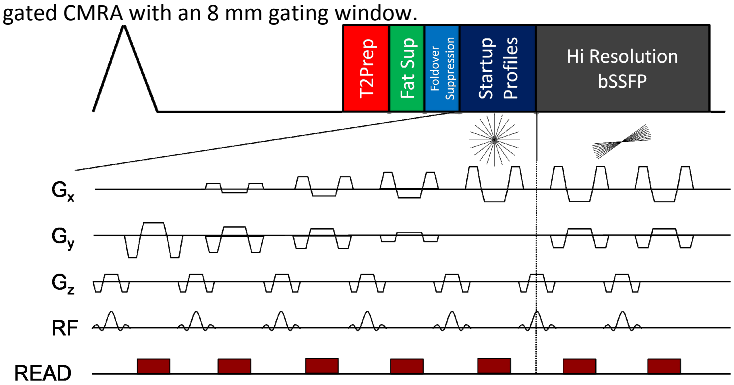

Figure 1 (Left): 3D CMRA sequence with radial sampling using startup profiles to acquire navigator data. For each set of high resolution profiles we acquired an undersampled data set. This 2DSN data is then used to calculate motion via template matching and to perform correction of the high resolution images. 2DSN: two dimensional self navigator.

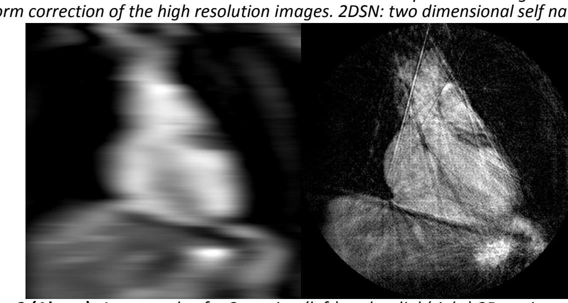

Figure 2 (Above): An example of a Cartesian (left) and radial (right) 2D navigator image (12 profiles each). Note the increased resolution (although highly undersampled) radial image, allows various features and structures of interest to be identified.

Material and Methods: The proposed sequence is shown in Figure 1. The radial 2DSN images were acquired in each R-R interval directly prior to the high resolution image acquisition in the coronal plane with no phase encoding performed in the slice selection direction. Thus, the 2DSN images are projections of the field of view. The imaging parameters included a FOV of 300x300mm, slab thickness of 80mm, a spatial resolution of 1x1x2mm, TR/TE = 5.3/2.6ms and FA = 70°. Twelve startup profiles were acquired for the radial 2DSN images resulting in a navigator resolution of 1x1mm. For comparison, a Cartesian whole heart dataset with identical parameters was acquired. Cartesian 2DSN resolution was 1x25mm. Five healthy volunteers were scanned on a Philips 1.5T Achieva scanner (Philips Healthcare, Best, NL). A template matching algorithm was used to extract motion data from the navigator images and data correction and reconstruction were performed in the MATLAB environment. Analysis of the vessel sharpness and reformatting of the images was performed with the Soapbubble tool (Etienne et al. MRM 2002).

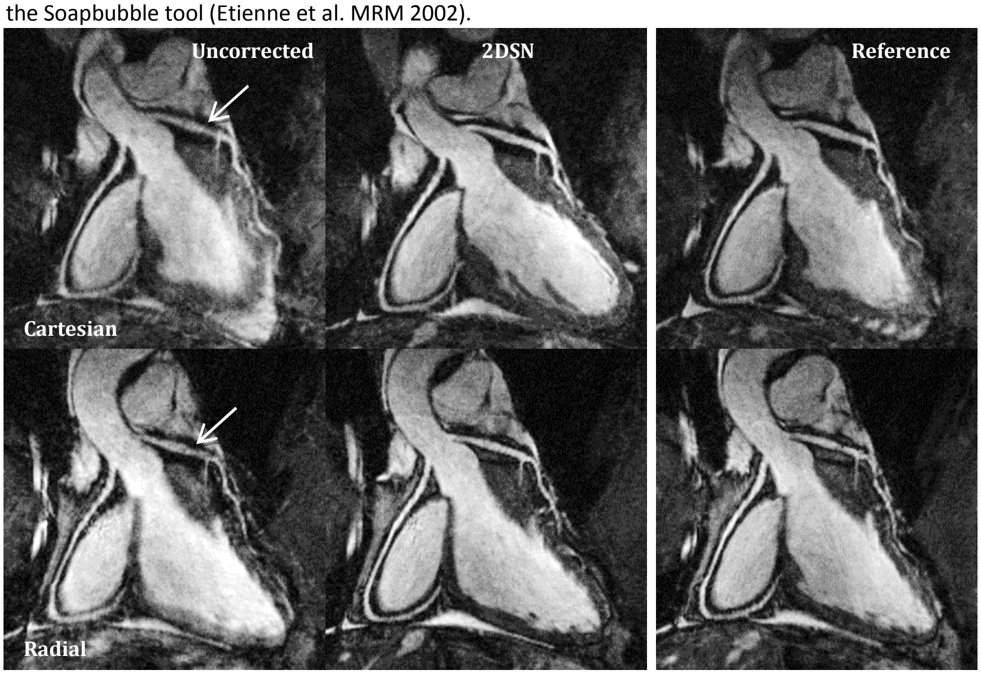

Figure 3: The first column shows the uncorrected images, the second shows the 2DSN corrected images. The third column shows the reference images acquired with an 8mm gating window.

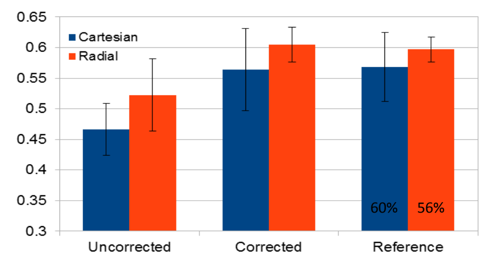

Figure 4: Vessel sharpness measures based upon a cross section of the first 40mm of each reformatted coronary artery. Our correction method is able to significantly improve vessel sharpness, equivalent to a gated scan.

Results: Representative imaging examples of gated (8 mm), ungated 2DSN corrected (100% efficiency) and uncorrected whole heart scans acquired with either radial or Cartesian profile order are shown in figure 3. Motion blurring is observed in the uncorrected image (arrows), while the corrected view shows similar image quality to the reference gated scan. Figure 4 displays the results of the analysis of vessel sharpness. Our method is able to recover image quality on the same level as a traditional 1D navigator gated scan with an 8 mm gating window. Between the reference and uncorrected scans we observe a significant drop in vessel sharpness from 0.57 ± 0.06 to 0.47 ± 0.04 ($p < 0.005$) in the Cartesian case and from 0.56 ± 0.05 to 0.50 ± 0.07 ($p < 0.05$) in the radial case. After correction we found that the vessel sharpness measures were equivalent to the reference images, 0.56 ± 0.07 in the Cartesian case and 0.57 ± 0.06 in the radial case. As our method does not involve navigator gating, we were able to improve scan efficiency to 100% from 56.0% ± 0.05% in the Cartesian case and 60.3% ± 0.10% in the radial case.

Discussion and Conclusion: The initial results of the proposed self-navigation scheme with 100% scan efficiency are very promising as they provide similar image quality to traditional 1D gated scans. Furthermore the scan time is significantly shorter and predictable, as data is not rejected due to it being outside of a gating window. In patients with significant RL motion of the heart during the respiratory cycle, this correction method should lead to better results due to the 2D navigator's ability to measure and correct for this motion. Future work will extend this motion correction to motion models with higher degrees of freedom such as affine and non-rigid, as well as investigating the use of trailing navigators to measure and correct for AP motion. **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 2011 67:2 437-445