3D projection reconstruction based respiratory motion correction technique for free-breathing coronary MRA

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INTRODUCTION: Respiratory motion is one of the major challenges for coronary MRA. Current navigator based free-breathing techniques measure the position of the diaphragm and use a fixed correlation factor to estimate the position of the heart. Such techniques suffer from errors due to the indirect estimation of heart position and are plagued by low scan efficiencies (typically between 30 and 50 %). The purpose of this work was to develop a 3D projection reconstruction (3D PR) based coronary MRA technique which accepts all the data during the scan, irrespective of respiratory position, and retrospectively corrects for respiratory motion by using 3D image registration.

METHODS: 3D PR based respiratory motion correction: A schematic of this technique is shown in Fig. 1. During the scan all the data are accepted. The navigator signal is acquired, but not used for gating or slice tracking. The data is retrospectively split into 6 bins (shown by the red lines), where each bin represents a particular state in the respiratory cycle. The navigator signal is used for the binning since it provides an excellent depiction of the respiratory cycle. Since 3D PR is used for data acquisition, it is possible to reconstruct 3D low resolution images in each respiratory bin. A Gaussian window is applied in k-space before reconstructing the low resolution images in order to eliminate ringing artifacts in the low resolution images. 3D image registration is then used to estimate the motion between each of the bins with the end expiratory bin used as a reference (blue arrow). The idea of using low resolution PR images for motion correction was originally proposed for 2D imaging [1]. An open-source toolkit, ITK (http://www.itk.org/) was used for image registration. The motion correction is then applied in k-space and all the data are combined to give the final motion corrected image. In this work we estimated and corrected only 3D translational motion between the respiratory bins and the correction was applied by using linear phase terms in k-space.
Volunteer Imaging: 3 healthy volunteers were scanned on a 1.5 Espree scanner (Siemens Medical Solutions) using a 3D PR TrueFISP sequence. The 3D PR trajectory was designed as a spiral running on the surface of a sphere [2]. In order to accommodate drifts in the breathing pattern, the proposed 3D PR technique should acquire projections in an interleaved fashion in each heart-beat. Additionally, to avoid eddy current related artifacts in TrueFISP imaging the gradients should not change drastically in subsequent TR intervals [3]. The 3D PR k-space trajectory used in this work was carefully designed to satisfy both these conditions. Scan parameters were similar to previous 3D PR coronary MRA studies [4]: FOV: 300 mm^3, matrix: 256^3, spatial resolution: 1.17x1.17x1.17 mm^3, flip angle = 90, linear flip angle preparation with 15 prep pulses, readout bandwidth = 797 Hz/pixel, TR = 3.4 msec, number of projections = 16320 to 16416 (undersampling factor of 4 compared with Nyquist rate), 25 to 38 segments in each heart-beat.
RESULTS: Fig. 2 shows reformatted coronary artery images using: i) navigator gating and slice tracking (left column), ii) proposed 3D PR based 3D translational motion correction after accepting all the data during the scan (middle column), and iii) images without any motion correction or gating (right column). The images with 3D translational motion correction and navigator gating and slice tracking show similar depiction of the coronary arteries. The images without any motion correction are corrupted by respiratory motion. Scan time comparison between the techniques is given in Table 1.

CONCLUSION: A novel technique for respiratory motion compensation during free-breathing coronary MRA based on 3D PR k-space sampling was proposed. In the current studies a scan efficiency of 100 % was achieved leading to a significant reduction in scan time. Further studies for validation and optimization of this technique are currently underway.

REFERENCES: [1] MRM 41: 954-63. [2] MRM 32:778-84. [3] MRI 25:1138-47. [4] MRM 52:197-203.

Technique (n = 3)	Scan time (mins)	Scan efficienc y (%)	RCA length (mm)	LAD length (mm)	LCX length (mm)
Navigator gating & slice tracking (window ± 3 mm)	18.2 ± 1.5	39.9 ±8.0	10.5±1.8	7.3 ±0.4	6.0 ±1.6
Motion correction (accept all data)	7.4 ± 1.6	100 ± 0	9.6 ± 2.2	7.0 ±0.9	6.3 ±2.1

Table 1: Quantitative evaluation of the 3D PR motion correction technique.

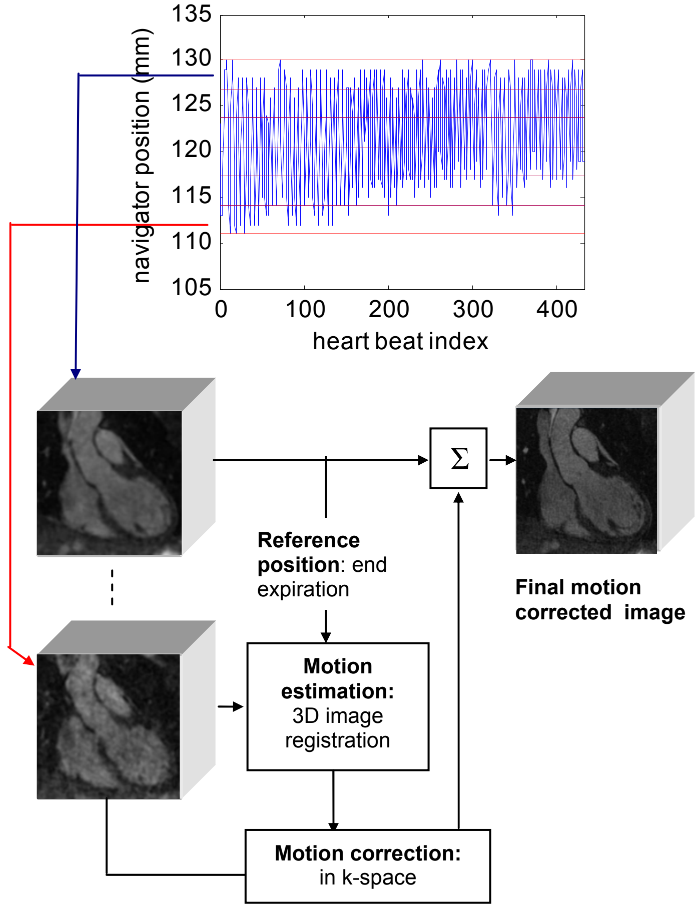

***FIg 1:** Schematic of the 3D PR based motion correction technique*

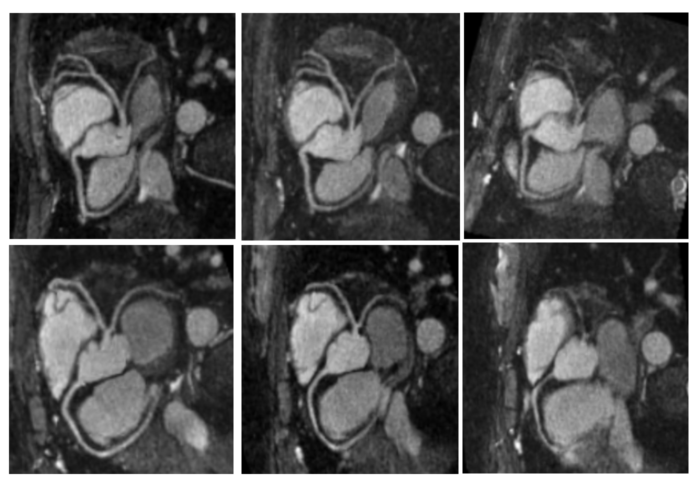

***Fig 2:** Coronary artery images using: i) navigator gating and slice tracking (**left column**); ii) 3D translational motion correction after accepting all the data during the scan (**middle column**), and iii) images without any motion correction or gating (**right column**).*