Undersampled Motion Compensated LOST Reconstruction for Free-Breathing Coronary MRA

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INTRODUCTION: Respiratory motion remains a major challenge in whole-heart coronary MR angiography (CMRA). Diaphragmatic navigators are commonly used for respiratory motion compensation in free-breathing CMRA but lead to prolonged scan times since only a fraction of the acquired data are used for image reconstruction (~20-50% efficiency). Moreover this approach compensates for foot-head translational motion only, using a fixed scaling factor. To overcome these problems methods based on image navigators have been introduced to achieve 100% scan efficiency and correct for more complex motion [1-3]. In particular a golden radial interleaved image navigator (2DiNav) has been recently proposed to correct for 2D beat-to-beat translational and bin-to-bin affine motion [4]. Here we propose to further reduce the acquisition time of the latter approach by combing 100% scan efficiency with a Cartesian undersampled acquisition. For this, the CMRA data is acquired with an undersampled golden-step spiral-like Cartesian acquisition (CASPR) and reconstructed with the low dimensional structure self-learning and thresholding (LOST) [5] approach. This motion corrected (LOST-MC) approach was tested on healthy subjects (for translational motion correction only) and compared against a conventional diaphragmatic navigator acquisition.

METHOD: *a) Image navigator*: A highly undersampled (8x) high-resolution golden radial 2DiNav is acquired per heartbeat before each segment of a whole heart 3D CMRA scan. Each 2DiNav is reconstructed with iterative SENSE and registered to a common position to estimate 2D translational beat-to-beat motion $\mathbf{T}_t$ (Fig1a). *b) Undersampled CMRA acquisition*: CMRA data is acquired using an undersampled golden-step spiral-like 3D Cartesian trajectory (CASPR). CASPR samples the phase encoding plane following approximate spiral interleaves on the Cartesian grid. The angular step between two consecutive spiral interleaves is given by the golden ratio $\varphi = 0.618$ (Fig.1b). *c) Motion corrected LOST reconstruction*: Using the estimated motion the undersampled 3D CMRA data is corrected in k-space for beat-to-beat translational motion. The undersampled motion corrected data is reconstructed using a B1-weighted LOST reconstruction with identical parameters to those in [5].

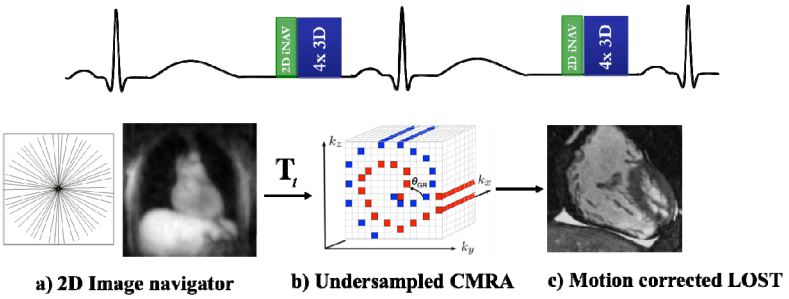

Fig.1: a) 2D golden-radial interleaved image navigator are registered to a common respiratory position to estimate translational beat-to-beat motion, b) CMRA data is acquired using an undersampled golden-step spiral-like 3D Cartesian trajectory (CASPR), c) Estimated motion parameters T are corrected for in k-space previous to undersampled LOST reconstruction.

In-vivo experiments were performed on two healthy subjects on a 1.5T Philips scanner using a 32-channel receiver coil. 3D segmented balanced-SSFP CASPR acquisitions were performed under free breathing with the interleaved 2DiNAV. Relevant scan parameters include: FOV = 288x288x100mm, resolution = 1x1x2 mm, TR/TE/flip angle = 4.5ms/2.2ms/70°, T2 preparation pulse (TE = 50ms), fat saturation prepulse (SPIR), subject specific mid-diastolic trigger delay, acquisition window ~ 100ms, 1 spiral-like interleaf per R-R interval, 4x undersampling, total acquisition time 2min 31s. A fully sampled 8mm navigator-gated acquisition was performed at end-exhale with the same trajectory and identical imaging parameters for comparison purposes. The nominal acquisition time of the navigator-gated acquisition was of 10 min 4s.

RESULTS: Reformatted images with the proposed approach are shown in Fig.2 for a healthy volunteer. The 4x undersampled ungated non-corrected (a), the proposed LOST-MC approach (b) and the navigator-gated (c) reconstructions are included. Severe motion blurring and aliasing artifacts are observed in the non-corrected images. The proposed approach reduces most of the aliasing but presents some remaining blurring in comparison to the navigator-gated scan. The navigator efficiencies for the gated scan were of 55% and 62% compared to 100% for the proposed approach.

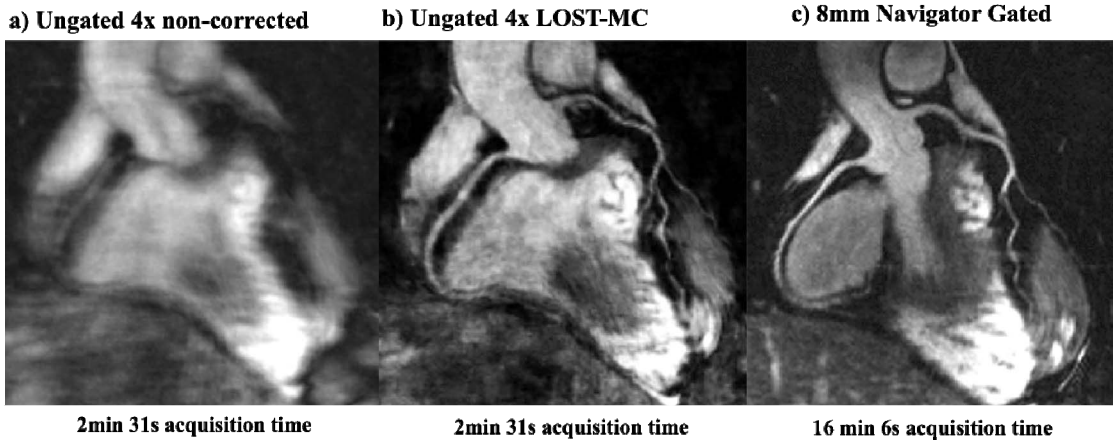

Fig.2: a) Ungated non motion corrected 4x undersampled, b) Proposed motion corrected 4x undersampled reconstruction, c) Fully sampled navigator-gated reference.

CONCLUSIONS: We have demonstrated the feasibility of the proposed approach to highly accelerating the acquisition of CMRA by combining a golden radial interleaved image navigator with undersampled LOST reconstruction. This approach achieves 100% scan efficiency and undersampling factor of 4 leading to slightly reduced image quality in comparison to that of an ~8 times longer navigator-gated approach. Combination with affine motion correction and further validation is now needed.

REFERENCES: [1] Bath et al, MRM 2011, 65:1269-77, [2] Wu et al, MRM 2013, 69:1083-93, [3] Henningsson et al, MRM 2014, doi: 10.1002/mrm.25149, [4] Aitken et al, MRM 2014, doi: 10.1002/mrm.25460, [5] Akcakaya at al, MRM 2011, 66:756-67.