Respiratory-resolved motion-compensated 3D Cartesian Coronary MR angiography

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Introduction: Diaphragmatic navigator gating is commonly used to minimise respiratory motion in free-breathing whole-heart 3D coronary MR angiography (CMRA). However, this approach leads to long and unpredictable scan times. Recently, XD-GRASP has been proposed to achieve 100% scan efficiency and generate respiratory-resolved 3D radial CMRA images, by exploiting sparsity along the respiratory dimension.[1,2] However, for Cartesian liver imaging XD-GRASP has been shown to suffer from reduced image quality.[3] Here, a robust framework for Cartesian imaging is proposed, which provides high-quality respiratory-resolved images by incorporating motion information from image navigators[4] (iNAV) to increase the sparsity in the respiratory dimension. Additionally, 2D translational motion information extracted from iNAVs is used to minimise intra-phase motion. XD-ORCCA was tested on ten healthy subjects and three patients with cardiovascular disease and compared against XD-GRASP.

Methods: Free-breathing 3D Cartesian[5] CMRA bSSFP acquisitions were performed using a 1.5T scanner (Siemens Magnetom Aera) with: FOV=320x320x80-104 mm^3, 1x1x2mm^3 (1.2x1.2x1.2mm^3, for patients) resolution, TR/TE=1.56/3.6ms, flip angle=90°, T2-prep (40ms), fat-sat, acquisition time ~9-12min. For the 2D iNAVs, 14 bSSFP startup echoes were used. Patient 1) had a non-ischemic cardiomyopathy, 2) had previous stent deployment in the right coronary artery (RCA) and 3) had partial RCA and left coronary artery occlusion due to plaque. Respiratory-resolved images were reconstructed using XD-GRASP and XD-ORCCA. The latter exploits sparsity in a motion-corrected respiratory domain.

Results: Reformatted respiratory-resolved images obtained with XD-ORCCA and XD-GRASP are shown in Fig.1 for a representative healthy subject. Images correspond to the phase that typically presents less respiratory motion (end-expiration, phase 1) and the two phases with largest motion (phases 4 and 5, end-inspiration). Figure 2 shows reformatted XD-GRASP and XD-ORCCA images (best phase) for three patients. Motion blurring is observed in XD-GRASP images, for subjects with more irregular breathing patterns. This is evident for subject 1 and patients 1-2 (Fig.2). Comparison against CT coronary angiography (CTCA) is shown in Fig.3, showing excellent agreement for stenosis visualisation. Significant improvements in visible vessel length and sharpness were observed for XD-ORCCA in comparison to XD-GRASP for both coronaries in healthy subjects (Fig. 4).

Discussion: A robust respiratory-resolved motion-compensated framework for Cartesian CMRA has been proposed. XD-GRASP provides good-quality images for subjects with regular breathing. The proposed XD-ORCCA provides high-quality images for all respiratory phases, independently of the regularity of the breathing pattern.

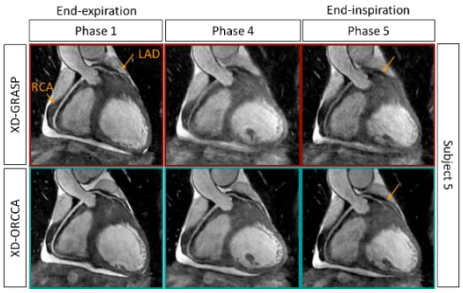

Fig1. XD-GRASP and XD-ORCCA respiratory-resolved images (3 phases) for a healthy subject, showing the right (RCA) and left (LAD) coronary arteries. XD-ORCCA improves the visibility and sharpness of the coronary tree, particularly for respiratory phases with more motion (arrows).

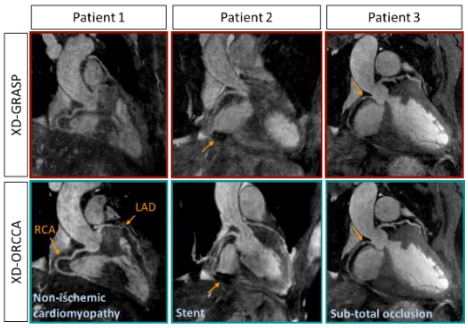

Fig2. XD-GRASP and XD-ORCCA images (best phase) for 3 patients. XD-ORCCA recovers both coronary arteries, coronary stent in patient 2 and occlusion in patient 3 (arrows).

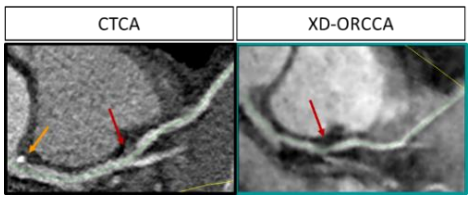

Fig3. CTCA and XD-ORCCA images, showing the left coronary artery. Plaque calcification (yellow arrow) is visible in CTCA and stenosis is visible in both images (red arrows).

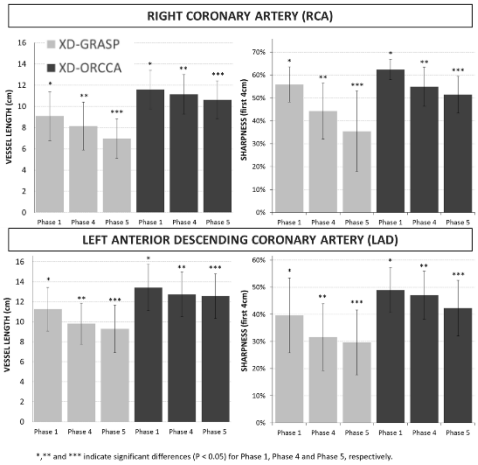

Fig4. Metrics for ten healthy subjects for the XD-GRASP and XD-ORCCA approaches.

References: 1. Feng L *et al.* MRM 2016; 75:775-788. **2**. Piccini D *et al.* MRM 2017; 77:1473-84. **3.** Feng L *et al.* ISMRM 2017; #1285. **4.** Henningsson M *et al*. MRM 2012; 67:437-445. **5.** Prieto C *et al*. JMRI 2015; 41:738-746. **Acknowledgments:** This work was supported by the following grants: EPSRC EP/N009258/1, EP/P032311/1 and EP/P001009/1; MRC MR/L009676; FONDECYT 1161051 and 1161055; Wellcome/EPSRC Centre WT 203148/Z/16/Z.