Post-Contrast Inversion Recovery Self-Navigated 3D Whole-Heart MRI for Combined Coronary Tree and Scar Tissue Visualization

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TARGET AUDIENCE: Scientists and clinicians interested in myocardial fibrosis, coronary MRA, and ablation procedures.

PURPOSE: With the introduction of respiratory self-navigation (SN) [1], the acquisition of whole heart coronary MR angiography (MRA) datasets during free-breathing can be achieved without the need of a respiratory navigator [2]. With SN, respiratory displacement is directly extracted from superior-inferior (SI) readouts contained in the data acquired for imaging and motion compensation is incorporated in the image reconstruction. SN requires minimal planning and achieves 100% scan efficiency, as the only determinant of the scan duration is the heart rate of the subject. The SN technique, in combination with a 3D radial trajectory [1,3] has successfully been tested for the acquisition of non contrast and post-contrast whole-heart coronary MRA datasets in both volunteers [3] and patients [4]. However, the potential of the 3D radial SN imaging technique with high spatial isotropic resolution has never been explored for combined visualization of both coronary anatomy and scar tissue in 3D in one single acquisition. For these reasons, the 3D SN technique was extended to inversion-recovery (IR) for late gadolinium enhancement (LGE) imaging. The modified sequence was then integrated into a dedicated protocol where 3D SN coronary MRA was acquired also pre-contrast and during slow infusion [6] for comparison. This new approach has been tested for the first time in vivo in patients.

METHODS: Examinations were performed on a 1.5T clinical MRI scanner (MAGNETOM Aera, Siemens AG, Erlangen, Germany). Patients (n=12) with coronary artery disease and positive findings on 2D LGE identified during clinical routine MRI were asked to return for the research protocol (Fig. 1, upper panel). Data acquisition was performed during the most quiescent systolic phase with a prototype segmented 3D radial trajectory with SN [3] and was repeated 3 times in each patient: (A) before contrast injection, (B) during slow infusion (total of 0.2 mmol/kg of Gadobutrol [Gadovist, Bayer Schering Pharma, Zurich, Switzerland] – infused for a total of 8min), and (C) post contrast with IR for LGE imaging. A T2-prep pulse (A, B) or a non-selective IR pulse (C) was added prior to each acquired k-space segment to the segmented, ECG-triggered, fat-saturated bSSFP imaging sequence. Parameters: TR/TE 3.1/1.56ms, FOV (220mm)^3, matrix 192^3, voxel size (1.15mm)^3, RF excitation angle 115°, and receiver bandwidth 898Hz/Px. While TE of the T2Prep was constantly 40ms, TI (= 250-300ms) was assessed with a 2D radial scout scan prior to 3D LGE. A total of about 12000 radial readouts were acquired for each 3D scan during free breathing with 100% respiratory efficiency. Blood signal-to-noise ratio (SNR), blood/myocardium contrast-to-noise ratio (CNR), vessel length, and percent vessel sharpness (%VS) on the proximal 3 cm of the coronary arteries [5] were measured on all datasets for the right coronary artery (RCA) and the left anterior descending coronary artery (LAD). The 3D LGE datasets were also qualitatively compared to the standard 2D LGE for scar tissue detection in the myocardium.

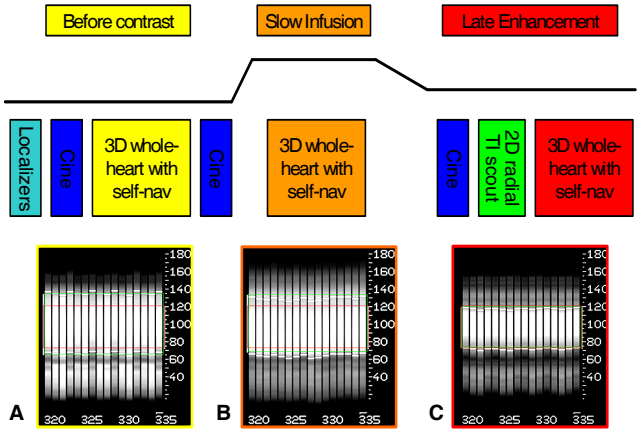

Fig. 1: Schematic of the three SN acquisitions performed as part of the protocol (upper panel) and corresponding examples of SI projections used for self-navigation (lower panel).

RESULTS: Despite the transient changes in contrast (Fig. 1, lower panel), the automated SN algorithm successfully corrected for respiratory motion prior to contrast agent administration, during slow infusion, and post contrast and independent of the pre-pulses employed. All acquisitions lasted for about 8min. RCAs and LADs could successfully be visualized in all cases (Fig. 2). Numerical values are reported in Table 1. Increases in SNR and CNR were statistically significant in the slow infusion datasets with respect to the other two (*: $p<0.05$), while the visualized length of the RCA was significantly higher in the slow infusion datasets when compared to the non-contrast acquisitions (*: $p>0.05$, +30%, on average). %VS of both coronary vessels and length of the LAD, although increased in both the slow infusion and the LGE acquisitions with respect to the non-contrast scans, were not significantly different. All scars visualized by 2D LGE (e.g. Fig. 3(A), yellow circle) could also be identified in the corresponding 3D LGE datasets (Fig. 3(B), yellow circle). SN LGE datasets were also successfully reformatted for color-coded 3D visualization (Fig. 3(C)). In particular, the 3D LGE datasets seemed to be better suited for the visualization of sub-endocardial scars (Fig 3, arrows).

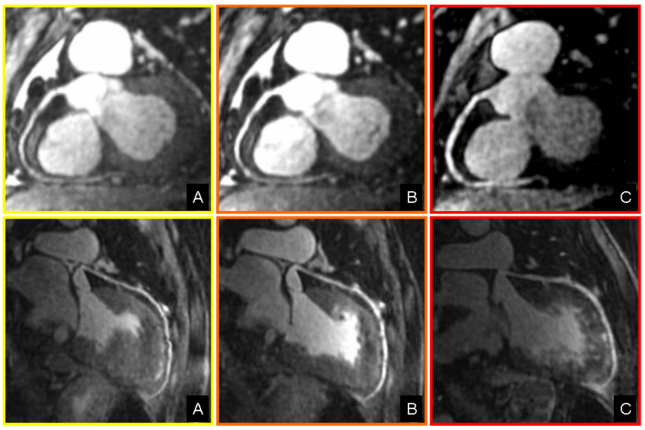

Fig. 2: Example of reformatted RCA (top) and LAD (bottom). A: before contrast, B: during slow infusion, and C: post contrast.

DISCISSION AND CONCLUSIONS: The performance of SN prior to contrast injection, during slow infusion and post contrast is not affected by the transient changes in contrast or the different types of pre-pulses used. SNR, CNR and the depiction of the coronary arteries improved both qualitatively and quantitatively during slow infusion as compared to imaging before contrast. While the anatomy of the coronary arteries is still well visible post contrast, the scar tissue was also reliably visualized in all cases. In conclusion, this work introduces a simple method to visualize both coronary anatomy and scar tissue in 3D in one single acquisition with easy setup and pre-determined scan time, and therefore, this approach may be appealing e.g. for planning ablation as part of re-synchronization procedures.

REFERENCES: [1] Stehning C, et al, MRM 54:476-480 (2005); [2] Ehman RL, et al, Radiology 1989; 173:255-263; [3] Piccini D. et al, MRM 2012; 68:571-579; [4] Piccini D, et al, Radiology; In press; [5] Bi X, et al, MRM 2007; 58:1-7; [6] Etienne A, et al, MRM 2002; 48:658-666.

Table 1	(A) No Contrast	(B) Slow Infusion	(C) 3D LGE
SNR (Blood)	*27.2 ± 8.5**	*35.4 ± 12.9**	*22.4 ± 7.9**
CNR (Blood/Myo)	*15.4 ± 6.6**	*22.4 ± 10.1**	*13.8 ± 7.1**
RCA Length [mm]:	*47.7 ± 19.1**	*60.8 ± 18.1**	*51.3 ± 20.1*
RCA Sharpness [%]:	*50.6 ± 9.2*	*52.7 ± 10.6*	*52.2 ± 10.5*
LAD Length [mm]:	*49.4 ± 19.6*	*54.6 ± 22.5*	*53.0 ± 16.6*
LAD Sharpness [%]:	*39.8 ± 8.3*	*40.6 ± 8.5*	*42.0 ± 10.6*

Fig. 3: Corresponding 2D (A) and 3D (B) LGE datasets. A 3D rendering (C) of the complete myocardium (red) and scar (yellow) is enabled with the 3D method.