MR Imaging of myocardial scar and coronary vein anatomy in patients awaiting cardiac resynchronization therapy using a high-relaxivity contrast agent.

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Introduction
With cardiac resynchronization therapy (CRT) becoming more widely available for the treatment of patients with heart failure (HF), there has been increased interest in imaging the coronary sinus (CS) and it tributaries. Previous studies using CMR have mainly focused on using intravascular contrast agents (CA), which give no useful information about myocardial scar, and require a separate MR-exam to assess scar and viability. Furthermore, in most of these studies patients with normal left ventricular (LV) function have been recruited. However, imaging the coronary venous anatomy in patients with HF imposes numerous technical difficulties, such as irregular heart rhythms and irregular breathing patterns due to difficulty lying flat for long periods.

Purpose
We aimed to evaluate the coronary venous anatomy and myocardial scar in HF patients awaiting CRT in a single cardiac magnetic resonance (CMR) examination with slow infusion of a high-relaxivity CA, dimeglumine-gadobenate (Gd-BOPTA).

Methods
14 patients (ejection fraction from trans thoracic echocardiography 27±7.0%, 7 with ischaemic and 7 with non ischaemic cardiomyopathy (CM)) referred for CRT and 2 patients with normal LV function were assessed with CMR. A 1.5T MR-scanner with a 32-element cardiac coil (12 patients) and a 5-element cardiac coil (4 patients due to claustrophobia) was used. After localization and a coil sensitivity reference scan an interactive real-time scan was performed to determine the geometry of the short axis (SA), four (4CH), three (3CH) and two chamber (2CH). A multiple slice (M2D) cine steady state free precession (cine-SSFP) scan was performed in SA orientation to assess the ventricular function (FA=60°, TR/TE=2.9/1.5ms, resolution 2.2x2.2x10mm, 30 heart phases). Visual assessment of the 3Ch (FA=60°, TR/TE=3.0/1.5ms, 60 heart phases) view was used to determine end systole. For contrast enhanced MRI of the coronary vein, Gd-BOPTA was slowly infused (dose of 0.2ml/kg at rate 0.3ml/sec) with subsequent saline flushing as proposed by Bi et al [1] for coronary arteries. In order to determine the optimal start point of the whole heart coronary vein MR-scan, a dynamic ECG-triggered 2D-scan with inversion recovery (IR) preparation (TI=300ms) was used. For coronary vein visualization, an ECG-triggered respiratory navigated 3D IR-SSFP MR-scan was applied to acquire the whole-heart during a short interval (60-80ms) in end systole using the following parameter: FA=50°, TI=300ms, TR/TE=4.25/1.44ms, resolution was 1.5 x 1.5 x 2mm (contiguous slices). After the coronary vein scan a delayed contrast-enhanced multi-slice IR gradient echo sequence (FA=25°, TR/TE=5.8/2.0ms) was performed at end systole 19.2±7.2min after start of contrast injection to depict areas of scar.

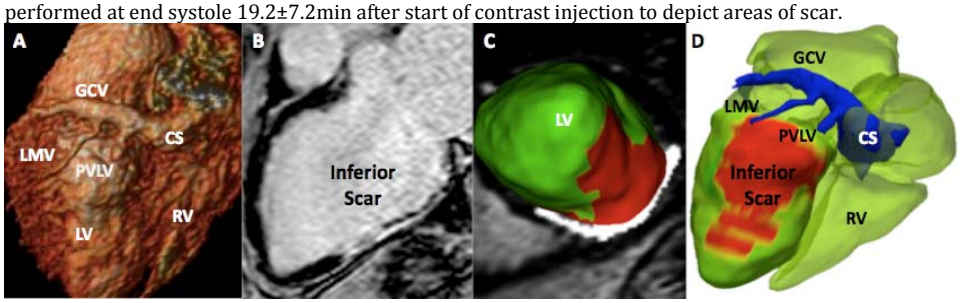

Figure 1, **A** Volume rendered 3D whole heart image with coronary sinus and tributaries. **B** Late enhancement imaging showing inferior scar. **C** Segmented left ventricle (LV) with scar registration shown as red area. **D** Segmented whole heart image with co-registration of scar and coronary vein anatomy.

Table1 Vessel seen	Number of vessel seen	
Coronary sinus (CS)	16	100%
Great cardiac vein (GCV)	16	100%
Posterior Inter-ventricular vein (PIV)	12	75%
Posterior vein of the LV (PVLV)	8	50%
Vein of Marshall	0	0%
Left marginal vein (LMV)	12	75%
Anterior inter-ventricular vein (AIV)	11	69%
Additional lateral veins	4	25%
Additional posterior veins	1	6%

LV volumes and volume rendering analysis was performed using Phillips Viewforum software. The arrival of contrast agent bolus in LV was determined from dynamic ECG-triggered IR-scan. A linear regression analysis was performed between the time taken for contrast to reach maximum signal intensity and cardiac output. Multiplanar reformatting was used to measure the starting diameter and length of each tributary. Cardiac veins were classified according to terminology of Jongbloed et al [2]. To correlate coronary venous anatomy with myocardial scar the 3D whole heart images were manually segmented with ITK-SNAP software. Scar was manually segmented using Osirix software and then registered to the 3D segmentation of the left ventricle using geometry information stored in the DICOM header. Once registered, scar segmentation images were projected onto the left ventricular segmentation to provide 3D visualization of the scar geometry (Figure1).

Results
The time taken for the contrast agent to reach the LV varied from 48.7±9.5 seconds in patients with normal LV function to 70.0±13.7 seconds in HF-patients. The time taken for contrast to reach maximum signal intensity and cardiac output were correlated with r=0.82. In all subjects the coronary sinus (CS) and great cardiac vein (GCV) were visualized. Using an image quality score of 0 to 4 (0=CS/GCV not visible, 4=CS/GCV visible with sharply defined borders or edges), 2 independent observers assessed with an average score of 3 for the CS and 2.6 for the GCV. The number of branches visualized from the volume rendered images was similar to studies using intravascular contrast agents (table 1). The mean distance from the ostium of the CS to the PIV was 12.0±4.3mm, PVLV 32.6±16.4mm, LMV was 68.8 ±19.4mm, and AIV was 146.5±27.6mm. Patients with ischemic cardiomyopathy and one with non-ischaemic cardiomyopathy showed late enhancement. The average scan time for the 3D whole heart scan was 16.3±7.6min due to respiratory gating efficiency between 18-43%.

Conclusion
We have demonstrated that coronary vein and myocardial scar can be delineated in a single CMR examination by using a slow infusion of Gd-BOPTA with similar results to studies using patients with normal LV function. Furthermore, we have shown it is possible to provide clinically relevant information about the relationship of myocardial scar to vein anatomy to aid in the planning of CRT implantation.

References
[1] Bi *et al MRM.* 2007;58(1):1-7. [2] Jongbloed et al *J Am Coll Cardiol.* 2005;45(5):749-753.