Coronary Magnetic Resonance Vein Imaging

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Introduction: Recently, there has been increased interest in imaging the coronary vein anatomy for interventional cardiovascular procedures. Coronary vein assessment is crucial in cardiac resynchronization therapy (CRT), a novel approach for treating congestive heart failure (CHF). With CRT, the lateral wall of the left ventricle is electrically paced using a transvenous coronary sinus lead or surgically placed epicardial lead. Proper transvenous lead placement is facilitated by the knowledge of the coronary vein anatomy. Particularly important is the determination of the presence, location and orientation of a suitable venous branch over the lateral wall of the heart. In this study, we sought to develop a cardiovascular MR (CMR) methodology to image the coronary vein anatomy non-invasively.

Materials and Methods: A high resolution CMR vein imaging sequence structurally analogous to that used for coronary artery imaging was developed based on a 3D free-breathing, ECG-triggered gradient-echo Cartesian acquisition with fat saturation and respiratory navigators [1]. We investigated a magnetization transfer (MT) prepulse to enhance contrast between venous blood and myocardium by suppressing myocardial signal without affecting venous blood [2]. Ideally, the MT prep sequence has center frequency close to the Larmor frequency (e.g. 300-500Hz) for best myocardial suppression. However, this could cause unwanted direct irradiation of the water pool. Since our coronary MR vein acquisition is ECG-triggered, there is a long time period prior to the start of image acquisition (>400-500ms) that is available for preparation sequences. This permits the use of excitations pulses with better frequency response and lower SAR. Numerical Simulation: We studied four widely used RF pulse-shapes for MT contrast: *Gaussian*, *Fermi*, *Sinc*, and *Gaussian-weighted-Sinc*. Based on these results, the latter pulse was chosen and used for *in vivo* studies which empirically optimized the number, flip angle and frequency-offset of the MT pulses. These studies acquired a series of 2D axial mid-ventricular images in healthy subjects and used venous blood-myocardium signal difference as a metric. Phantom Study: A phantom study was performed to evaluate the efficacy of our MT preparation sequence for coronary MR vein imaging using aqueous gel phantoms containing different agar concentrations of 4% and 8% and water-doped phantom. All three phantoms were imaged with and without the MT preparation sequence. *In Vivo* Imaging: Coronary MR vein images were acquired in 8 healthy subjects to study the effect of MT on SNR and blood-myocardium contrast. Images were acquired with and without an MT preparation sequence and SNR and CNR metrics were compared. Coronary MR vein images were acquired in 6 CHF patients referred for CRT. SNR of venous blood, arterial blood and myocardium was measured. All images were acquired on a Philips 1.5T Achieva system with 5 element cardiac receive coil. Imaging Parameters: $\alpha = 30^0$, TR = 5.5 ms, TE = 1.6 ms, FOV= 270 mm× 270mm, 20-30 slices with scan matrix of 272 × 218 reconstructed to 512 × 512 with a resultant voxel size of 0.53×0.53×1.5 mm^3.

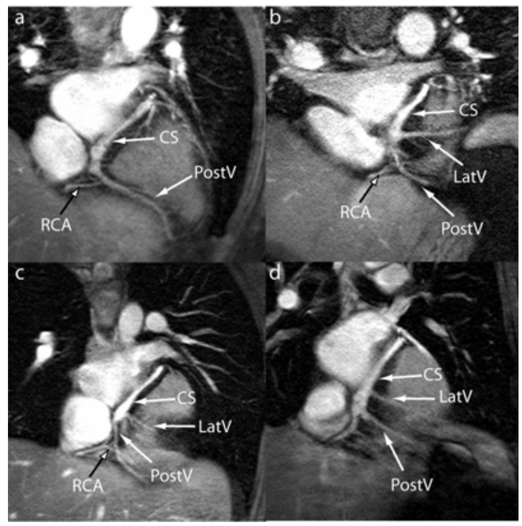

Figure 1: Coronary venous anatomy in four healthy adult subjects. The images show variations of the coronary vein anatomy between different individuals. In subject a, there is no visible lateral vein (LatV), while the other shows the presence of lateral vein. Throughout the whole volunteer pool, there are variations in the branching point, angle and diameter of different tributaries of CS. These variations show the necessity of non-invasive assessment of coronary venous

Results: Numerical simulations of RF pulses show that the *Gaussian-weighted-Sinc* and *Sinc* pulse are the most energy efficient pulses among the four pulses studied with minimal ripples in the frequency response. Our initial *in vivo* images used for optimization of the MT pre-pulse yielded a train of 8-10 off-resonance pulse with duration of 15-20ms and resonance-frequency of 300-500Hz. Phantom studies showed an increased level of saturation in higher agar concentration without any significant change in water signal. Fig. 1 shows coronary vein anatomy in 4 different healthy adult subjects. Fig. 2 shows coronary vein anatomy in a CHF patient referred for CRT. When comparing the image data obtained with MT contrast to non-MT acquisition, there was a significant change in myocardial signal and CNR of venous blood-myocardium (P<0.001) with no significant change in arterial or venous blood SNR. SNR of venous blood, arterial blood and myocardium were 26.6±2.2, 48.8± 5.6, 53.4±4.5 with MT and 40.1±14.7, 46.8±15.8, 52.2±16.3 without MT preparation.

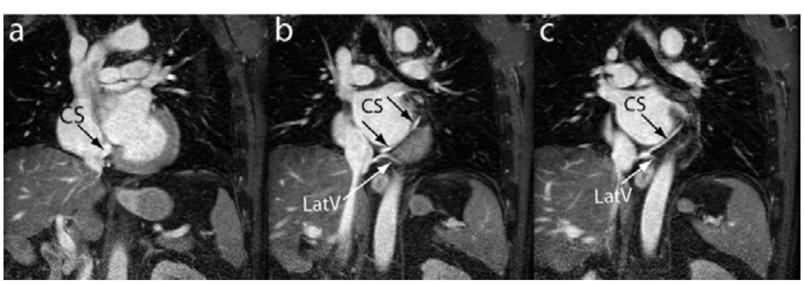

Figure 2: Coronary MR vein images of a congestive heart failure patient referred for cardiac resynchronization therapy. Coronary sinus and the small lateral vein (LatV) branch are visible in the images.

Conclusion: We have proposed and implemented a coronary MR vein imaging methodology designed to demonstrate the potential of CMR to assess coronary vein anatomy in healthy subjects and CHF patients. This pre-procedural CMR assessment for CRT patients could have the potential to reduce the high failure rate of this therapy (30%) and thereby improve the healthcare of the large CHF population. **References:** [1] Kim NEJM, 2001, Dec. (345):1863-1869 [2] Balaban RS. et.al MRM. 1989 Apr;10(1):135-44.