Non-ECG-Triggered Perfusion Imaging with Integrated T1 Mapping for Quantifying Myocardial Blood Flow

David Chen[1,2], Behzad Sharif[1], Janet Wei[1], Reza Arsanjani[1], Louise EJ Thomson[3], C. Noel Bairey Merz[1], Daniel S Berman[3], and Debiao Li[3]

[1]Cedars Sinai Medical Center, Los Angeles, CA, United States, [2]Biomedical Engineering, Northwestern University, Evanston, IL, United States, [3]Cedars Sinai Medical Center, Los Angeles, California, United States

Target Audience: Researchers investigating myocardial ischemia

Purpose: Quantification of myocardial blood flow (MBF) using MRI is limited by the nonlinearity of image signal intensity to Gadolinium concentration. An integrated T1 mapping method using highly constrained back projection (HYPR) was previously developed for accurate quantification of myocardial blood flow [1]. The T1 values of the arterial input function (AIF) are calculated accurate during first pass, overcoming saturation problem. Compared to conventional methods for quantifying MBF, the T1 mapping method requires less scan time (compared to dual sequence) and has no additional setup time (compared to dual bolus). However, cardiac motion caused by arrhythmias, changing heart rates, and mis-triggering due to poor ECG signal may cause image artifacts in HYPR reconstructed images because data is shared across multiple cardiac cycles. MR myocardial perfusion imaging without ECG-triggering has potential advantage in dealing with cardiac motion than ECG-triggered imaging [2,3]. We propose using a non-ECG-triggered acquisition with cardiac motion self-triggering for integrated T1 mapping derived AIF for MBF quantification.

Methods: 210 measurements were acquired continuously with no ECG triggering. 60 projections were acquired immediately following a saturation recovery (SR) magnetization preparation with a golden angle trajectory. Without ECG, the triggering signal was produced from the collected data. Images were produced from consecutive 60 projections using non-Cartesian SENSE. A sliding window was used to achieve 43 ms temporal resolution. The mean signal intensity in a region of interest drawn over the heart was measured. Local maxima corresponding to increased ventricular blood pool volume in diastole were used for triggering.

The true AIF was found using the integrated T1 measurement. Seven images were reconstructed each cardiac cycle with TI times of 20, 40, 57, 77, 95, 115, and 132 ms using a HYPR-like compressed sensing based approach. T1 values of the AIF could then be found by fitting the signal intensity to the Bloch equation [1]. Contrast agent concentration in the blood pool were found using T1 values. MBF was found using linear time invariant model-independent deconvolution.

Six healthy volunteers underwent rest perfusion MRI studies on a Siemens 3T Verio with IRB approval and written consent. First pass studies were performed at rest using a 0.05 mmol/kg dose and chased with 20 ml saline. First, a dual bolus protocol with a 1/10 dilute bolus was performed using a conventional clinical Cartesian sequence [4]. Imaging parameters were as follows: FOV = 300; bandwidth = 897 Hz/pixel; flip angle = 12°; TR = 2.5 ms, TI = 115 ms; matrix size = 160×120; TGRAPPA = 2. 10 min following the first perfusion scan, a second first pass perfusion experiment was performed using the proposed method. The radial imaging parameters were as follows: FOV = 270 mm; BW = 744 Hz/pixel; flip angle = 12°; TR = 2.5 ms;; resolution 1.7x1.7mm^2; 160 readouts x 128 projections. A two sided Student t-test was performed to MBF at a p=0.05 significance level.

Results: Mean MBF found from the dual bolus and proposed non-ECG triggered, integrated T1 mapping acquisitions were 0.81±0.29 ml/min/g and 0.93±0.21 ml/min/g. There was no significant difference (p=0.43) between them.

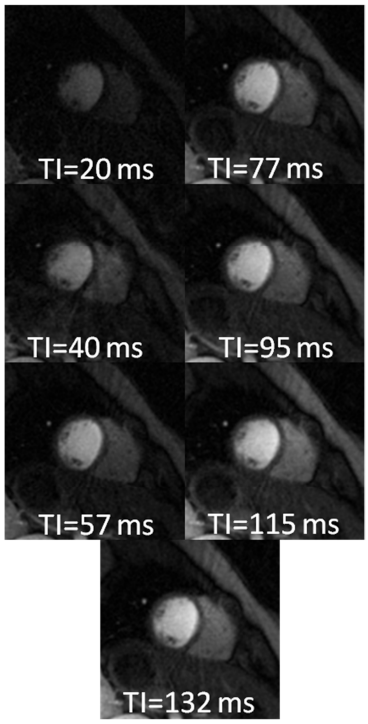

Figure 1: Non-ECG triggered images of each TI during a single cardiac cycle. Images were created from 15 projections and used for T1 mapping.

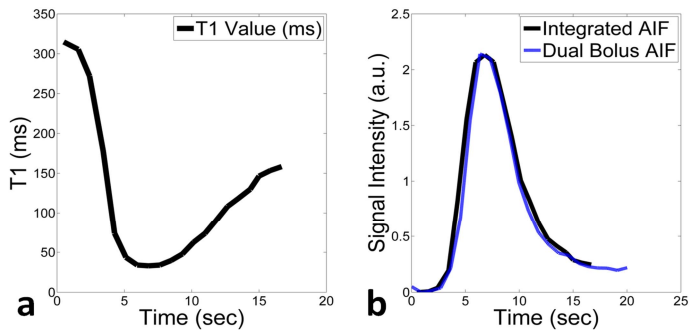

Figure 2: a) Change in T1 values in the left ventricular blood pool. b) Comparison of the arterial input function derived from non-ECG-triggered integrated T1 mapping protocol and the dual bolus protocol.

Discussion: The proposed non-ECG-triggered myocardial perfusion quantification MR method with fast T1 mapping for integrated AIF measurement provides accurate MBF measurement compared to the ECG-triggered dual bolus method. Integrated T1 mapping alleviates the need for a separate scan specifically for the acquisition of the AIF, improving feasibility of quantitative myocardial perfusion using MR. Data acquisition without ECG may improve robustness to cardiac motion and clinical reliability of quantitative myocardial perfusion imaging.

References: 1) Chen, Li. MRM 2013, In Press. 2) Sharif, Li. MRM 2013, In Press.3) DiBella, McGann. MRM 2012: 67, 609-613. 4) Ishida, Nagel. JCMR 2011: 13, 28.