

Absolute quantification of myocardial blood flow using CAMM estimation of the AIF

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Introduction: Myocardial stress perfusion imaging is a valuable tool for evaluating coronary artery disease (CAD). Quantification of stress perfusion in dynamic contrast-enhanced MRI (DCE-MRI) requires measurement of the time course of gadolinium concentration in the left ventricular (LV) blood pool, commonly known as the arterial input function (AIF). This measurement is made difficult due to the high concentration of contrast in the LV as compared to the concentration in the myocardial tissue. A method has been developed for estimating the AIF directly from myocardial tissue concentration curves at rest (1). This method, called constrained alternating minimization with model (CAMM), estimates the AIF signal using the LV blood pool as a constraint. The work in this abstract applies this method to myocardial perfusion data obtained in canine models of coronary stenosis measured at both rest and pharmacologically induced stress. Flow results from the proposed method are correlated with results measured following microsphere injection.

Methods: Ten DCE-MRI studies were acquired on three canines: 5 studies at rest and 5 studies during adenosine vasodilation. The canines were chronically instrumented as previously described (2) enabling the creation of variable degrees of stenosis to the left anterior descending and/or left circumflex coronary arteries. Studies obtained at both rest and stress utilized a similar imaging protocol. All acquisitions were done at 1.5T on an Siemens Espree scanner (Siemens Medical Solutions, Erlangen, Germany). A

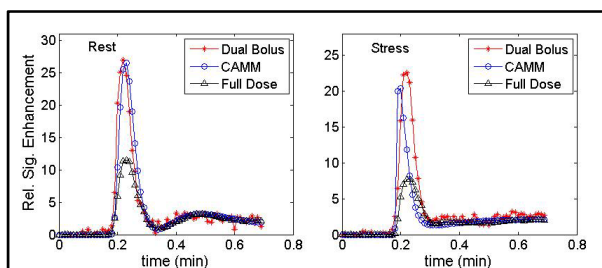


Figure 1 - AIFs estimated with the proposed method (blue) and that measured using a dual bolus protocol (red). The saturated signal from the LV of a 0.05 dose scan (black) is shown for comparison.

saturation recovery, turboFLASH sequence was used with TR/TE = 166/1.39 ms, flip angle of 12°, slice thickness of 8 mm, and isotropic in plane resolution of 1.79 mm. A dual bolus protocol was used to validate the estimation method. A 0.005 mmol/kg dose of Gd-DTPA was injected and approximately one minute of data was acquired. Following this injection a second dose of 0.05 mmol/kg was injected during a second acquisition of approximately one minute. Immediately following the second injection, fluorescent microspheres were administered into the left atrium and aortic blood was sampled to enable calculation of myocardial blood flow (3). For each study, a manually drawn region of interest in the LV blood pool was used to measure the AIF by two methods: 1) appropriate scaling of the low dose scan data, and 2) estimation from the full dose data using the CAMM method outlined in (1). Briefly, the CAMM method generates a cost function which is then minimized by alternately refining estimates for the

AIF and pharmacokinetic model. Two sets of flow values were calculated regionwise using both the dual bolus and CAMM-estimated AIFs, and these flow values were compared to microsphere flows using linear regression and Pearson's correlation coefficient.

Results/Discussion: Figure 1 shows sample AIFs from one canine imaged at both rest and stress. The AIF obtained from the low dose scan is shown in red. The CAMM estimated AIF is shown in blue and the LV blood pool signal from the high dose scan is shown in black for comparison. Figure 2 shows the region-averaged flow values from the dual bolus protocol as well as those from the CAMM estimate compared to the microsphere results. The values displayed correspond to both the normal and stenotic regions of the mid-ventricular slice of the stress injections for each of the animals studied. The r^2 -values for these sets of data were both 0.85. For reference, the r^2 -value between the flow from the dual bolus and CAMM AIFs was 0.88. The lines of best fit are also shown in figure 2. For the dual bolus protocol the equation for the line of best fit is $y=0.39x + 0.84$, and for the CAMM the equation is $y=0.59x + 0.36$. These results suggest that the constrained estimation method developed in (1) for use with resting perfusion scans may show promise for use with myocardial stress perfusion imaging. This method requires only a single injection of contrast agent along with a single acquisition for each study, thus greatly reducing the imaging time and complexity of analysis. However, further validation with a larger cohort of patients and patients with diagnosed CAD is needed.

References: 1. Fluckiger et al., *Mag. Res. Med.* 66(2) 419-427

2. Lee et al., *Circulation.* 110(1) 58-65

3. Glenn et al., *J Appl Physiol* 74(5) 2585-97

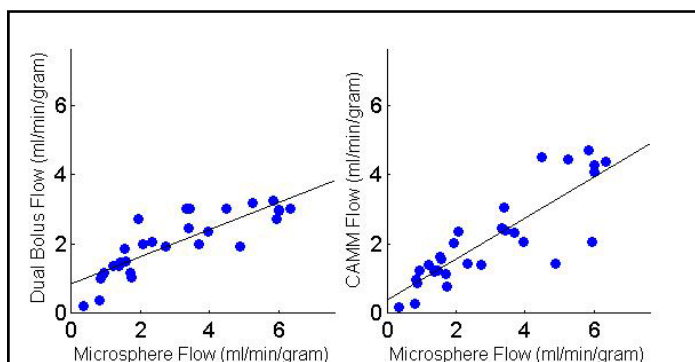


Figure 2 – Flow values (in ml/min/gram of tissue) obtained from the dual bolus protocol (left) and CAMM estimation (right) as compared to those measured following microsphere injection (vertical axis). The line of best fit is shown on each plot (equations in text).