Performance Of A Two Compartment Model Methodology For Myocardial Perfusion Imaging

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Introduction: Myocardial perfusion imaging plays a crucial role in the detection and assessment of single and multi-vessel coronary artery disease (CAD). While other groups have compared SPECT and MRI perfusion imaging and X-ray angiography, these studies have used dipyridamole [1] and used the Fermi function model for analysis [2]. This study assesses the performance of myocardial perfusion with a two-compartment model under adenosine-induced vasodilation. 20 patients and 10 normal volunteers (48 ± 15 years, 184 ± 41 lbs) were imaged to better assess the presence or absence of CAD. We speculated that the washin parameters estimated from fitting the tissue uptake curves to a two-compartment model with the fraction of blood in tissue region and the time delay parameters being fit, can accurately predict coronary angiography results and may outperform conventional methods like upslopes and scoring by blinded reading.

Methods: The perfusion images were obtained on a GE Signa 1.5 Tesla MRI scanner (Lx 8.4) using the FGRET multi-shot notched saturation [3] perfusion sequence. Contrast agent (Omniscan) was injected at a rate of 6.5cc/sec, with the exception of two patients for whom the rate was 5.0cc/sec, with a varying dose of 0.05mmol/kg to 0.12mmol/kg. Images were obtained at rest and stress (induced by the injection of adenosine, at the rate of 0.14mg/kg/min administered for about 5 minutes) to assess the presence of ischemia.

(a) Parameter Estimation: Each image was automatically registered for motion artifacts and then the blood pool, endocardium and epicardium were manually selected (Fig. 1), converted to Gd concentration ([Gd]) and fit to the two-compartmental model [4] to obtain the tissue uptake and the washin and washout parameters, using equation (1).

$$a(t) = (1-f_v)\, C_a(t-t_0) * k^{trans} e^{-kep(t-t_0)} + f_v C_a(t-t_0) \qquad (1)$$

where $a(t)$ = measured tissue contrast concentration in one of the six regions (Fig. 1); f_v = fraction of blood in the chosen tissue region; k^{trans} = contrast washin parameter; k_{ep} = contrast washout parameter; t_0 = time delay and $C_a(t)$ is the blood input function. The method involved fitting for all four parameters, k^{trans}, k_{ep}, f_v and t_0. Equation (2) describes the conversion of signal intensity to [Gd] using values obtained from an experimental set of [Gd] vials.

$$R_1 = -\log[(S_{max} - S_{bld})/S_{diff}]/exp\_coeff \qquad (2)$$

where $S_{diff} = S_{max} - S_{min}$; S_{max} and S_{min} = Maximum and minimum signal intensity obtained from an experimental set of [Gd] vials; S_{bld} = Signal intensity of the blood curve obtained from the images; exp_coeff = value determined from a set of experimental [Gd] vials.

Polar maps of the upslopes and washin parameters, expressed as [Gd], as well as signal intensities in arbitrary units were made with six regions corresponding to the six regions of the heart that were scored (Fig.2 and Fig.3). Thresholds for the images processed were obtained as a percentage of the mean of the three maximum values of upslopes and washin parameters that were calculated for every slice. Fifty, sixty and seventy percent thresholds were used to determine the presence or absence of CAD.

(b) Scoring by blinded readers: Two blinded readers, a radiologist and a cardiologist, scored the images to decide whether there were any perfusion defects, on a scale of 1 to 4 as being normal, mild, moderate and severe. The image quality was also scored on a scale of 1 to 3 as being poor, fair and good. The readers were first trained to read the images obtained from five volunteers and then blinded to read the mixed set of twenty patients' and remaining five normal volunteers' images.

(c) Coronary Angiograms: Fifteen of the twenty patients had undergone angiography and these were used as a gold standard. The data from the remaining five patients who did not undergo coronary angiography were not counted for the calculation of sensitivity and specificity. Subjects with ≥ 50% stenoses were counted as positive for CAD.

Results: Five sets of images that were scored as poor quality by the blinded readers were not included in the analysis. The fitting of the tissue uptake curves to this two-compartment model gave a sensitivity and specificity value of 80% and 100% for a threshold of fifty percent of the maximum value of the estimated washin parameter for every slice. At a threshold of 60%, the values of sensitivity and specificity were 90% and 80% respectively. The values obtained at the same thresholds of 50% and 60% of the maximum upslopes as a function of [Gd] were 60%, 80% for the former and 80%, 60% for the latter respectively. The scoring by the blinded readers gave a good sensitivity but not a very high specificity.

Discussions and Conclusions: The results show that this new two-compartment model method does outperform the less complex method of upslopes and scoring by blinded readers. The results reported by [1] are 91% and 94% respectively, with respect to coronary angiography (diameter stenosis ≥ 50%). Our method's results suffer from the following two primary limitations. The data was obtained without a fixed protocol, for example, the dose of contrast agent [Gd] was not the same for every patient and the study involved a small number of subjects, thereby limiting the analysis and the training data for the blinded readers. However, good agreement with the angiography reports was still obtained. Further work will determine how accurately this method can predict which coronary distribution is diseased.

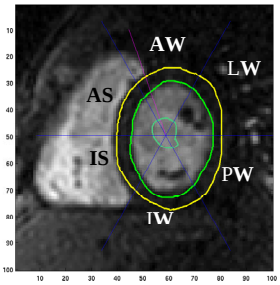

Figure 1.

Figure 1. Figure showing the manual selection of the endocardium, epicardium and the blood input function and the six regions corresponding to the coronary distributions. A=Anterior, I=Inferior, S=Septal, W=Wall, L=Lateral, P=Posterior.

Figure 2(a). and 2(b). Shown are the polarmaps of the upslopes and washin parameters respectively, obtained at stress, expressed as a function of [Gd], with a threshold of 60%, for a patient with acute single vessel disease (SVD) of the LAD. The anterior septum looks darker corresponding to the perfusion defect there.

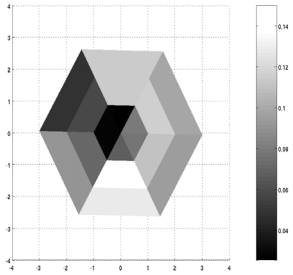

Figure 2(a).

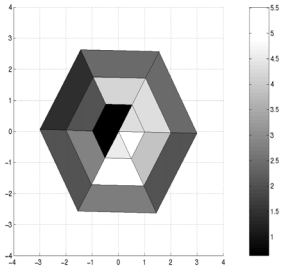

Figure 2(b).

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