Dual Bolus Myocardial Stress Perfusion Quantification in Normals

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INTRODUCTION

Studies have shown that myocardial perfusion quantification can improve the diagnostic accuracy in ischemic disease, especially in coronary triple vessel stenosis or microvascular obstruction cases. Model based deconvolution methods can be used to derive absolute perfusion based on the relative image pixel intensity and timing between left ventricular blood and segmental myocardium contrast arrival. However, a high contrast dosage, though necessary for high SNR, might overestimate myocardial perfusion because of the signal saturation in the blood. To overcome this problem, a dual bolus perfusion technique has been used. We studied the regional myocardial perfusion values in normal volunteers under stress (SMBF), at rest (RMBF), and flow reserve (FR) with both standard half dose (0.05mM/kg) (SD) and mini bolus (0.005mM/kg) (MD) contrast agent concentration.

METHODS

To ensure the normality of the data, strict exclusion criteria were used in volunteer recruitment, including exclusion of hypertension, diabetes, smoking, family history of cardiac disease, a cardiac ultrasound and CT coronary calcium score≤20. Sixteen volunteers (ages: 43.8±15.9, 20 to 67, 11 females) were enrolled after IRB approval. All subjects were injected with a SD of 0.05 mM/kg Gd at 6ml/s, seven of them were studied using dual bolus injection technique, with additional MD of 0.005 mM/kg Gd injection immediately prior to the SD. During the contrast administration, the first pass perfusion imaging under pharmacological stress was performed on a 1.5 T scanner (Siemens, Malvern, PA) with adenosine (140 ug/kg/min) using a saturation recovery SSFP technique; followed by a resting perfusion after 20-minute washout.. A voxel spatial resolution of $1.9\times2.8\times8mm^3$ was achieved in 3 rotational long axis slices per heartbeat over 50 heartbeats using an acquisition time of 160 ms per slice. Using MASS (Medis, Leiden, the Netherlands) software, the endo- and epi-myocardial contours were manually drawn on an image showing good myocardial contrast and then automatically propagated at each time frame. The myocardium was divided into 6 equal segments. Mean signal intensities of all pixels in each myocardial segment at every time point were transferred to custom developed program to calculate absolute regional myocardial flow. To solve the deconvolution equation, a Fermi function was selected as the distribution of tracer residence times to search for the best fit of the myocardial dynamic signal curve for each sector, with blood signal as arterial input function. The FR was determined as the ratio of stress to rest perfusion. 24 out of total 162 sectors were excluded due to artifacts. DB perfusion results were generated by combining the blood signal from the MD perfusion (×10) and myocardial signal from the SD. Standard deviation (STD) was the variation of the mean among individuals. The association between MD and SD FR was analyzed by ANCOVA (Analysis of covariance).

RESULTS

An example of a pair of MD and SD perfusion images and their corresponding dynamic signal intensity curves are shown in **Figure 1**. The mean ± STD of FR at SD and DB were 2.49±1.03 (n=288, 16 subjects) and 2.31±0.79 (n=126, 7 subjects), respectively; while the mean ± STD of SMBF were 5.64 ± 2.14 using SD only and 2.30 ± 0.94 using DB, the mean ± STD of SD RMBF were 2.07 ± 0.69 and 0.69 ± 0.23 at DB, as shown in the **Table**. The results of ANCOVA showed a significant correlation between SD and DB adjusted by age, gender, slice and sector ($p < 0.0001$). The regression analysis between FR using SD and age showed a significant association, r=0.65, p=0.006, n=16, as shown in **Figure 2**.

CONCLUSION

The mean of stress and rest perfusion quantification values in normal volunteers show large variations. The standard dose quantification clearly overestimates both stress and rest perfusion. However, the regional flow reserves between DB and SD are significantly correlated and their means are not significantly different. This finding is probably due to the saturation effects on both stress and rest cancel out, suggesting FR might be a more reliable perfusion quantification measurement even using SD.

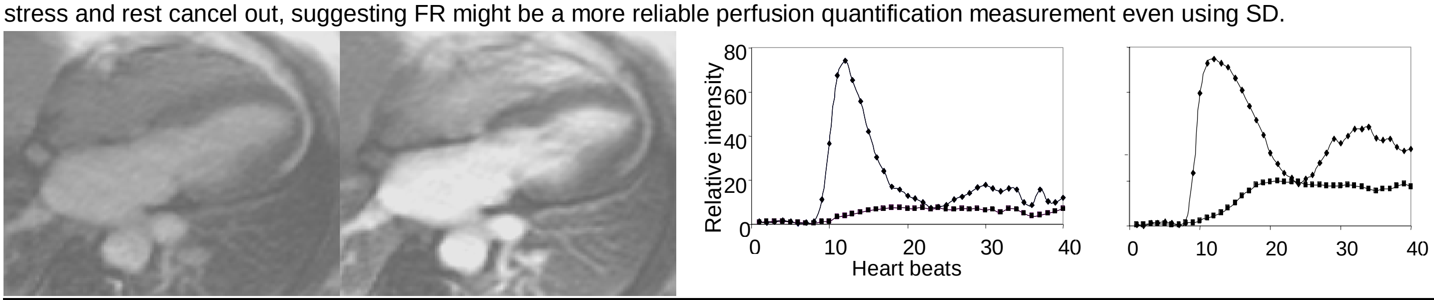

Figure 1. MD (left most) and SD (middle left) perfusion images and their dynamic signal intensity curves at MD (middle right) and SD (right)

Table Quantification Perfusion Results for Both DB and SD

	Stress Perfusion (SMBF in ml/min/g)	*Rest Perfusion (RMBF in ml/min/g)*	*Perfusion Reserve (FR)*	*Number of sectors (n)*
Dual Bolus (DB)	2.07 ± 0.69	0.69 ± 0.23	2.31 ± 0.79	126
Standard Dose (SD)	5.64 ± 2.14	2.30 ± 0.94	2.49 ± 1.03	288

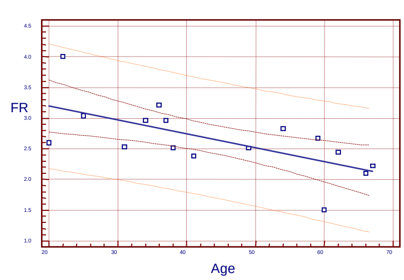

Figure 2. Scatter Diagram shows the association between the FR using SD and subject age, R=0.65, p=0.006, n=16.