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Quantitative Signature of *Coronary Steal* in a Patient with Occluded Coronary Arteries Supported by Collateral Circulation Using Dynamic SPECT

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Abstract

Coronary steal (CS) is a physiological process that induces absolute decrease in blood flow in collateralized myocardium compared to resting flow during coronary vasodilation due to redistribution of blood away from collateral-dependent myocardium. Although, CS has been well known for decades, there are very few noninvasive perfusion studies in humans that quantitatively predict the existence of CS. In this study, we show that the quantitative measurement of absolute value of regional myocardial blood flow (MBF) and coronary flow reserve (CFR) using dynamic single photon emitted computed tomography (SPECT) can help estimate the presence of CS in myocardium with obstructed coronary artery and collateral circulation.

I. Introduction

Myocardial perfusion imaging (MPI) using single photon emission computed tomography (SPECT) has remained a critical tool in diagnosis and risk stratification of the coronary artery disease (CAD). Although the conventional approach of visual assessment can be a powerful predictor, SPECT has not been tested, heretofore, for the kinetic parameter (tracer wash-in and wash-out rates) estimation, and quantifying the myocardial blood flow (MBF) and coronary flow reserve (CFR) due to limited spatial resolution and low photon signal to noise ratio (SNR). Measurement of regional MBF is a comprehensive approach for detecting

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CAD and related abnormalities. It can assess local tissue lesions and endothelial dysfunction, and will become a critical component of cost-saving initiative for screening CAD patients for medical intervention and/or referral to cardiac catheterization.

Coronary steal (CS) refers to a generic heart condition in which an increase in flow in stress, due to vasodilation, to an area with already well-perfused myocardium leads to a decrease in flow to another area of the myocardium supported primarily by collateral circulation. Myocardial ischemia due to CS is generally believed to be manifested clinically by measuring a pressure drop proximal to the collateral origin during adenosine induced hyperemic flow. However, there are limited noninvasive measurements, mostly using positron emission tomography (PET), for the absolute magnitude of CS in human hearts. A quantitative signature of CS may help diagnose the early symptoms of myocardial ischemia and triple vessel disease. Thus, the goal of this study was to evaluate, using commercially available dual-head SPECT camera (GE healthcare), whether pharmacologically induced vasodilation trigger absolute flow reductions in collateralized myocardium in patients with occluded coronary arteries.

II. Methods

A patient (male, 54y) with known CAD referred by cardiologist was recruited at the Imaging Center, University of California, San Francisco, (UCSF Medical Center, San Francisco, California, USA) to evaluate a new dynamic SPECT rest/pharmacologically-induced-stress MPI protocol. A low/high-dose rest/pharmacologic-induced-stress (20 min / 20 min) protocol was implemented in a single day visit using a SPECT/CT scanner (Infinia Hawkeye 4, GE Healthcare). The dynamic image acquisition began just prior to infusion with patient lying in supine position. Once the scanner heads began rotating, he manually received a continuous 10 second infusions of approximately 370 MBq (10 mCi) of ^{99m}*Tc-tetrofosmin* (140 keV) (Myoview; GE Healthcare) for the rest study. For stress study, a 0.4 mg bolus injection of a *regadenoson* (Lexiscan; Astellas Pharma, Inc.), and a dose of 937 MBq (25 mCi) of ^{99m}*Tc-tetrofosmin* were injected approximately 1 min afterwards. The scanner detector heads equipped with low-energy high-resolution (LEHR) collimators were configured in H-mode (i.e., oriented 180° to each other) for the dynamic acquisition. Two views with every second 3° rotation and a total of 120 projection images were acquired in each rotation. Projection data were binned into 128×128 detector pixels having bin area 4.4×4.4 mm^2. The dynamic SPECT data was reconstructed using the standard 4-dimensional spatiotemporal image reconstruction software package developed by LBNL/UCSF research group. The myocardium was oriented along the long-axis/short-axis view under standardized segmentation Nomenclature for tomographic imaging of heart using PMOD-PCARD software (PMOD technologies). The region of interest (ROI) was drawn manually and the myocardium was divided into standard seventeen segments from basal to mid-cavity and apex. The time activity curves for all segments plus total myocardium for each rest-stress pair were fitted with a one-tissue-compartment model, and corresponding uptake, washout rates and perfusion flow were estimated.

The same patient also underwent coronary angiography (CA) for further evaluation, and diagnosed with severe lesion at the left anterior descending artery (LAD) that was totally

occluded proximally after it gave rise to a small diagonal. Right coronary artery (RCA) was a large caliber dominant vessel that provided collateral to the proximal LAD arose from *Vieussens ring canal*. Left Circumflex (LCX) was found to have 30% distal sequential stenosis.

III. Results and Discussions

Figure 1 shows a representative perfusion images with anterior post-septum wall defect with clear LAD abnormality in three horizontal long, vertical long and short axis view after 6 minutes of tracer infusion.

Figure 2 shows the polar plots of the segmental MBF during rest and pharmacological induced stress. The average values with standard deviation for three different territories are also tabulated in table I. In RCA and LCX territories the CFR values are greater than two indicating moderate response to vasodilation. However, the CFR value in the LAD territory is less than one, a signature of CS.

In an ordinary situation when there is a low demand of oxygen the LAD territory of the myocardium was supported via collaterals from dominant RCA. During vasodilation, the driving pressure diminished at the proximal end of the collateral vessels due to decreased resistance in RCA, resulting less MBF in the LAD territory compared to base-line flow.

Collateral territories defined by manual segmentation may not have one to one correlation with those supplied by collateral vessels in the area where the proximal occluded LAD vessel observed in coronary angiogram, and could be a potential source of error in flow measurement and its interpretation. Careful correlations of the distribution and extent of collateralized myocardium to the DSPECT images could co-localize and improve the quantitative accuracy of CS.

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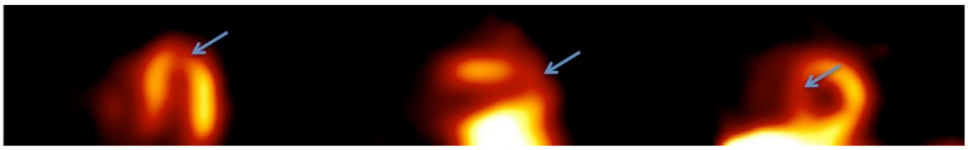

Fig. 1.

Myocardial perfusion images with anterior post-septum defect (shown by arrow) in the horizontal long, vertical long and short axis view after 6 minutes of tracer infusion.

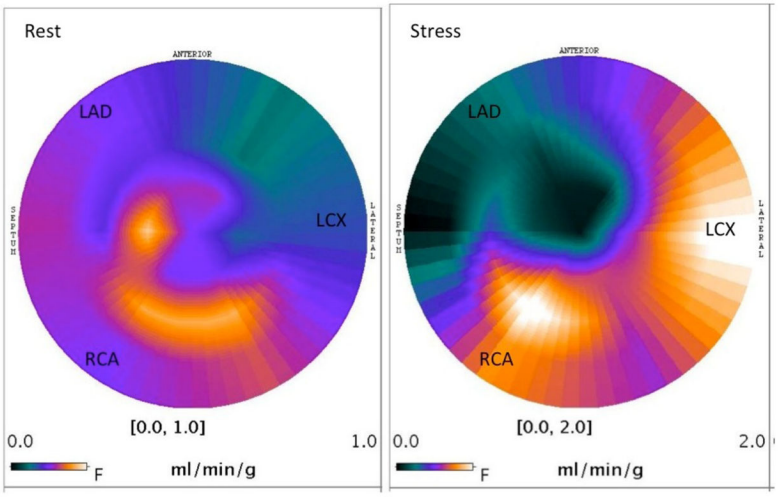

Fig. 2.

Bull's eye (Polar) plots of the MBF measured with dynamic SPECT in Rest (left) and pharmacological Stress (right) (with lexiscan) for a patient with severe lesion at the left anterior descending artery (LAD) that was totally occluded proximally. Severe lesion at left anterior descending artery (LAD) is clearly visible. Right coronary artery (RCA) had provided collateral to the proximal LAD in rest and lead to reduction in blood flow due to coronary steal during stress.

Table 1

	Flow (ml/gm/min)		
	LAD	**RCA**	**LCX**
Rest	0.49±0.32	0.82±0.41	0.41±0.27
Stress	0.21±0.23	1.62±0.32	1.51±0.31
CFR	0.43±0.52	1.97±0.65	3.68±0.81