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IMAGING VIGNETTE

PET Measurement of Absolute Myocardial Blood Flow and LV Function in Dilated Cardiomyopathy

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QUANTITATIVE POSITRON EMISSION TOMOGRAPHY (PET) imaging to assess absolute myocardial blood flow (mbf) is superior to standard stress/rest tracer uptake images for functional assessment of the coronary circulation (1) and in selected patients (e.g., renal insufficiency, low prior probability of coronary artery disease [CAD]) may provide an attractive alternative to coronary angiography to assess for CAD. PET measurements of absolute MBF provide detailed information concerning: 1) extent and functional severity of CAD (Fig. 1); 2) presence of uniform marked reduction in hyperemic response to adenosine (Fig. 2); and 3) evidence of coronary steal (Fig. 3), which is often associated with impaired regional contractile function (2). Moreover, electrocardiography gated images of the left ventricular (LV) myocardium can provide absolute measurements of LV volumes (Fig. 4) from which physiological parameters such as stroke work and power are derived. These indexes are essential to assessment of absolute values of MBF and provide important clinical information such as response to therapy in patients with dilated cardiomyopathy (DCM).

The studies presented below demonstrate the importance of PET measurements of absolute MBF and LV contractile function in improving the evaluation of patients with DCM. Absolute MBF measurements make it possible to detect regional asymmetries in response to vasodilator stimuli (Fig. 1), including coronary steal (Fig. 3), which are not detectable by standard uptake images (Fig. 1) and thereby considerably enhance recognition of the extent and severity of CAD. Similarly, absolute MBF measurements make possible the recognition of globally impaired responsiveness to vasodilator challenge (Fig. 2) and suggest the presence of a nonischemic etiology for DCM. Since severe triple vessel disease with dilated LV in theory may result in relatively uniform reduction in responsiveness to vasodilator stimulus and so be indistinguishable from DCM due to diffuse microvascular disease (e.g., DCM associated with combination of obesity, hypertension, and type 2 diabetes mellitus, without significant epicardial CAD), additional clinical studies will be needed to better define the extent of asymmetries which can be seen in each. In selected cases it also may be necessary to make measurements of rest MBF in patients being evaluated for etiology of DCM, since coronary steal, an important sign of DCM related to epicardial CAD as opposed to diffuse microvascular disease, cannot be recognized without them.

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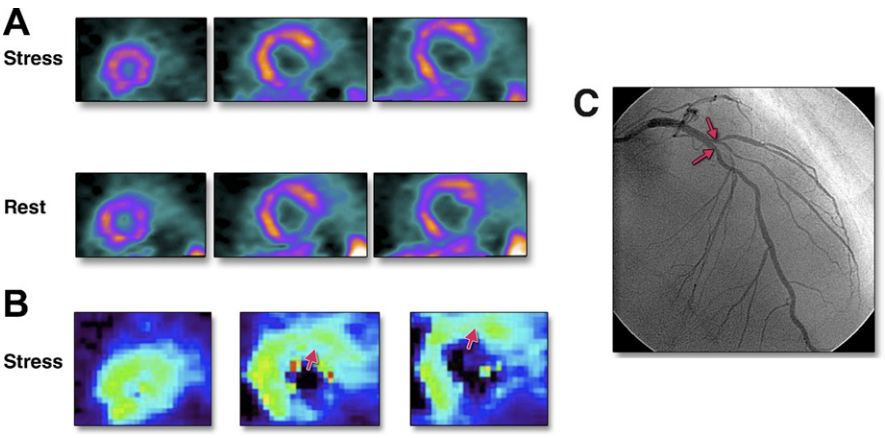


Figure 1. Absolute MBF With Adenosine Is Superior to Uptake Images for Recognition of Extent and Severity of CAD in DCM Evaluation

Positron emission tomography (PET) ^{13}N-ammonia uptake images (**A**, adenosine stress **[upper row]**, rest **[lower row]**), PET adenosine stress myocardial blood flow (MBF) parametric short-axis images (**B**, distal, mid, base levels **[left, middle, right]**), and coronary angiogram **(C)** from a 56 year old man with type 2 diabetes mellitus who presented with marked weight gain (23 kg) over a 1 month period are shown. The uptake images show a moderate, partially reversible inferior and inferolateral defect at base and mid left ventricular (LV) levels. The entire left anterior descending (LAD) distribution appears normal in the uptake images. The PET parametric images show impaired MBF response to adenosine in anterior and adjacent anterolateral segments at base and mid LV levels **(C, red arrows)** (mean MBF 1.61 ml/min/g; normal ≥ 1.85 ml/min/g) in addition to more severe impairment in lateral, inferolateral, and inferior segments (mean MBF 1.04 ml/min/g). **(C)** Coronary angiography demonstrated proximal, caliper measured, 75% stenosis near the origin of a large diagonal system **(red arrow)** and 60% proximal LAD stenosis **(red arrow)**. Angiography (not shown) also demonstrated occlusion of left circumflex artery (LCx) after obtuse marginal branch 2, mid 70% right coronary artery stenosis and posterior descending coronary artery occlusion at its origin. The patient had reduced cardiac index (2.3 l/min/m^2) with left ventricular end-diastolic pressure (LVEDP) equal to 27 mm Hg and left ventricular ejection fraction (LVEF) equal to 35% at catheterization. Accordingly, analysis of absolute MBF depicted in the PET parametric images correctly detected significant stenoses in the LAD system which were unrecognizable by standard uptake images and so correctly indicated the presence of triple vessel disease. CAD = coronary artery disease; DCM = dilated cardiomyopathy.

Figure 2. Absolute MBF With Adenosine for Recognition of Nonischemic DCM

PET ^{13}N-ammonia short-axis parametric MBF images at distal **(left)**, mid **(middle)**, and base LV levels **(right)** of a patient with reduced cardiac index (2.2 l/min/m^2) and moderate/severely depressed LV function (LVEDP 20 mm Hg) with LVEF 26% by echo and moderate LV dilation (LVIDd 58 mm) are shown. Regional MBF at distal **(left)**, mid **(middle)**, and base LV levels **(right)** demonstrated relatively uniform, markedly reduced MBF response to adenosine. Mean MBF in LAD segments 0.71 ml/min/g (range 0.43 to 0.93 ml/min/g). LCx mean MBF 0.72 ml/min/g (range 0.43 to 1.17 ml/min/g). Coronary angiography demonstrated a left dominant system with only "minor plaque" of the LAD. Left main coronary artery and LCx were clear. Thus, analysis of absolute MBF depicted in the PET parametric images; notably marked, uniform, impairment of MBF response to adenosine correctly indicated a nonischemic etiology for DCM in this patient. LVIDd = left ventricular internal dimension diastole; other abbreviations as in Figure 1.

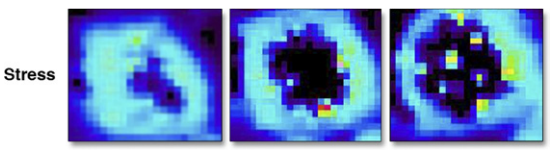
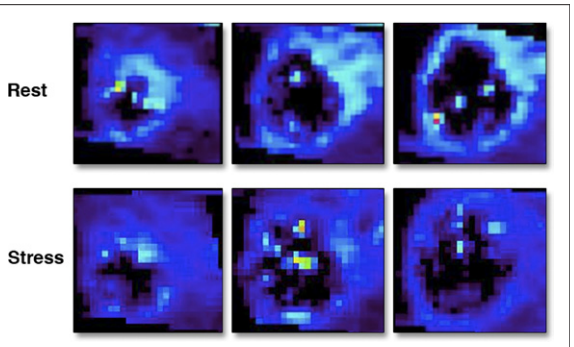


Figure 3. Absolute MBF With Adenosine Permits Identification of Coronary "Steal" as a Cause of Chronic LV Dysfunction and DCM

PET ^{13}N-ammonia short-axis parametric MBF images at distal **(left)**, mid **(middle)**, and base LV levels **(right)** at rest **(top row)** versus adenosine **(bottom row)** are shown. Note higher flows correspond to **lighter blue colors**. Analysis of regional MBF at distal, mid, and base LV levels demonstrated an absolute reduction versus rest in response to adenosine (i.e., coronary steal) in anterior, anterolateral, inferior, and inferolateral segments (MBFado - MBFrest delta ≥−0.15 ml/min/g in each [2], range −0.18 to −0.30 ml/min/g). Coronary angiography demonstrated severe triple vessel CAD. The patient had reduced cardiac index (2.3 l/min/m^2) and severely depressed LV function by echo with marked LV dilation (LVIDd 70 mm) and LVEF 14%. Thus, analysis of absolute rest and stress MBF depicted in the PET MBF images, notably evidence of coronary steal with adenosine, indicated an ischemic etiology for DCM in this patient. MBFado = myocardial blood flow during adenosine; MBFrest = myocardial blood flow at rest; other abbreviations as in Figures 1 and 2.



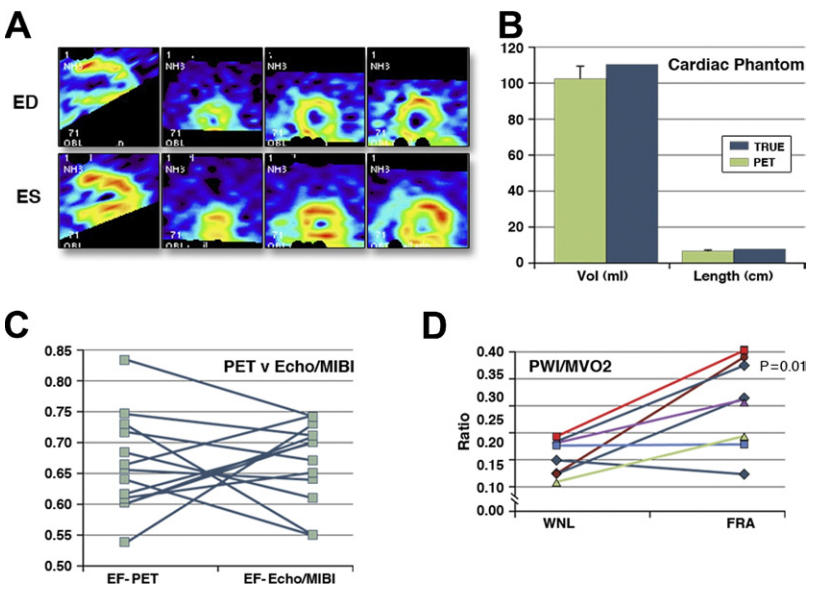


Figure 4. Quantitative Evaluation of LV Size and Function With Gated PET ^{13}N-Ammonia

(A) Shows gated short-axis sections of the LV at distal **(2nd panel, top and bottom)**, mid **(3rd panel, top and bottom)**, and basal **(4th panel, top and bottom)** levels at end diastole (ED) and end systole (ES). A mid LV, vertical long axis section at ED and ES is also shown **(1st** panel, top and bottom). Short-axis areas and vertical long-axis length at ED and ES are used to obtain absolute LV volumes by modified Simpson rule. Validation of the method was performed by imaging a cardiac phantom of known volume (ml) and length (cm) **(B)**. The data demonstrate excellent agreement of absolute values of volume and length. Once LV volumes at ED and ES are known it is a straightforward matter to compute ejection fraction (EF) **(C)**, stroke work (stroke volume∗systolic blood pressure), and power (stroke work∗heart rate) as well as a load free index of LV contractility (systolic arterial pressure/LV ES volume). Comparisons of ejection fraction measurements obtained by PET versus echo or gated Tc-99m-MIBI in 13 patients for whom data were available by each method **(C)** demonstrate excellent agreement. The lower left panel **(D)** demonstrates use of the ratio of power work index (PWI) to myocardial oxygen consumption (MVO_2) to assess efficiency of MVO_2 (assessed by quantitative PET ^{11}C-acetate method) in performance of external work in normal individual (WNL) versus those with Fredreich Ataxia (FRA) without heart failure. The same methodology can be used to assess response to therapy over time in an individual patient. TRUE = real phantom dimension.

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