ASNC

American Society of Nuclear Cardiology

ASNC PET MYOCARDIAL BLOOD FLOW PRACTICE POINTS

Performance, Interpretation, and Reporting

PET MYOCARDIAL BLOOD FLOW
ASNC PRACTICE POINTS

Performance, Interpretation, and Reporting

INTRODUCTION

The purpose of this document is to provide a practical guide to help physicians perform, interpret, and report quantitative myocardial blood flow (MBF) measurements acquired in conjunction with cardiac positron emission tomography (PET) myocardial perfusion imaging (MPI).

Quantification of MBF at rest and at peak stress is an important capability of cardiac PET that can be obtained routinely as a part of every rest/pharmacological stress PET MPI study without lengthening the procedure or increasing radiation exposure to staff or patients. The most useful measurement is the stress/rest MBF ratio expressed as the myocardial blood flow reserve (MBFR). Other terms for this measure have been used, including myocardial flow reserve (MFR)[1,2] and coronary flow reserve (CFR). Although MBFR is the most useful measurement, it is also important to focus on absolute rest and peak stress MBF values, discussed below.

There are many clinical situations in which MBF measurements enhance the diagnostic and/or prognostic information of traditional PET MPI data (**Table 1**).

Table 1. Examples of clinical value of PET MBF quantification beyond traditional MPI[1]

Scenario	Flow pattern
Suspect unsuccessful vasodilation	MBFR <1.2
Identify low risk for cardiovascular events	MBFR >2 has good prognosis
Assess probability for LM or MVD	Global MBFR >2 reduces probability
Confirm single-vessel CAD in patients with single territory perfusion defect	Reduced MBFR in a single coronary territory
Suspect MVD in patients with single territory perfusion defect	Reduced MBFR across more than one coronary territory
Guide revascularization decisions in patients with obstructive epicardial disease	Reduced global MBFR with perfusion defects
Identify potential CMD in patients with INOCA or ANOCA	Normal perfusion and global decrease in MBFR
Identify potential CMD in patients with epicardial CAD	Globally reduced MBFR with or without perfusion defects
Identify allograft vasculopathy in heart transplant patients	Reduced rate-pressure product corrected MBFR, and/or reduced peak stress MBF

ANOCA, angina with nonobstructive coronary arteries; CAD, coronary artery disease; CMD, coronary microvascular dysfunction; INOCA, ischemia with no obstructive coronary arteries; LM, left main; MBF, myocardial blood flow; MBFR, myocardial blood flow reserve; MVD, multivessel disease.

PERFORMING MBF MEASUREMENTS

Tracers

- Evaluation of MBF in this document focuses on assessment with rubidium-82 PET MPI. Longer half-life tracers require consideration for spillover between the rest and stress injections.

Equipment

- MBF can be measured on most PET and PET/CT scanners without additional acquisition time or extra patient radiation dose.

Patient Selection

- All patients with suspected ischemia or coronary microvascular disease (CMD) undergoing rest/pharmacologic stress PET MPI are candidates for quantitative MBF assessment. No special preparation is needed.

ACQUISITION OF MBF DATA

- MBF acquisition is performed both at rest and stress in conjunction with the standard myocardial perfusion data acquisition.
- Start the PET scanner **before tracer injection to avoid potentially missing critically important data (eg, 'input function') for accurate determination of MBF** (**Figure 1**).

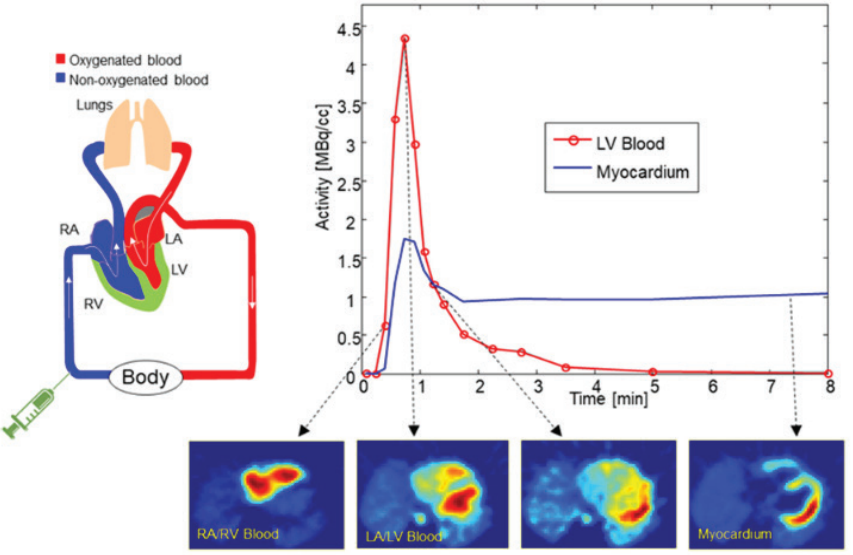

Figure 1. Dynamic PET imaging starts with intravenous injection (Time = 0) and follows the tracer distribution first through the right heart cavities (RA/RV blood pool), then the lungs, in the left heart (LA/LV blood pool), and is gradually extracted from the blood pool and retained in the myocardium.[1] Image courtesy of Robert deKemp, PhD, MASNC.

Practical Tips for Ensuring Consistent MBF Measurements

- Ensure a good free-flowing forearm intravenous (IV) catheter. An 18-gauge IV is preferable.
- Start camera acquisition before injection of the radiotracer at both rest and stress. Be consistent with the time interval between stressor injection/infusion and the start of the tracer infusion. A stopwatch is recommended.
- For serial studies, use the same pharmacologic stressor to facilitate comparison of MBF values.

- Allow the patient to relax under the camera for a few minutes prior to the study to avoid spuriously high resting blood flow.
- Record heart rate (HR) and blood pressure (BP) prior to data acquisition of MBF at rest.
- Know the requirements and computational blood flow models of your software: retention or compartment models.

MBF Quality Control

- Specific details regarding quality control (QC) procedures depend on the model and software used.
- Review QC parameters relevant to the model and software used at rest and stress for each patient study. If QC fails, attempt to address the issues. If you cannot, do not include MBF information in the patient assessment.
- Review registration of emission and transmission scans.
- Review placement of blood pool and myocardial regions of interest.
- Review time-activity curves for correctness based on the software program.
- MBF values may look reasonable despite major technical errors. It is important to review the MBF acquisition curves carefully as well as the rest-and-stress MBF information.

Quality Control Failures

Quality control is an important component to obtain accurate MBF information. **Table 2** lists common QC failures that affect MBF results.

Table 2. Quality control failures

• Camera acquisition started too late/too early
• Misregistration of transmission and emission scans*
• Patient motion during acquisition**
• IV-line restriction
• Poor tracer bolus
• Improper placement of ROI

*Rest-and-stress transmission scans are often used for rubidium-82 and necessary for N-13 ammonia.
**Especially important for single-compartment model software.
IV, intravenous; ROI, region of interest.

EXAMPLES OF QUALITY CONTROL FAILURES

Camera Acquisition

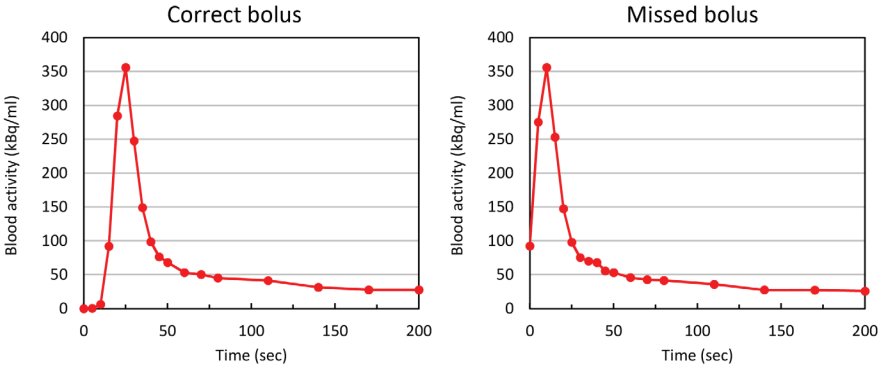

Figure 2. Start the camera acquisition before the tracer arrives to ensure all the bolus is captured (see **left plot**). Starting the camera too late may produce a blood input curve as seen on the right. This will lead to an overestimation of MBF. Images courtesy of Ian Armstong, PhD.

Patient Motion During Stress Acquisition of MBF

Compartment models can be affected by significant patient motion. When using these models, motion must be corrected before reporting MBF values. Net retention models are less affected by patient motion.

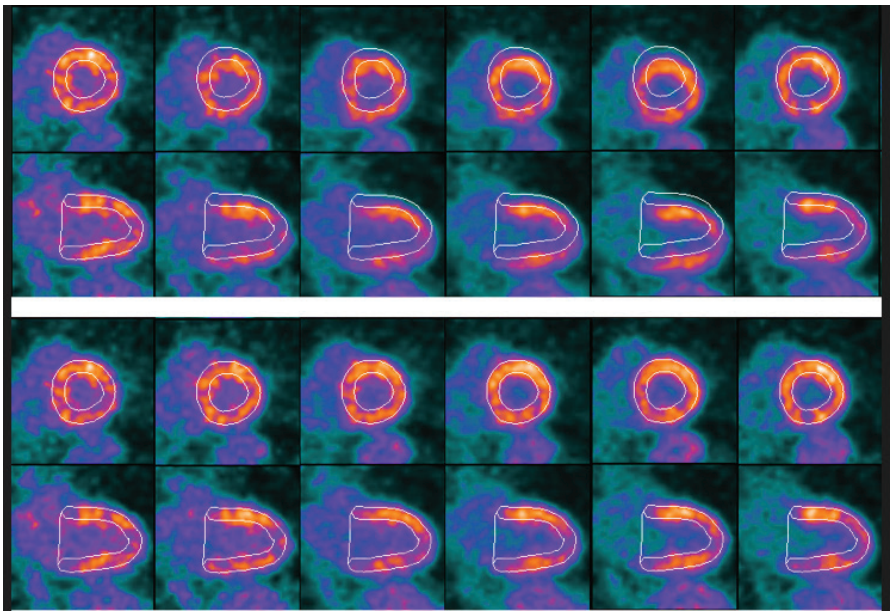

Figure 3. Patient motion during stress MBF data acquisition (**top**) and motion corrected images (**bottom**). Images courtesy of Ian Armstrong, PhD.

REVIEW OF MBF DATA

Rest MBF

- When there are large regional rest MBF differences in normal-appearing rest images, there may be a misregistration artifact that is confined to the dynamic datasets.
- Severe patient motion during perfusion acquisition at either rest or stress can result in abnormal MBF and should be considered technically inadequate.

Stress MBF

- Assess stress MBF before evaluating MBFR data.
- Generally, stress MBF data should be two-fold higher than resting MBF.
- Evaluate stress MBF data globally, regionally, and in the area of any perfusion defects.

MBFR

- MBFR is the ratio of stress MBF/rest MBF and can be displayed as segments (eg, 17-segment model), coronary territories, or for the myocardium in total.
- Assess MBFR in the territory of the perfusion defect, regionally in all three coronary territories, and globally.

INTERPRETATION OF MBFR

After careful evaluation of QC, as well as rest-and-stress MBF data, MBFR may be examined. Interpret MBFR with other clinical data, including perfusion, function, and coronary calcium, if available. The values for MBFR and their interpretation and impact on relative risk of future cardiovascular events are summarized in **Table 3**.

Table 3. General interpretation and classification of risk in relation to global MBFR[1]

Global MBFR	Interpretation	Relative Risk
>2	Normal	Low
1.7–2	Mildly abnormal	Intermediate
1.2–<1.7	Abnormal	High
<1.2 with a perfusion defect	Highly abnormal	Very high
<1.2 without a perfusion defect	Consider non-diagnostic study	Indeterminate
Cutoffs are arbitrary and may vary slightly between labs, software used, stressors used, and published studies. The principle is that the lower the MBFR, the greater the relative risk.		

Discordance: Normal Perfusion and Abnormal Global MBFR

A. Perfusion images are normal, but global MBFR is mildly abnormal (1.7–2)

- In patients with normal perfusion, interpretation of mildly abnormal global MBFR (1.7–2) should be done in the context of individual patient characteristics, such as age, sex, presenting symptoms, and presence of coronary calcium.
  - Stress MBF and MBFR values decrease with age. For older patients, mildly abnormal MBFR may be low risk if other factors are normal. Conversely, if other parameters, such as left ventricular ejection fraction (LVEF), coronary calcium, or patient symptoms are abnormal, mildly abnormal global MBFR may indicate a higher risk for the patient.[3,4]

B. Perfusion images are normal, but global MBFR is abnormal (1.2–<1.7)

- Confirm there are no technical errors or patient-specific explanations (eg, end-stage renal disease, liver failure, prior coronary artery bypass graft surgery (CABG), cardiomyopathy). In the absence of these considerations, normal perfusion and low MBFR may be associated with:
  - MVD;
  - CMD; or
  - A combination of moderate diffuse epicardial CAD and CMD.
- A coronary artery calcium score (CACS) can be helpful in deciding next steps:
  - High CACS: depending on patient symptoms, consider invasive coronary angiography to differentiate epicardial CAD from CMD.
  - Low CACS: cardiac computed tomography angiography (CCTA) to rule out non-calcified plaque might be considered.
- If invasive coronary angiography is selected, consider concomitant provocative functional testing for endothelial-dependent and independent dysfunction if epicardial coronary arteries appear normal or have non-obstructive CAD.

C. Perfusion images are normal, but global MBFR is <1.2

- Confirm there is no technical error or patient-specific explanation.
- Confirm the absence of vasodilator antagonists. Review HR and BP response to the vasodilator, and check images for evidence of splenic switch-off to rule out circulating vasodilator antagonist.[5] If there remains uncertainty, consider retesting with a vasodilator with antagonists withheld for 48 hours or sooner with dobutamine.
  - Caffeine is generally withheld for 24 hours, but the effect may be as long as 48 hours.
  - The results are inconclusive for either epicardial or MVD.
  - Other testing procedures may be necessary, such as coronary angiography or CCTA.

REPORTING MBF AND MBFR INFORMATION

It is recommended that regional and global rest-and-stress MBF and MBFR values be reported in the body of the report, with a summary statement of MBF interpretation in the conclusions. The report needs to be sufficiently instructive and clinically meaningful to referring physicians, so they fully understand the significance of MBFR. **Table 4** summarizes when to exercise caution in reporting MBF in clinical practice.

Table 4. When to exercise caution in reporting abnormal MBFR[3]

End-stage renal disease
Prior CABG
Large prior myocardial infarction
Suspected caffeine/methylxanthine ingestion
Be cautious reporting MBFR when it provides no diagnostic or prognostic value, as there is the potential to confuse patient management decisions, or this might lead to unnecessary testing.

The report should include the following:

- Assess segmental and global MBF and MBFR values, expressed in numerical format, to allow for each vascular territory; and
- Consider diagrammatic representation of the 17 segments with numerical values for stress-and-rest MBF and MBFR as separate bulls-eye maps to provide a more detailed display on a segment-by-segment basis. This may be useful in some situations.

Useful statements to include in the description and conclusion sections of the report are listed in **Table 5**.

Table 5. Examples of useful sentences for reporting PET MBFR[1]

In the Description
There is a rise in MBF between rest and stress.
There is no rise in MBF between rest and stress.
Global MBFR was <<provide number>>.

Table 5. continued.

In the Conclusion
Normal MBFR confirms study normalcy, which indicates lower risk of CAD beyond normal perfusion and predicts a low risk for major coronary-related events.
Despite normal myocardial perfusion, MBFR is abnormal, placing the patient in a higher risk category for CAD and cardiac-related events in patients with no known CAD.
There is a perfusion defect in a single coronary territory along with corresponding regional reduction in MBFR. Normal MBFR within the remainder of the myocardium makes more extensive CAD unlikely.
While the perfusion study indicates single-vessel disease, MBFR is globally reduced, raising concern for more extensive CAD.
The absence of a rise in MBF with normal perfusion does not exclude CAD.
MBFR is not reported in this patient due to technical or patient-specific concerns that can affect accuracy and may lead to inappropriate clinical decisions.
The global MBFR is reduced, <2.0; however, this is mostly driven by an elevated resting MBF, as can be observed in states associated with increased myocardial oxygen demand (hypertension, obesity, etc.)

CASE EXAMPLES OF MBF and MBFR FOR INTERPRETATION AND REPORTING

Interpretation and reporting of MBF requires careful evaluation of the QC of the procedure, as well as rest-and-stress MBF and MBFR data. When interpreting any cardiac PET MPI study, evaluate these four elements: perfusion, function, MBF, and coronary calcium data (if available) to provide a comprehensive report.

The rubidium-82 case examples (**Table 6**) provided in the separate **Case Compendium**, describe commonly encountered clinical scenarios where reporting of MBF will be helpful beyond perfusion defect evaluation. In some cases, CACS data, derived from the CT study, adds important clinical management information.

Table 6. Clinical cases where MBF measurements were helpful beyond perfusion defect evaluation

Case 1	Normal myocardial perfusion, normal LVEF reserve, normal MBFR, low CACS
Case 2	Normal myocardial perfusion, abnormal LVEF reserve, abnormal MBFR, high CACS
Case 3	Normal myocardial perfusion, no augmentation of LVEF with stress, global MBFR <1.2
Case 4	Normal perfusion, normal LVEF reserve, reduced global MBFR, low/absent CACS
Case 5	Single-vessel reversible perfusion defect, single-vessel reduction in MBFR
Case 6	Single-vessel reversible perfusion defect, global reduction in MBFR
Case 7	Normal perfusion, normal stress MBF, high rest MBF, low MBFR
Case 8	Abnormal perfusion, no increase in MBF

Click here to view the Case Compendium

REFERENCES

1. Bateman TM, Heller GV, Beanlands R, Calnon DA, Case J, deKemp R, et al. Practical guide for interpreting and reporting cardiac PET measurements of myocardial blood flow: An information statement from the American Society of Nuclear Cardiology, and the Society of Nuclear Medicine and Molecular Imaging. *J Nucl Cardiol* 2021;62(11):1599-1615.
2. Gupta A, Taqueti VR, van de Hoef TP, Bajaj NS, Bravo PE, Murthy VL, et al. Integrated noninvasive physiological assessment of coronary circulatory function and impact on cardiovascular mortality in patients with stable coronary artery disease. *Circulation* 2017;136(24):2325-2336.
3. Chareonthaitawee P, Bateman TM, Beanlands RS, Berman DS, Calnon DA, Di Carli MF, et al. Atlas for reporting PET myocardial perfusion imaging and myocardial blood flow in clinical practice: an information statement from the American Society of Nuclear Cardiology. *J Nucl Cardiol* 2023;30(6):2850-2906.
4. Sperry BW, Metzinger MP, Ibrahim AO, Thompson RC, Cho YJ, et al. Age- and sex-specific myocardial blood flow values in patients without coronary atherosclerosis on Rb-82 PET myocardial perfusion imaging. *Circ Cardiovasc Imaging* 2024:17(e)016577.
5. Saad JM, Ahmed AI, Han Y, El Nihum LI, Alahdab F, Nabi F, et al. Splenic switch-off in regadenoson 82Rb-PET myocardial perfusion imaging: assessment of clinical utility. *J Nucl Cardiol* 2023;30(4):1484-1496.

www.asnc.org

ASNC thanks the following members for their contributions to this document:

Writing Group:

Timothy M. Bateman, MD, MASNC

Cesia Gallegos-Kattán, MD, MHS, FASNC

Linda Giering, PhD

Gary V. Heller, MD, PhD, MASNC

Krishna K. Patel, MD, MSc, FASNC

Version History
First Issue: January 2025