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Positron Emission Tomography Myocardial Perfusion Imaging

OVERVIEW

The purpose of this document is to highlight the key elements of appropriately performed, high quality positron emission tomography (PET) myocardial perfusion imaging (MPI). Covered topics include: indications, contraindications, advantages and disadvantages relative to single photon emission computed tomography (SPECT) MPI, optimal testing protocols, and reporting templates.

INDICATIONS

The 2016 American Society of Nuclear Cardiology (ASNC) imaging guidelines/Society of Nuclear Medicine and Molecular Imaging procedure standard for positron emission tomography (PET) nuclear cardiology procedures identifies appropriate indications for PET MPI. In addition, the ASNC and SNMMI Joint Position Statement on the clinical indications for myocardial perfusion PET states:

- Rest-stress myocardial perfusion PET is a *first-line preferred test* for patients with known or suspected CAD who meet appropriate criteria for a stress-imaging test and are unable to complete a diagnostic-level exercise stress imaging study. There are no clinical scenarios where PET should not be considered a preferred test for patients who meet appropriate criteria for a stress imaging test and who require pharmacologic stress.

CONTRAINDICATIONS

Contraindications to pharmacologic or exercise stress testing are reviewed in the 2016 ASNC Imaging Guidelines for SPECT Nuclear Cardiology Procedures: Stress, Protocols, and Tracers. Contraindications to PET imaging include:

- Inability to lie flat or still during image acquisition;
- Pregnancy;
- Weight exceeding the PET machine table limit or inability to fit inside the gantry;
- Claustrophobia (rarely).

ADVANTAGES VS. SPECT MPI

- Higher spatial and temporal resolution;
- Peak stress rather than post-peak image acquisition;
- Quantitation of absolute myocardial blood flow (MBF; mL/g/min), increasing sensitivity to identify diffuse atherosclerosis, microvascular dysfunction, coronary steal and/or hibernating myocardium;
- Short half-lives of radionuclide tracers allow lower effective radiation doses and faster imaging protocols (i.e., increased laboratory throughput).

DISADVANTAGES VS. SPECT MPI

- Short half-lives of current radionuclide tracers make exercise stress protocols challenging;
- Requirement for on-site cyclotron or relatively expensive monthly generator purchase.

TEST PREPARATION

- Assess patient's height, weight, chest circumference, ability to lie flat, pregnancy status, and history of claustrophobia.
- 6-hour fast except water; 12-hour caffeine avoidance; 48-hour theophylline avoidance.

RADIONUCLIDES

Table 1. Key PET MPI radionuclide characteristics.

	Rubidium-82 (^{82}Rb)	^{13}N-Ammonia (N-13)
Half-life	75-sec	10-min
Supply Source	Strontium-82 generator, replaced every 4-6 weeks	On-site cyclotron
Positron Range	Long (worse image resolution)	Short (better image resolution)
Allows Exercise Stress	No	Yes

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IMAGING PROCEDURE

Figure 1 outlines the typical flow for rest PET MPI study followed by a stress PET MPI study. Table 2 describes the important parameters associated with PET MPI study acquisition protocol. Most new PET scanners have 3D imaging which improves sensitivity, allows for a reduction in radiation exposure but has increased scatter, dead time and random events compared with 2D imaging.

Figure 1. Typical clinical flow of a PET MPI study

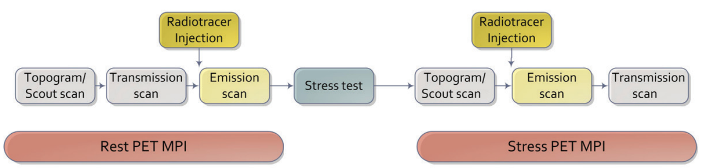

Table 2. Preferred PET MPI protocol.

Patient Positioning	
Supine, arms raised above shoulders and supported, maintain same position throughout transmission and emission	
CT Topogram/Scout for Heart Localization	
Transmission CT for Attenuation Correction	
80-140 kVp, 10-20 mA, 4-5 mm slice thickness, ungated to ECG, field of view from carina to 2 cm below inferior heart border, obtain at end-expiration or during shallow breathing. Shallow breathing is most commonly used.	
Emission Scan	
Acquisition Mode	2D or 3D, list mode (simultaneous dynamic and ECG-gated) beginning at radionuclide injection
Radionuclide Dose	2D ^{82}Rb: 20-40 mCi 3D ^{82}Rb: 10-20 mCi 2D or 3D ^{13}N-ammonia: 10-20 mCi (larger patients, 25-30 mCi)
Duration	^{82}Rb: 3-10 min ^{13}N-ammonia: 10-15 min
Reconstruction	Filtered backprojection or iterative (e.g., ordered-subsets expectation maximization), matched resolution between rest/stress, reconstructed pixel size 2-4 mm and matched between rest/stress
Prescan delay	Static images are reconstructed with a prescan delay to minimize blood pool activity on the static and gated images. ^{82}Rb: 70-90 seconds (LVEF >50%); 90-130 seconds (LVEF < 50%) ^{13}N-ammonia: 90-180 seconds

STRESS PROCEDURES

- Typically pharmacologic stress, using regadenoson, adenosine, dipyridamole or dobutamine;
- Exercise stress is feasible with ^{13}N-ammonia but is associated with increased personnel radiation exposure, must be timed to account for radionuclide decay, and image quality may be compromised by patient motion due to immediate post exercise imaging;
- Radionuclides are typically intravenously injected during peak hyperemia.

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QUALITY CONTROL

- Assess CT transmission images for streak artifacts (e.g., obese patients), truncation, beam hardening artifacts (e.g., arms down), metal artifacts (e.g., ICDs), breathing artifacts;
- Ensure adequate count statistics on emission images;
- Ensure precise alignment between the transmission and emission images in the transaxial, sagittal and coronal planes. If misalignment is detected software based correction is recommended; only attenuation corrected images should be interpreted clinically;
- Evaluate for motion by a review of a cine loop of the dynamic image frames. If motion is noted, reconstruct images by eliminating the frames with motion;
- Motion correction (if available) to ensure accurate myocardial and blood pool time-activity curves for quantitation of absolute MBF.

INTERPRETATION AND REPORTING

Table 3 summarizes some of the key recommendations from the 2017 ASNC Information Statement: Standardized Reporting Matrix for Radionuclide Myocardial Perfusion Imaging.

Table 3. Key recommendations for reporting PET MPI studies

Patient Demographics & Clinical Information	
Patient identifiers, ordering provider, interpreting MD, date of interpretation, appropriate use criteria indication for study	
Methods	
Stress protocol, imaging protocol, radiotracer dose(s), radiotracer route of injection	
ECG Interpretation	
Rest ECG interpretation, stress ECG interpretation including any ST segment changes suggestive of inducible ischemia, rest and peak stress hemodynamics, symptoms during stress, reason for stress termination	
Findings	
MPI	• Semi-quantitative or quantitative 17-segment interpretation of images displayed in short, vertical long, and horizontal long axis (reduction in the lateral wall and apex is a common variant with ^{13}N-ammonia); • Calculate summed stress, summed rest and summed difference scores; • Stress perfusion defects should be characterized by extent, severity, location, reversibility; • Quantitation of global LV and regional MBF at rest and after stress can help identify balanced ischemia/diffuse atherosclerosis/microvascular disease
Gated MPI	LV end-diastolic and -systolic volumes, transient ischemic dilatation, rest and stress LV ejection fraction, LV wall motion abnormalities
Ancillary Findings	Re Review emission and transmission scans (3D maximum intensity projection display may be helpful) for increased lung/RV uptake, persistent blood pool activity and/or extracardiac pathology (e.g., effusions, calcification, masses)
Calcium Score	From gated CT transmission images or attenuation correction CT scan Include percentile values based on age and gender.
Overall Impression	
Integration of all above findings into a clear, clinically-relevant summary statement.	

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SUGGESTED READING

Dilsizian V, Bacharach SL, Beanlands RS, et al. ASNC imaging guidelines/SNMMI procedure standard for positron emission tomography (PET) nuclear cardiology procedures. *J Nucl Cardiol*. 2016;23(5):1187-226.