Myocardial Perfusion Imaging in Coronary Artery Disease

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Cover Illustration by mb cunney
Nuclear cardiology is a well-established field, and its usefulness in clinical decision making for patients with coronary artery disease (CAD) is supported by substantial trial data. Single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) studies provide important diagnostic and prognostic information for detection of CAD, risk stratification of patients with CAD, and myocardial viability assessment. SPECT MPI can guide decision making in a number of other clinical scenarios (Table 1).

The accuracy of SPECT MPI in detecting CAD has been improved by advances in quality control, more effective radiotracers, and new technologies, such as electrocardiogram (ECG)-gated SPECT, relative quantitative analysis, and attenuation correction. The further development of molecular imaging is one of the next major steps for nuclear cardiology. New radiotracers for detection of apoptosis, atherosclerosis, unstable plaque, hypoxia, and angiogenesis are being developed. Over the next few years, clinical trials will be conducted to evaluate the appropriate utilization of these radiotracers in patients. This manual discusses the role of SPECT MPI in detection and risk stratification of CAD and in the assessment of myocardial viability and reviews the application of positron emission tomography (PET) in myocardial viability assessment.

SPECT MPI is based on the fact that injected radiotracer is distributed in the myocardium in proportion to coronary blood flow. The single gamma photons emitted by the decay of injected radioisotopes are detected by imaging devices known as gamma cameras. These cameras produce planar projection images. Mathematical reconstruction techniques are applied to data sets comprising many planar views taken by the camera over 180 degrees from the right anterior oblique to the left posterior oblique position around the patient’s chest (heart) to yield 3-dimensional tracer distribution data, known as SPECT images. These images are viewed as tomographic slices of the left ventricular myocardium in 3 projections (Figure 1, see page 6).

Technetium-99m (Tc-99m)-labeled tracers and thallium-201 chloride (Tl-201) are widely used with a variety of SPECT protocols to detect CAD. Tc-99m-labeled tracers are extracted from the blood by myocytes in proportion to regional coronary blood flow. Uptake of Tc-99m-sestamibi and Tc-99m-tetrofosmin has a linear correlation with blood flow at flow rates up to approximately 2 mL/min/g. Above this rate, uptake decreases and the distribution of Tc-99m tracers plateaus, which results in an underestimation of blood flow (a phenomenon known as “roll-off”). With low flow rates, usually less than 10% of the baseline blood flow, uptake of Tc-99m increases, resulting in an overestimation of coronary blood flow. Uptake of Tl-201 also has a nearly linear correlation with blood flow and plateaus at a higher blood flow rate than Tc-99m (2.5 mL/min/g). Overestimation of coronary flow at low flow rates is also seen with Tl-201.

SPECT MPI with Tl-201 can be used to evaluate ischemia and myocardial viability. A disadvantage of Tl-201 is that the photons it emits upon radioactive decay have lower energy compared with those emitted by Tc-99m (69–81 keV versus 140 keV). Lower photon energy results in more scatter, greater attenuation, and lower quality images, particularly in overweight patients. Tc-99m has higher energy emission than Tl-201 as well as a shorter half-life (6 versus 73 hours), which allows higher millicurie doses to be administered without increasing the patient’s radiation exposure. Therefore, many more counts can be obtained with Tc-99m than with Tl-201 in the same amount of time. For this reason, Tc-99m produces higher quality images than Tl-201, and Tc-99m is more suitable for ECG-gating. Dual-isotope protocols (stress with a Tc-99m agent, rest with Tl-201) can be performed in less time than other commonly used
protocols and combine the characteristics of good quality Tc-99m images of myocardial perfusion with Tl-201’s capability for myocardial viability assessment.

**STRESS PROTOCOLS**

Exercise is the stressor of choice if the patient is able to exercise, primarily because valuable prognostic information is derived from observing the patient’s functional capacity, ST abnormalities, and hemodynamic response to exercise. The most commonly used protocol is the Bruce treadmill stress protocol, although some institutions use bicycle stress. Exceptions to this preference for treadmill stress include patients with left bundle branch block (LBBB), some patients with pacemakers, and those unable to exercise or with contraindications to exercise. Asynchrony of septal contraction that occurs in LBBB has a deleterious effect on coronary flow, leading to hypoperfusion of the septum. This effect is dependent on heart rate and is not related to CAD. In these patients, adenosine or dipyridamole is the protocol of choice.3,4

Adenosine is a direct coronary arteriolar vasodilator and results in a 3.5- to 4-fold increase in myocardial blood flow. Dipyridamole is an indirect coronary artery vasodilator that increases tissue levels of adenosine by preventing the intracellular reuptake and deamination of adenosine. These agents increase myocardial blood flow by inducing arteriolar vasodilatation and a relative flow heterogeneity between areas supplied by normal and stenosed (> 50%) coronary arteries. Low-level exercise can be combined with pharmacologic stress in patients who are able to exercise. This approach improves image quality by decreasing splanchnic uptake of the radiotracer, which can interfere with imaging of the inferior wall of the myocardium. Additionally, pharmacologic stress combined with low-level exercise decreases the undesirable adverse effects associated with dipyridamole or adenosine.5,6

The most common adverse effects of pharmacologic stressors are due to systemic vasodilatation, atrioventricular (AV) block, and bronchospasm but true ischemia with ST depression due to coronary steal related to the presence of collaterals can be seen. Because of the short half-life of adenosine (< 10 s), most side effects resolve without intervention. However, the side effects of dipyridamole can last several minutes to hours and intravenous administration of aminophylline may be needed. Aminophylline blocks the adenosine receptors and immediately reverses the side effects. If the patient is unable to exercise and has a contraindication (ie, second or third AV block, asthma, bronchospasm) to vasodilator stress, dobutamine is the alternative stressor of choice. New pharmacologic stressors (adenosine A2A receptor agonists) have been developed to avoid the adverse effects secondary to vasodilator stress. They induce specific coronary vasodilatation without stimulating the A1, A2B and A3 adenosine receptors, which are responsible for the undesirable effects of adenosine and dipyridamole.7 These new stressors are not yet approved by the U.S. Food and Drug Administration (FDA).

**POSITRON EMISSION TOMOGRAPHY**

PET can be used to evaluate perfusion and myocardial metabolism. PET tracers utilize radioisotopes that emit a positron (the anti-particle of an ordinary electron) when they decay. A positron emitted within tissue will collide with a nearby electron, producing an annihilation reaction that results in the emission of 2 511-keV gamma photons that travel in opposite directions. The detection of these 2 photons by 2 separate detectors within a narrow time window (electronic collimation) is called coincidence. Electronic collimation is used to produce data that is reconstructed into 3-dimensional tracer distributions that are viewed as tomographic images of the left ventricular myocardium in 3 projections (similar to SPECT).

The radiotracers rubidium-82 (Rb-82) and fluorine 18 fluorodeoxyglucose (F18-FDG) are approved by the FDA for use in PET scanning of myocardial perfusion and myocardial metabolism for detection of CAD and evaluation of myocardial viability, respectively. Only pharmacologic stress testing can be performed with Rb-82 because of its short half-life (75 s); this limitation is considered a disadvantage by some. F18-FDG is discussed in the section “Myocardial Viability Assessment.” Because PET hardware and software has the capacity to perform attenuation correction, Rb-82 PET perfusion studies perform slightly more accurately than SPECT in detecting CAD.8,9
CLINICAL INDICATIONS FOR MYOCARDIAL PERFUSION STUDIES

DIAGNOSIS OF CAD

Although there is more experience in MPI with Tl-201, the accuracy of Tc-99m agents is equivalent to that of Tl-201 for detection of CAD. The SPECT images of myocardial perfusion during stress are compared with images at rest. Because obstructed coronary arteries have impaired coronary reserve, relative reductions in regional flow during stress are detected by the gamma camera as myocardial perfusion defects. If the deficit in myocardial perfusion during stress reverses at rest, the pattern is called ischemia (Figure 1). If the defect remains fixed, the pattern is consistent with infarct (Figure 2, see page 7). Often a fixed defect can still be viable myocardium (hibernating myocardium), and further testing to assess myocardial viability may be needed. A third pattern that has been associated with CAD is reverse redistribution, where the perfusion deficit is more severe on resting images than on stress images (which can even appear normal). This pattern is seen more frequently with Tl-201 protocols and is thought by some to be related to subendocardial damage. Reverse redistribution has been associated with altered balance between tracer washout (ie, clearance) from myocardium and redistribution of the tracer. Reverse redistribution is characteristic of Tl-201 but also occurs to a much lesser extent with technetium tracers.

In 33 studies pooled from the literature, the overall sensitivity of SPECT MPI in the detection of CAD (using ≥ 50% stenosis as a threshold for coronary lesions) was 87% and the specificity was 73%. The accuracy of SPECT MPI is not affected by the stress protocol. However, in recent years specificity has been adversely affected by referral (selection/verification) bias, which results from the fact that patients with normal radionuclide myocardial perfusion studies are not referred for cardiac catheterization studies. The nuclear scan is used to select patients for the gold standard, cardiac catheterization/coronary angiography. Only patients who get coronary angiography are included in specificity/sensitivity determinations. To illustrate this phenomenon, if 1000 patients are referred for SPECT MPI and 500 have normal studies, only the 500 patients with abnormal results are referred for cardiac catheterization. Thus, when specificity is calculated (true negatives/[true negatives + false positives]), using the 500 abnormal MPI studies and assuming a high false-positive rate of 20% for MPI, the result is as follows: 0/[0 + 100] = 0. If the 500 patients with normal MPI studies had undergone cardiac catheterization and absence of CAD was confirmed, the calculation would be: 500/[500 + 100] = 87%. To minimize the inaccuracies resulting from selection/verification bias, many investigators use the normalcy rate, which is defined as the percentage of patients with less than 5% pretest likelihood of CAD who have normal SPECT MPI studies. In the analysis described above, the overall normalcy rate was 91%.

ECG-Gated SPECT MPI

ECG-gated SPECT MPI technology is used to evaluate global and regional left ventricular (LV) function and to calculate LV volumes and LV ejection fraction (LVEF). ECG-gated studies help to differentiate true defects (impaired wall motion) from artifacts due to photon attenuation caused by soft tissue (normal wall motion). Men commonly have decreased counts in the inferior wall due to diaphragmatic attenuation, and women commonly have decreased counts in the anterior wall due to breast attenuation. ECG-gated studies help in identifying such artifacts and enhance the readers’ confidence in scan interpretation, reducing the number of borderline or equivocal interpretations. Because of their physical characteristics, Tc-99m agents are easy to use in ECG-gated studies, although techniques to acquire good quality ECG-gated TI-201 studies have been developed.

Attenuation Correction

SPECT attenuation correction methodology has been developed to minimize or eliminate attenuation artifacts caused by differences in body habitus. As explained above, soft tissue attenuation degrades myocardial perfusion SPECT image quality, decreasing test sensitivity and specificity. If attenuation correction software is not available, reviewing rotating planar images, prone imaging, ECG-gated SPECT, and relative quantitative software programs that use normal data can help to differentiate true defects from breast, diaphragmatic, or soft tissue attenuation artifacts. However, these are indirect solutions.

Attenuation correction requires an estimate of the nonuniform attenuation coefficient distribution in the thorax and upper abdomen. With specific information on the spatial distribution of attenuation coefficients, the software calculates the attenuation that occurs when photons are emitted from a given location in the patient at a given angle, generating an attenuation map. The clinical results of this technology have been improved by second-generation attenuation correction software.
which possesses better quality control methodology and therefore produces improved transmission maps.\cite{17} The most important characteristic of attenuation correction is that breast, diaphragmatic, and soft tissue attenuation can be corrected, minimizing the effects of these artifacts on the accuracy of SPECT MPI studies in the detection of CAD. Several studies using attenuation correction have documented that it enhances the specificity and normalcy rate of SPECT MPI studies without compromising sensitivity for the detection of CAD.\cite{18–20} Also, attenuation correction may improve the recognition of three-vessel (so-called balanced ischemia) and left-main disease.\cite{21}

**Relative Quantitative Analysis**

A variety of software programs can be applied for relative quantitative analysis of SPECT studies of myocardial perfusion.\cite{1} In rare cases of perfectly balanced ischemic disease, such software programs may give falsely normal results. For most patients, however, relative quantitative analysis improves the accuracy of MPI. With this approach, a patient’s MPI study is compared with normal databases (polar maps), from which a relative quantification of the extent and severity of the perfusion defects is derived. This analysis theoretically minimizes inter- and intraobserver variability of interpretation of studies and allows for more standardized serial evaluations of patients. The polar map is a relatively quantitative representation of the distribution of counts at stress and rest displayed on a pixel-by-pixel basis. Each pixel correlates with an anatomic region of myocardium and is compared with a normal file of gender-matched subjects. Decreased counts in a region of the myocardium below the limits of the normal databases are demonstrated by “blackening out” the pixels on the polar map display. Statistically significant reversibility is shown by “whiting out” the blacked out pixels. Color codes on the severity maps indicate the number of standard deviations that each pixel location is below the mean number of counts for the gender-matched normal file. Standard deviation maps are also generated for stress and rest images and for reversibility at each pixel that has decreased counts on stress images (Figure 1).

**RISK STRATIFICATION**

One of the goals of SPECT MPI is to obtain information that will help determine a patient’s risk for cardiac events. Designating a patient as being at high or low risk may assist in deciding whether a more aggressive approach (catheterization) or more conservative management (medical therapy) is appropriate for a given patient. Specific MPI study findings have been validated as predictors of high risk for cardiac events (Table 2).

Studies have demonstrated that MPI provides incremental prognostic value over clinical and exercise ECG test, particularly when relative quantitative programs that generate severity scores are used.\cite{2,22,23} These studies also have shown that the larger and more severe the perfusion defect, the higher the chance of cardiac events. One of the major strengths of SPECT MPI is its high negative predictive value. Several studies have shown that for patients who have a normal perfusion study, the risk of cardiac events within the subsequent 1 to 2 years is less than 1%.\cite{24} This risk may be slightly higher (2%) when normal perfusion is demonstrated using pharmacologic stress and even higher if there is ST depression after vasodilator infusion (Figure 3, see page 7).\cite{25}

Functional analysis of the left ventricle with ECG-gated Tc-99m SPECT MPI studies provides a well-documented increase in prognostic value over MPI alone. It is well known that reduced LV function documented with ECG-gated SPECT indicates a worse prognosis than normal LV function.\cite{20–28}

Myocardial perfusion studies add important information to the assessment of prognosis after a myocardial infarction. LV function, infarct size, and residual myocardium at risk determined by stress-induced myocardial ischemia are important variables that can be obtained with an ECG-gated myocardial perfusion study. The efficacy and safety of performing a pharmacologic stress test early after a noncomplicated infarct have been reported.\cite{29,30} With this approach, it is possible to identify the patient as being at low or high risk for further cardiac events soon after the initial event and to initiate therapy accordingly. The clinical utility of this approach was demonstrated in a large prospective trial (INSPIRE trial), which showed that conservative management and an aggressive strategy could achieve equal decreases in SPECT myocardial perfusion deficits in selected patients.\cite{31}

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**Table 2. Scintigraphic Findings Predicting High Cardiac Risk**

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<tr>
<th>Findings</th>
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<tr>
<td>Multiple perfusion defects</td>
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<td>Extensive area of ischemia or infarct</td>
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<td>Stress-induced ischemic left ventricular dilatation</td>
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<td>Ejection fraction less than 40%</td>
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<td>Increased end-diastolic and end-systolic volumes</td>
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<td>Increased lung uptake of thallium-201</td>
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**Figure 1.** (A) Single photon emission computed tomography myocardial perfusion images acquired with a technetium-99m-sestamibi one-day protocol: short-axis (top 2 rows), vertical long-axis (middle 2 rows), and horizontal long-axis (bottom 2 rows) slices displayed at stress and rest. The gray images on the right of the scan show the planar camera acquisition in one projection (near left lateral) of the 180 degrees of the camera rotation around the patient’s chest from 45 degrees right anterior oblique to 45 degrees left posterior oblique. The tomographic slices show severe reversible hypoperfusion in the lateral and inferolateral segments. (B) Polar maps show significant reversibility in the lateral and inferolateral segments (white-out area). The size of the perfusion defect is measured as 29% of the left ventricle myocardium by the polar map program. 27% of the defect reverses on rest images (white region). SD = standard deviation.
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Figure 2. Dual-isotope single photon emission computed tomography images of myocardial perfusion: short-axis (top 2 rows), vertical long-axis (middle 2 rows), and horizontal long-axis (bottom 2 rows) slices displayed at stress (technetium-99m sestamibi) and rest (thallium-201). The tomographic slices show severe and large fixed hypoperfusion in the mid-anterior, apical anterior, septum, apex, mid-inferior, and apical inferior segments of the left ventricle.

Figure 3. Dual-isotope myocardial single photon emission computed tomography images: short-axis (top 2 rows), vertical long-axis (middle 2 rows), and horizontal long-axis (bottom 2 rows) slices displayed at stress (technetium-99m-sestamibi) and rest (thallium-201). The tomographic slices show normal perfusion at stress and rest and transient ischemic dilatation (TID) of the left ventricle at stress (TID index, 1.57; normal upper limit, 1.22). The patient had ST depression induced by adenosine infusion. Cardiac catheterization was performed, which showed triple-vessel disease. The dual-isotope study failed to show perfusion defects, probably because of balanced ischemia. However, the abnormal TID and ST depression induced by adenosine infusion are sufficient abnormalities to warrant cardiac catheterization.

Figure 4. Rubidium-82 (Rb-82)/18-fluorodeoxyglucose (F18-FDG) positron emission tomography images of myocardial perfusion: short-axis (top 2 rows), vertical long-axis (middle 2 rows), and horizontal long-axis (bottom 2 rows) slices representing perfusion (Rb-82) and metabolism (FDG-18). The images show a mismatch pattern in the septum, mid-anterior, and apical anterior segments of the left ventricle.
Myocardial Imaging in the Management of CAD

SPECT MPI is an excellent gatekeeper when deciding between aggressive therapy and medical therapy. The ability to stratify patients’ cardiac risk helps the cardiologist to define the best strategy for the patient. High-risk patients will be better managed with catheterization and possible revascularization, and low-risk patients will be better managed with medical therapy and aggressive risk factor modification. Patients with mild ischemic defects can be stratified into higher or lower risk groups depending on their functional capacity. Patients with low functional capacity or with diabetes may be referred for cardiac catheterization.

In the Economics of Noninvasive Diagnosis study, Shaw et al evaluated approximately 10,000 patients and demonstrated that selective catheterization after SPECT MPI is cost-effective when compared with direct catheterization. Cardiac event rates were similar in both groups (for pretest clinically low-, medium-, and high-risk patients), and there were substantial cost-savings with the noninvasive strategy. A study performed in Europe had similar results.

MYOCARDIAL VIABILITY ASSESSMENT

A subgroup of patients with chronic CAD and LV dysfunction have improved regional and global LV function after myocardial revascularization. Reversible LV dysfunction in patients with CAD can be caused by hibernating myocardium (chronic resting ischemia) or repetitive stunning (repetitive demand ischemia). These conditions have in common preserved myocyte metabolism and cell membrane integrity. Allman et al performed a meta-analysis of 24 published studies that showed that patients with CAD, LV dysfunction, and myocardial viability (assessed using different strategies) who were treated medically had a cardiac death rate of 16% per year, while those who underwent revascularization had a cardiac death rate of 3.2% per year. In cases of nonviable myocardium, revascularization did not change the outcome.

A variety of radionuclide techniques can be applied to assess myocardial viability. Because of its redistribution characteristics, Tl-201 is the agent of choice for SPECT MPI studies of myocardial viability. In a technique utilizing Tl-201, resting images are acquired, then a separate set of resting images is acquired after a time delay of 4 to 24 hours to allow redistribution of the Tl-201. Resting delayed images that show normalization or improvements of defects compared with earlier resting images are indicative of myocardial viability. Nitrate-enhanced imaging may improve the accuracy of SPECT with Tl-201 and Tc-99m-sestamibi or Tc-99m-tetrofosmin in detecting myocardial viability.

The most widely used PET protocol and the gold standard for assessing myocardial viability is metabolic imaging of the glucose analog F18-FDG. The glucose myocardial metabolic image is compared with a PET perfusion image obtained with Rh-82 or N-13 ammonia, and mismatch between the metabolism and perfusion (Figure 4, see page 7) images is indicative of viability. However, if the defect is primarily fixed and is severe, myocardial nonviability is likely. This PET protocol has slightly better overall accuracy than delayed (24-hour) SPECT MPI studies with Tl-201. However, F18-FDG has limitations in diabetic patients, who often require assessment of myocardial viability. Glucose loading with oral preparations or an intravenous load to enhance the uptake of FDG by the myocardium is typically used in nondiabetic patients to promote myocardial glucose metabolism rather than lipid metabolism. Because patients with diabetes have a limited ability to produce endogenous insulin, this approach does not work well in these patients. To improve the quality and accuracy of PET scans, strategies such as hyperinsulinemic/euglycemic clamp and administration of acipimox (a nicotinic acid that inhibits peripheral lipolysis and thus reduces free fatty acid levels) have been proposed. The hyperinsulinemic/euglycemic clamp is a rigorous and time-consuming procedure that uses infusion of dextrose and insulin to achieve better control of the metabolic substrates; the use of this procedure results in high-quality images.

EVALUATION OF ACUTE CHEST PAIN

In the United States, more than 5 million patients present to emergency departments each year with chest pain, and approximately 50% are admitted to the hospital. The rate of myocardial infarction in these patients ranges from 2% to 10%. Conversely, 5% to 10% of patients discharged from the emergency department have acute coronary syndrome. These statistics illustrate the challenge of promptly and accurately diagnosing the etiology of acute chest pain. Myocardial perfusion studies can help to differentiate between cardiac and noncardiac chest pain in a patient with a nondiagnostic ECG. Tc-99m-sestamibi or -tetrofosmin are preferred in this clinical setting because they do not redistribute significantly, as Tl-201 does. Thus, imaging can be performed 1 to 2 hours after the injection of the radiotracer, allowing time for the management of the patient in the emergency department with subsequent transfer to the nuclear medicine laboratory for imaging.

Acute rest imaging has superior sensitivity and specificity compared with clinical evaluation and rest ECG. The accuracy of rest imaging is highest if the
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Injection is performed while the patient has chest pain, but some authors have reported an acceptable window of time (2 to 3 hours) after resolution of the chest pain.41 The negative predictive value of a normal perfusion study is approximately 99%.42 Two randomized multicenter controlled trials have demonstrated the efficacy of this approach in the emergency department and the positive contribution of the myocardial perfusion scan to the management of these patients.43,44

**MYOCARDIAL PERFUSION IMAGING AND DIABETES**

Nearly 16 million Americans have diabetes, which is recognized as a major risk factor for CAD. A recent joint editorial statement suggests that the absolute risk for major coronary events in patients with type 2 diabetes approaches that of nondiabetic patients with established CAD.45 Consequently, most diabetic patients may deserve the same evaluation and risk factor interventions reserved for patients with established CAD. In addition, diabetic patients have increased morbidity and mortality following acute coronary events and revascularization (bypass or percutaneous revascularization).46 This evidence has stimulated interest in using MPI to predict risk and identify CAD in diabetic patients.

In a multicenter observational study, Kang et al compared diabetic and nondiabetic populations and demonstrated similar accuracy for detection of CAD using Tc-99-sestamibi SPECT MPI.46 The negative predictive value was the same in both groups, but the risk-adjusted event-free survival in patients with mildly and moderately to severely abnormal scans as a function of summed stress scores (derived using semiquantitative software with gender-matched normal file data) was worse in patients with diabetes. In another multicenter observational study, Giri et al compared 929 diabetic patients with 3826 patients without diabetes and demonstrated that diabetic patients with ischemic defects had worse prognoses than nondiabetic patients.47 A multivessel fixed defect was the strongest predictor of mortality among diabetic patients. In this study, women with diabetes had the reemergent outcome for any degree of reversible perfusion defect. A normal scan predicted the same survival for both groups over a period of 2 years, but after this period the prognosis became worse in diabetic patients, suggesting that after a normal scan these patients may need follow-up scans more frequently.

Because of the high risk for cardiac events in diabetic patients with CAD, evaluation of asymptomatic diabetic patients with stress MPI may be beneficial. Detection of silent ischemia may be a trigger for more aggressive management of these patients. Published data indicate that a significant proportion of patients with type 2 diabetes (~20%) have silent ischemia.48 The multicenter Detection of Ischemia in Asymptomatic Diabetics study has been designed to determine the prevalence of abnormal SPECT studies in asymptomatic patients with type 2 diabetes.49 A preliminary report of findings in 357 patients indicated that 22% had an abnormal scan and 19% showed inducible ischemia.

**CARDIAC BLOOD POOL IMAGING**

Cardiac blood pool imaging to evaluate ventricular function can be performed using 2 techniques: first-pass gated radionuclide angiography (RNA) or ECG-gated-blood pool imaging (sometimes called equilibrium RNA). Both techniques consist of dynamic imaging of the left and right ventricles using ECG gating. The changes in radioactivity in the LV chamber allow the determination of the end-systolic and end-diastolic frames that are used to calculate LVEF and volumes. The first-pass technique uses an intravenous Tc-99m radiotracer that can provide high count rates with no first-pass extraction by myocardium and no capillary trapping in the lungs after the injection. This feature allows first-pass RNA to be combined with other techniques, such as bone, renal or hepatobiliary scintigraphy. Gated-blood pool imaging (also called multiphase acquisition [MUGA] scan) allows for evaluation of LV function through ECG-gated imaging of labeled red cells within the cardiac chambers. Red blood cell labeling with technetium-99m can be accomplished by in vivo labeling, in vitro labeling, or a hybrid method that uses a combination of both techniques.

Gated blood pool imaging is an accurate and highly reproducible technique for assessing LVEF and LV volumes at rest and during supine bicycle exercise.50 Early studies have demonstrated the importance of the LVEF and LV volumes measured by RNA techniques to predict cardiac event rates after a myocardial infarction.51,52 In the Multicenter Post Infarction Research Group study,52 60% of all deaths in 1 year occurred in patients with a LVEF of 40% or lower. Patients with LVEF lower than 20% had a 1-year mortality of 47%. Although the presence of induced ischemia detected by RNA may further improve risk stratification, exercise gated-RNA largely has been supplanted by gated SPECT MPI for risk stratification.53

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SUMMARY POINTS

- Thallium-201 (TI-201) and technetium-99m (Tc-99m)-sestamibi or -tetrofosmin are radiotracers used in single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI); studies done with TI-201 and Tc-99m have comparable accuracy.
- TI-201 is used more often to assess myocardial viability. Tc-99m radiopharmaceuticals have better imaging capability for gated SPECT evaluation of ejection fraction, left ventricular (LV) wall motion and wall thickening, and provide better image quality than TI-201.
- A normal perfusion study indicates low risk of cardiac events within the subsequent 1 to 2 years (risk < 1%).
- Reversible LV dysfunction in patients with coronary artery disease caused by hibernating (chronic resting ischemia) myocardium or repetitive stunning (repetitive demand ischemia) can be identified by TI-201 myocardial perfusion studies that show normalization of improvements of defects on resting delayed images compared with earlier resting images.
- Positron emission tomography (PET) scan with fluorine-18-fluorodeoxyglucose (F18-FDG) is the gold standard for identifying myocardial viability. Increased perfusion relative to metabolism is consistent with viability, while a matched severe metabolism and perfusion defect suggests nonviability.
- The sensitivity and specificity of acute rest imaging is superior to clinical evaluation and rest electrocardiogram in the emergency room for patients with chest pain. Its accuracy is highest if the injection is performed while the patient has chest pain, but injection and imaging 2 to 3 hours after resolution of the chest pain may be acceptable.
- Comparisons between patients with diabetes and patients without diabetes show that diabetic patients with ischemic defects have worse prognosis than nondiabetic patients; multivessel fixed defects are a strong predictor of mortality among diabetic patients.
- Selective catheterization after SPECT MPI is cost-effective when compared with direct catheterization. Cardiac events are similar for both groups (for pretest clinically low-, medium-, and high-risk patients), and there are substantial cost-savings with the noninvasive strategy.
- First-pass radionuclide angiography or gated blood pool imaging are 2 approaches for obtaining accurate ejection fraction and wall motion information using a Tc-99m tracer.

REFERENCES


