Radionuclide techniques may be used to identify, localize, and estimate the size of myocardial infarctions. Radionuclide methods may also be used to assess myocardial perfusion and estimate the impact of a myocardial infarction and of residual myocardial ischemia on ventricular function. These assessments provide diagnostic, therapeutic, and prognostic information.

Detection of Acute Myocardial Infarction with Infarct-Avid Imaging

Technetium-99m Stannous Pyrophosphate Scintigraphy

The prototype radionuclide imaging technique for detecting acute myocardial infarction is technetium-99m stannous pyrophosphate ($^{99m}$Tc-PPI) myocardial scintigraphy. Today, this imaging assessment is commonly made with single photon emission computed tomography (SPECT) that allows the detection of infarcts as small as 1 g, localization of the site of infarction, and accurate measurements of the size of the infarct. Technetium-99m-PPI scintigraphy was developed with the hypothesis that pyrophosphate might bind to calcium deposited in irreversibly damaged myocardial cells with myocardial infarction. Large numbers of patients have been evaluated with this technique and it has been repeatedly demonstrated that pyrophosphate administered one to four days after acute myocardial infarction, without reperfusion, identifies 85 to 90 percent of infarctions ordinarily missing only those less than 3 g in size, many of which are subendocardial in location. With thrombolytic therapy and the reestablishment of coronary blood flow soon after infarction, $^{99m}$Tc-PPI may be used for detection of infarction within one to two hours after the onset of symptoms suggestive of infarction. Given intravenously, $^{99m}$Tc-PPI and SPECT imaging within one to two hours of successful thrombolytic therapy allow accurate detection of small infarctions and the sizing of these lesions.

Previous clinicopathologic correlates have established that pyrophosphate is incorporated into areas of irreversible cellular damage with some persistent coronary blood flow and that pyrophosphate complexes with calcium deposited in soluble and insoluble form in the injured myocardial cells. Some of the pyrophosphate uptake may also be the result of nonspecific trapping within injured cells. More than four days after myocardial infarction, approximately half the abnormal pyrophosphate scans revert to negative as the area of infarction is replaced by inflammatory tissue and a scar develops. In patients who retain “persistently abnormal” results of $^{99m}$Tc-PPI myocardial scintigrams, clinicopathologic correlates have established continuing myocardial ischemia and chronic myocardial cellular injury as mechanisms for the “persistently abnormal” scintigrams.

Antimyosin Antibody Scintigraphy

An alternative to $^{99m}$Tc-PPI myocardial scintigraphy for detection of infarction is the utilization of antimyosin antibodies. Haber et al in Boston, Massachusetts have developed monoclonal antibodies specific against myosin that enter dying myocardial cells and bind to myosin in the interior of these cells. The antimyosin antibodies have been labeled with indium, iodine, and, more recently, technetium-99m. Extensive clinical studies have not yet been performed with this approach, but a sufficient number of patients have been evaluated to indicate that it may be used for purposes of infarction detection and to estimate the size of the lesions within hours to a few days after infarction. It is not yet established whether serial imaging using the antimyosin antibody approach will be safe and feasible.

Indications for Infarct-Avid Myocardial Scintigraphy

When it is not clear whether myocardial infarction has occurred, $^{99m}$Tc-PPI or possibly antimyosin antibody imaging may be useful in identifying new myocardial infarction. Patients with left bundle branch block, those who delay their hospital admission by more than one day after the onset of symptoms suggestive of infarction, patients undergoing open heart surgery with suspected perioperative myocardial infarction, patients whose infarctions are most likely to be "non-Q
wave" or subendocardial lesions, and patients who have had several previous infarctions are particularly good candidates for Tc-PPi or antimony antibody myocardial scintigraphy with SPECT. Following thrombolytic therapy, the presence of successful reperfusion may be documented utilizing the Tc-PPi myocardial imaging test since the scintigram findings are abnormal in patients within one hour of successful reperfusion and often do not show abnormal findings for several days in patients without successful reperfusion. Moreover, estimates of infarct size may be obtained from SPECT imaging with Tc-PPi or with antimony antibody imaging. Since infarction size (both old and new infarctions) is a major determinant of patient prognosis in-hospital, there are occasions when measurement of infarct size may be clinically important.

**Myocardial Perfusion Imaging**

*Thallium-201 Myocardial Scintigraphy*

Thallium-201 myocardial (Tl-201) scintigraphy may be used to identify myocardial infarcts and estimate the overall extent of ischemia-infarction when administered intravenously within eight to ten hours of symptoms suggestive of myocardial infarction. When more than 24 hours have elapsed following the onset of symptoms, Tl-201 scintigraphy loses sensitivity in detection of infarction, presumably as a result of the development of collateral flow to the injury. Thallium-201 accumulates in the myocardium in proportion to coronary blood flow; therefore, Tl-201 perfusion defects may indicate either ischemia or infarction. However, with reversible myocardial ischemia, the Tl-201 perfusion defects are generally transient and either totally or partially disappear with resolution of the myocardial ischemia, since Tl-201 accumulates in proportion to myocardial blood flow and its concentration is decreased in ischemic and/or infarcted myocardium.

The major use of Tl-201 imaging (and presumably of the technetium-labeled isonitril analogs) is with exercise testing for purposes of identifying exercise-induced myocardial ischemia or with pharmacologic-induced coronary vasodilation, using an agent such as dipyridamole. When Tl-201 is injected intravenously as 2.0 mCi at the peak of exercise, or after maximal physiological effect from intravenously or orally administered dipyridamole, the demonstration of a transient perfusion defect in the heart that resolves with repeat imaging three to four hours later usually represents reversible myocardial ischemia. In patients with recent myocardial infarction, low-level exercise testing at the time of hospital discharge, coupled with the administration of Tl-201, may be useful in predicting future prognosis, since patients with reversible Tl-201 perfusion defects are at increased risk for future myocardial infarction, unstable angina, death, and the need for surgical revascularization. Maximal exercise tests performed six weeks to three months after myocardial infarction coupled with Tl-201 myocardial scintigraphy may be used to identify reversible myocardial ischemia and the presence of additional physiologically significant coronary artery stenoses outside of the infarct area.

**Radionuclide Ventriculography**

Radionuclide ventriculography, either as single pass methodology or multigated image acquisition study (MUGA imaging), may be used to establish the effect of a myocardial infarction on both left and right ventricular function by measuring ventricular ejection fraction, end-systolic volume, and segmental ventricular function. This allows the identification of ventricular dysfunction when it is not apparent clinically, and it is also useful in predicting prognosis. Patients with left ventricular ejection fractions less than 40 percent have a relatively poor prognosis in the future.

Radionuclide ventriculography may also be used at low level exercise at the time of hospital discharge to identify ventricular dysfunction caused by additional physiologically important coronary artery stenoses. Patients demonstrating reductions in their left ventricular ejection fractions and/or increases in their LV end-systolic volumes at low levels of exercise have a higher risk of death, new myocardial infarction, unstable angina, and for developing heart failure in the subsequent eight months.

**Fatty Acid Myocardial Scintigraphy**

Patients with previous myocardial infarction demonstrate reductions in fatty acid uptake and more rapid clearance of fatty acids when assessed either using positron emission tomography and C-11 palmitate or iodine-123 phenylpentadecanoic acid. With successful reperfusion therapy and containment of infarction size, one may be able to demonstrate relatively normal fatty acid uptake and clearance in jeopardized myocardial regions when reperfusion is accomplished early and substantial viable myocardial tissue remains. In addition, myocardial imaging with 18F 5-fluorodeoxyglucose may allow one to identify ischemic myocardium, especially with early reperfusion and/or at the margins of an area of infarction since ischemic myocardium depends more heavily on glucose and less significantly on fatty acids as a preferred metabolic substrate.

**Magnetic Resonance Imaging**

Preliminary assessments have made it clear that magnetic resonance imaging may be used to detect areas of myocardial infarction and of reperfusion following infarction, especially when coupled with para-
magnetic enhancing agents, such as gadolinium DTPA. Furthermore, magnetic resonance imaging may allow the detection of areas of infarction as regions of systolic wall thinning and of hypokinetic function. This imaging modality has the advantage of obtaining images without the need for administering ionizing radiation. Most likely, magnetic resonance imaging systems for diagnostic imaging and spectroscopy (metabolie study) will be available in major medical centers in the coming years. The imaging and spectroscopic assessments should be of diagnostic assistance in recognizing areas of myocardial injury, including myocardial infarction and estimating the size of such lesions. They should also be of assistance in identifying myocardial regions supplied by severely narrowed coronary arteries. As imaging times are shortened, it should become possible to couple some form of stress with magnetic resonance imaging and spectroscopy providing assessments of global and segmental LV function, perfusion, and metabolism.

BIBLIOGRAPHY


