

RADIONUCLIDE IMAGING IN ACUTE CORONARY SYNDROMES

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INTRODUCTION

More than 6 million patients present with *acute chest pain* to emergency departments (EDs) in the United States annually. Only a minority will have diagnostic electrocardiogram (ECG) changes and be diagnosed with *acute coronary syndrome* (ACS).¹ In fact, the vast majority of patients presenting with acute chest pain will have normal or nondiagnostic ECG findings. However, most of these patients are typically hospitalized to rule out myocardial infarction despite actually having a very low rate of acute infarction, and less than half will be found to have a cardiac etiology for their chest pain. This practice of admitting most patients with chest pain has been estimated to cost more than 10 billion US dollars annually, or almost \$2 million per-life saved in this group.² This conservative approach arises from observational studies finding that as many as 5% of myocardial infarctions occur in patients sent home from the ED. These *missed* myocardial infarctions are associated with both poor patient outcomes and significant medicolegal consequences, accounting for more than 20% of malpractice dollars awarded in emergency medicine litigation.³⁻⁷ In response to this significant dilemma, many medical centers have developed chest pain protocols or dedicated chest pain centers (CPCs) in an attempt to reduce the number of unnecessary hospitalizations for acute chest pain.

Rest radionuclide *myocardial perfusion imaging* (MPI) has been used in this setting to enhance diagnostic accuracy in detecting acute infarction and thus reduce unnecessary hospitalizations. Furthermore, recent advances in

the development of radiopharmaceuticals that specifically target *myocardial ischemia* or infarction have substantial promise in the triage of patients with acute chest pain. The role of *hot spot imaging* for acute infarction or ongoing ischemia in the ED holds promise as a means to identify acute ischemia more rapidly than currently available tests (eg, serum markers of infarction such as creatinine kinase and troponin). Hot spot imaging would thereby facilitate more appropriate triage of patients with ACS who should be admitted with acute chest pain from those patients with non-cardiac chest pain who can be safely released from the ED.

MYOCARDIAL PERFUSION IMAGING IN THE TRIAGE OF PATIENTS WITH ACUTE CHEST PAIN

Because the clinical risk stratification of acute chest pain is challenging in patients who do not have overt ECG changes, a variety of diagnostic techniques have been employed in the ED to improve diagnostic certainty and facilitate the timely identification of acute ischemia. These techniques include *continuous 12-lead electrocardiography*, *immediate treadmill stress testing without any serum marker evaluation*, *serial serum markers of myocardial injury*, *resting echocardiography*, and *resting single-photon-emission computed tomography (SPECT) MPI*. Most chest pain protocols first exclude myocardial infarction with one or more of these tests, and many of these protocols involve some provocative testing (eg, exercise ECG, exercise or pharmacologic stress testing with MPI) before the patient is discharged.

DETECTION OF MYOCARDIAL INFARCTION

Rest SPECT imaging has been studied extensively in the evaluation of patients with acute chest pain; this modality has been shown to be a reliable diagnostic technique for excluding both myocardial infarction and significant coronary artery disease. In the 1970s, Wackers and colleagues^{8,9} demonstrated the ability of *thallium* imaging (after injection at rest) to identify the infarct region in patients with acute myocardial infarction who were admitted to the coronary care unit. However, the need for a cyclotron to produce thallium

limited its widespread clinical use in this setting. The development of generator-produced technetium-labeled imaging agents, such as *sestamibi* and *tetrofosmin*, has renewed interest in radionuclide imaging of patients with possible ACS. Many studies have demonstrated these agents to be highly sensitive for detecting acute myocardial infarction when injection and imaging are performed within a few hours of chest pain onset. In most of these studies, the sensitivity to detect acute myocardial infarction exceeds 95%.¹⁰⁻¹⁷ Perhaps of greatest importance is the finding that normal resting perfusion imaging after injection within 6 hours of chest pain onset is associated, on average, with a >99% *negative predictive value* for excluding acute myocardial infarction (Table 1). This excellent sensitivity in detecting acute infarction makes immediate rest SPECT MPI a valuable screening tool for patients with acute chest pain who do not have other overt indications of an ACS on presentation. An example of a patient evaluated with rest SPECT MPI imaging in the ED is shown in Figure 1.

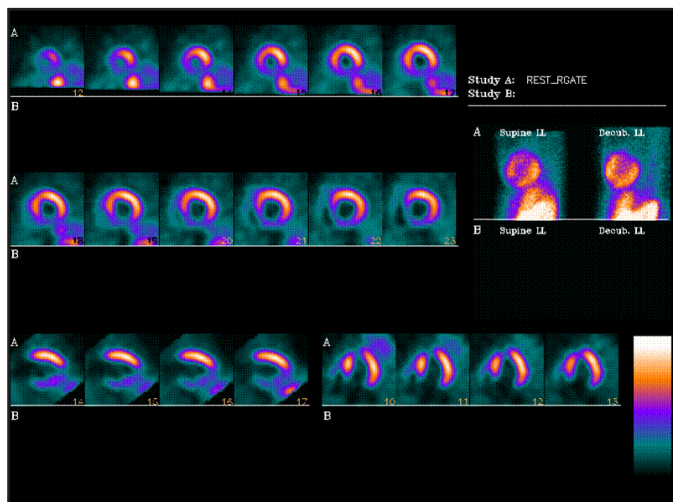


FIGURE 1. Example of SPECT MPI performed in a patient who presented to the emergency department chest pain center with ongoing chest pain and normal ECG findings. The images acquired after rest injection of Tc-99m-labeled sestamibi demonstrate an extensive defect involving the inferior wall. Because of these abnormal findings on imaging, the patient was brought directly to the cardiac catheterization laboratory. Coronary angiography showed a subtotal occlusion of the right coronary artery, which was subsequently treated successfully with percutaneous transluminal coronary angioplasty and intra-coronary stenting.

Triage strategies that incorporate rest SPECT imaging into the clinical decision making process have demonstrated an incremental benefit over risk stratification that is based on clinical, ECG, and serum marker criteria alone. The ERASE study¹¹ was a multicenter trial involving 2,456 patients presenting to the ED with chest

pain and normal or nondiagnostic ECG findings; these patients were randomized to usual care or immediate rest SPECT MPI. Overall, 14% of patients were diagnosed clinically as having ACS. Those patients without ACS were then randomized to usual care or evaluation with immediate rest Tc-99m-labeled sestamibi SPECT MPI within a few hours of chest pain onset. Overall, 52% in the usual care group were hospitalized compared with 42% in the group assigned to treatment with immediate rest. What is more important, there was a 14% reduction in total hospitalizations, and a 32% reduction in unnecessary hospitalizations, when SPECT MPI was incorporated into the initial triage decision; however, there was no difference in *appropriate* admissions using this strategy.

IDENTIFYING MYOCARDIAL ISCHEMIA

Perhaps the greatest clinical value of rest SPECT imaging is the ability to detect myocardial ischemia/injury earlier than widely used serum markers, such as *troponin*. Kontos and co-workers¹⁵ compared the ability of rest SPECT imaging and serum cardiac troponin I to detect myocardial infarction and significant coronary artery disease in 620 patients with acute chest pain in the emergency department. Rest SPECT MPI and *serial* measurements of troponin detected 92% and 90% of all infarcts diagnosed at discharge, respectively. However, rest SPECT imaging was more sensitive in the early detection of myocardial infarction on presentation (92% vs 39%) and was also more predictive of the need for revascularization. Thus, the use of rest SPECT MPI not only improves the triage of patients with chest pain by increasing the accuracy in detecting myocardial infarction, but is also useful in determining which patients should undergo further evaluation.

Radionuclide imaging has also been used to facilitate the evaluation of patients once acute myocardial infarction has been excluded with rest MPI or serum markers. Although infarction has been excluded, the etiology of the chest pain may still be secondary to underlying coronary disease and ischemia. As such, it is ideal to employ some form of provocative testing in these patients to identify or exclude significant ischemia as part of the triage process. Although provocative testing can typically be performed using *exercise ECG*, as many as one third of ED chest pain patients will not be able to perform physical stress testing due to inability to exercise (ie, pulmonary or musculoskeletal problems) or a baseline ECG abnormality (ie, left ventricular hypertrophy, digitalis therapy, pacemaker, left bundle branch block, baseline ST-T wave abnormalities) that precludes performance of an adequate exercise ECG test. In such circumstances, MPI can be used to facilitate the complete evaluation of these patients before discharge from the ED. MPI with pharmacological stress (ie, dipyridamole, adenosine, and dobutamine) has been used safely and effectively in patients who cannot undergo

exercise ECG. With such a protocol of using rest and/or stress SPECT imaging when necessary, Abbott and co-workers were able to reduce the proportion of patients with chest pain admitted from the ED from 54% to 45%.¹⁸ Moreover, the proportion of chest pain patients admitted with a diagnosis of “rule out myocardial infarction” decreased significantly (from 32% to 18%).

PRACTICAL CONSIDERATIONS

The decision to use rest SPECT imaging in the ED triage of acute chest pain requires the coordinated effort of many hospital staff members, including emergency medicine physicians, cardiologists, and nuclear cardiology or nuclear medicine personnel. The radiopharmaceuticals must be prepared in advance and should be readily available for use at all times, including nights and weekends. Eligible patients can be injected at rest with *Tc-99m-labeled sestamibi* or *tetrofosmin*, and imaging can be performed even a few hours later when the patients are pain free and hemodynamically stable. The advent of web-based teleradiology permits off-site expert interpretation of these imaging studies during off-hours.

The American Society of Nuclear Cardiology recently published guidelines summarizing both the diagnostic and prognostic importance, as well as the cost effectiveness, of the use of rest MPI in ED patients with suspected acute ischemic syndromes.¹⁹ When applied to appropriate patients in the ED, MPI at rest is an invaluable tool to risk-stratify patients at low risk who can be safely discharged from those patients at higher risk of short-term cardiac events who should be admitted for further evaluation.

‘HOT-SPOT’ IMAGING IN ACUTE CORONARY SYNDROMES

Although rest MPI has been shown to be highly sensitive for detecting acute ischemia and infarction in patients with chest pain and a normal or nondiagnostic ECG finding, its application can be limited in patients with known coronary artery disease, because a rest injection of radiotracer cannot readily distinguish between acute ischemia and prior injury (ie, scarring). This is a significant limitation of rest SPECT MPI in the evaluation of patients with known coronary artery disease—a limitation that reduces the overall specificity of rest MPI.

INFARCT-AVID RADIONUCLIDE IMAGING

Rest SPECT MPI will demonstrate a *myocardial defect* in both ACS and prior MI. One solution to this lack of differentiation would be the use of a radionuclide that more specifically detects acute myocardial infarction or ischemia by only showing uptake or accumulation in myocardium that is ischemic or necrotic. This para-

digm of “hot-spot” imaging is more widely used in other nuclear medicine studies, such as tumor imaging, but has also been employed in cardiac imaging. In 1989, *Tc-99m-pyrophosphate*, an agent (initially designed for bone imaging) that binds avidly to calcium, demonstrated excellent sensitivity for detecting calcium deposition in recent transmural infarcts.²⁰ However, later studies have shown that the sensitivity to detect subendocardial infarction was suboptimal. A major practical limitation of *Tc-99m-pyrophosphate* as an infarct-avid imaging agent is that acute infarction can only be reliably detected 12 to 24 hours after the acute event, which is too late to be of clinical value.

Immunoscintigraphy, which is also more widely used in the field of tumor oncology, can be used for detecting acute infarction. Radiolabeled antibodies designed to bind such specific targets as exposed myosin in necrotic myocardial tissue have been studied in animals and more recently in the clinical setting. Indium-111-labeled antimyosin has been shown to be highly sensitive in detecting Q-wave and non-Q-wave infarcts.²¹ However, slow clearance of this agent from the blood pool does not permit imaging earlier than 18 hours after administration, thereby limiting the usefulness of this agent in evaluating acute chest pain.

Recently, *Tc-99m-labeled annexin-V*, which binds to the plasma membrane of myocytes undergoing apoptosis due to infarction or repetitive ischemia, has been evaluated in animals as well as a limited number of humans early in the course of acute infarction after reperfusion.²² This agent has demonstrated excellent co-localization with sestamibi in areas of acute injury, and interpretable images can be acquired within 4 hours of injection.

Perhaps the most promising radiopharmaceutical for detecting acute infarction is *Tc-99m-labeled glucarate*, which binds to nuclear histones exposed in recently damaged myocytes. Preclinical studies of *Tc-99m-glucarate* have documented early visualization of both reperfused and nonreperfused infarcts with *in vivo* imaging, and have noted a lack of accumulation of this agent in models of ischemia or chronic infarction.^{23,24} These characteristics—along with a short biologic half-life, favorable target-to-background ratio, and rapid blood pool clearance—make this imaging agent ideal for detecting acute infarction in ED patients who have chest pain. In patients with chest pain and a high likelihood of infarction on presentation, planar imaging of *Tc-99m-glucaric acid* localized acute myocardial injury when injected within 9 hours of chest pain onset. Uptake of glucarate was found to be highly specific for acute myocardial injury because tracer uptake was not observed in patients with *unstable angina* or patients with acute infarction injected > 9 hours after the onset of chest pain. This early experience in high-risk patients appears promising, but further study of this agent is necessary in low- to moderate-risk patients who have acute chest pain.

IMAGING ISCHEMIA

The ability to detect or exclude myocardial ischemia in patients with acute chest pain is of substantial value in the emergency department, because patients without acute infarction may still have unstable angina or significant coronary disease as the cause of their symptoms. Resting myocardial perfusion imaging is unable to differentiate between acute infarction and ischemia. Moreover, radionuclide myocardial perfusion imaging is confounded by attenuation artifacts that may mimic perfusion defects. The development of imaging agents that specifically localize within areas of ongoing ischemia would be advantageous for risk-stratifying ED patients with chest pain and nondiagnostic ECG findings. Furthermore, a radiopharmaceutical that is highly sensitive for low levels of ischemia could be used to reliably *exclude* ischemia, thus permitting early discharge of low-risk patients without further evaluation.

Once again drawing from the field of tumor oncology, the use of nitroimidazoles—a class of compounds used as adjuvants in chemotherapy to sensitize tumors—may have potential in the evaluation of acute chest pain. These agents are retained in hypoxic tissue and can be labeled with Tc-99m or fluorine-18 for imaging. In vivo imaging studies using the nitroimidazole compound BMS181321 in animal models of transient coronary occlusion, partial coronary occlusion, and both low flow and demand ischemia have demonstrated significant focal uptake and retention of this compound in ischemic regions.²⁵ However, robust hepatic uptake prevented adequate image acquisition within the first hour after injection, and this agent has not been evaluated clinically.

Findings from preliminary studies of Tc-99m HL-91—another marker for the detection of acute ischemia—have also indicated tracer localization in areas of low flow and hypoxia; thus, Tc-99m HL-91 is a potential agent for clinical evaluation.²⁶

The positron-emitter ¹⁸F-fluorodeoxyglucose (FDG) has been widely used clinically for the determination of myocardial viability. FDG is taken up in proportion to glucose uptake; it concentrates in ischemic myocardial tissue due to alterations in metabolic extraction and substrate utilization. The specificity of FDG to localize ischemia makes this agent a theoretically reasonable choice for use in patients with acute chest pain, and recent advances in camera technology have made the SPECT imaging of positron-emitting agents feasible. However, the use of FDG for detecting acute ischemia has not been evaluated. Furthermore, it has a short half-life and must be synthesized in a cyclotron.

THE IDEAL POSITIVE IMAGING AGENT

The main goals for the evaluation of patients with acute chest pain and nondiagnostic ECG findings are to exclude acute infarction and ischemia in low- to mod-

erate-risk patients as well as reliably detect ongoing or impending myocardial injury and ischemia in patients with atypical presentations of acute coronary syndrome. All of the aforementioned radionuclide imaging agents have the potential to achieve these goals; however, they also have significant limitations, such as robust hepatic uptake or slow blood pool clearance. An ideal imaging agent to distinguish patients with ACS from those patients without significant ischemia (ie, those patients who could be sent home) should have the following characteristics:²⁷

- Very high sensitivity for ongoing low levels of ischemia
- Good specificity for acute injury (ie, not taken up in areas of prior injury)
- Sufficient specific activity to detect small regions of injury
- Favorable target-to-background ratio with rapid blood pool clearance and minimal extracardiac activity (ie, gastrointestinal) to permit early imaging
- Ability to image with standard equipment

Infarct- and ischemia-avid imaging has great potential to reliably risk-stratify patients with chest pain and nondiagnostic ECG findings at the time of presentation in the ED. Further evaluation of currently available radiopharmaceuticals and the development of novel imaging agents that localize in acute cardiac injury will be necessary before hot-spot imaging can be used routinely in the emergency department for the evaluation of acute chest pain.

SUMMARY

Radionuclide imaging is a highly useful tool in the ED setting. Rapid detection of myocardial infarction and ischemia can be achieved using resting myocardial perfusion imaging. This approach has been demonstrated to be very sensitive in detecting ongoing ischemia, such that a normal scan at rest within a few hours of symptom onset has a >99% negative predictive value for acute myocardial infarction as well as subsequent short-term events. Rest MPI has also been shown to be cost-effective in the triage of ED patients with acute chest pain by reducing unnecessary hospitalizations and avoiding inappropriate discharge of patients who have *missed* myocardial infarctions. Novel hot-spot imaging agents that specifically target myocardial ischemia and infarction have the potential to more accurately identify ischemia in the ED; these agents are currently under investigation.

REFERENCES

1. McCaig LF, Burt CW. National Hospital Ambulatory Medical Care Survey: 2001 Emergency Department Survey [CDC Web Site]. *Adv Data*. 2003; 335:1-29 Available at: <http://www.cdc.gov/nchs/data/ad/ad335.pdf>. Accessed June 13, 2011.
2. McCullough PA, Ayad O, O'Neill WW, Goldstein JA. Costs and outcomes of patients admitted with chest pain and essentially normal electrocardiograms. *Clin Cardiol*. 1998;21:22-6.
3. Freas GC. Medicolegal aspects of acute myocardial infarction. *Emerg Med Clin North Am*. 2001;19:511-21.
4. Lee TH, Rouan GW, Weisberg MC, et al. Clinical characteristics and natural history of patients with acute myocardial infarction sent home from the emergency room. *Am J Cardiol*. 1987;60:219-24.
5. McCarthy BD, Beshansky JR, D'Agostino RB, Selker HP. Missed diagnoses of acute myocardial infarction in the emergency department: results from a multicenter study. *Ann Emerg Med*. 1993;22:579-82.
6. Pope JH, Aufderheide TP, Ruthazer R, et al. Missed diagnoses of acute cardiac ischemia in the emergency department. *N Engl J Med*. 2000;342:1163-70.
7. Storrow AB, Gibler WB. Chest pain centers: diagnosis of acute coronary syndromes. *Ann Emerg Med*. 2000;35:449-61.
8. Wackers FJ, Sokole EB, Samson G, et al. Value and limitations of thallium-201 scintigraphy in the acute phase of myocardial infarction. *N Engl J Med*. 1976;295:1-5.
9. Wackers FJ, Lie KI, Liem KL, et al. Thallium-201 scintigraphy in unstable angina pectoris. *Circulation*. 1978;57:738-42.
10. Varetto T, Cantalupi D, Altieri A, Orlandi C. Emergency room technetium-99m sestamibi imaging to rule out acute myocardial ischemic events in patients with nondiagnostic electrocardiograms. *J Am Coll Cardiol*. 1993;22:1804-8.
11. Udelson JE, Beshansky JR, Ballin DS, et al. Myocardial perfusion imaging for evaluation and triage of patients with suspected acute cardiac ischemia: a randomized controlled trial. *JAMA*. 2002;288:2693-700.
12. Hilton TC, Thompson RC, Williams HJ, Saylor R, Fulmer H, Stowers SA. Technetium-99m sestamibi myocardial perfusion imaging in the emergency room evaluation of chest pain. *J Am Coll Cardiol*. 1994;23:1016-22.
13. Heller GV, Stowers SA, Hendel RC, et al. Clinical value of acute rest technetium-99m tetrofosmin tomographic myocardial perfusion imaging in patients with acute chest pain and nondiagnostic electrocardiograms. *J Am Coll Cardiol*. 1998;31:1011-7.
14. Kontos MC, Jesse RL, Schmidt KL, Omato JP, Tatum JL. Value of acute rest sestamibi perfusion imaging for evaluation of patients admitted to the emergency department with chest pain. *J Am Coll Cardiol*. 1997;30:976-82.
15. Kontos MC, Jesse RL, Anderson FP, Schmidt KL, Ornato JP, Tatum JL. Comparison of myocardial perfusion imaging and cardiac troponin I in patients admitted to the emergency department with chest pain. *Circulation*. 1999;99:2073-8.
16. Radensky PW, Hilton TC, Fulmer H, McLaughlin BA, Stowers SA. Potential cost effectiveness of initial myocardial perfusion imaging for assessment of emergency department patients with chest pain. *Am J Cardiol*. 1997;79:595-9.
17. Tatum JL, Jesse RL, Kontos MC, et al. Comprehensive strategy for the evaluation and triage of the chest pain patient. *Ann Emerg Med*. 1997;29:116-25.
18. Abbott BG, Abdel-Aziz I, Nagula S, Monico EP, Schriver JA. Selective use of single-photon emission computed tomography myocardial perfusion imaging in a chest pain center. *Am J Cardiol*. 2001;87:1351-5.
19. Anonymous. Imaging guidelines for nuclear cardiology procedures. American Society of Nuclear Cardiology. Myocardial perfusion SPECT protocols. *J Nucl Cardiol*. 1996;3:G34-46.
20. Khaw BA, Haber E. Imaging necrotic myocardium: detection with 99mTc-pyrophosphate and radiolabeled antimyosin. *Cardiol Clin*. 1989;7:577-88.
21. Senior R, Bhattacharya S, Manspeaker P, Liux XJ, Leppo JA, Lahiri A. 99mTc-antimyosin antibody imaging for the detection of acute myocardial infarction in human beings. *Am Heart J*. 1993;126:536-42.
22. Hofstra L, Liem IH, Dumont EA, et al. Visualisation of cell death in vivo in patients with acute myocardial infarction. *Lancet*. 2000;356:209-12.
23. Narula J, Petrov A, Pak KY, Lister BC, Khaw BA. Very early noninvasive detection of acute experimental nonreperused myocardial infarction with 99mTc-labeled glucarate. *Circulation*. 1997;95:1577-84.
24. Johnson LL, Schofield L, Mastrofrancesco P, Donahay T, Farb A, Khaw BA. Technetium-99m glucarate uptake in a swine model of limited flow plus increased demand. *J Nucl Cardiol*. 2000;7:590-8.
25. Okada RD, Nguyen KN, Strauss HW, Johnson G 3rd. Effects of low flow and hypoxia on myocardial retention of technetium-99m BMS181321. *Eur J Nucl Med*. 1996;23:443-7.
26. Okada RD, Johnson G 3rd, Nguyen KN, Edwards B, Archer CM, Kelly JD. 99mTc-HL91 effects of low flow and hypoxia on a new ischemia-avid myocardial imaging agent. *Circulation*. 1997;95:1892-9.
27. Abbott BG, Wackers FJ. Use of radionuclide imaging in acute coronary syndromes. *Curr Cardiol Rep*. 2003;5:25-31.
28. Duca MD, Giri S, Wu AH, et al. Comparison of acute rest myocardial perfusion imaging and serum markers of myocardial injury in patients with chest pain syndromes. *J Nucl Cardiol*. 1999;6:570-6.

RADIONUCLIDE IMAGING IN ACUTE CORONARY SYNDROMES POST TEST

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1. **Missed myocardial infarctions make up approximately what percentage of malpractice dollars awarded in ED litigation?**
 - a. 2
 - b. 7
 - c. 10
 - d. 20
2. **Currently, the most commonly used method employed in the ED to identify acute ischemia is**
 - a. cardiac CT calcium scoring.
 - b. testing for serum markers of infarction (ie, troponin).
 - c. cardiac catheterization.
 - d. MR angiography.
3. **Using generator-produced technetium-labeled imaging agents, the sensitivity to detect acute myocardial infarction is estimated to exceed what percentage?**
 - a. 60
 - b. 75
 - c. 85
 - d. 95
4. **If the resting perfusion study is performed during or within 6 hours of chest pain onset, acute myocardial infarction can be excluded with a confidence of greater than**
 - a. 75%.
 - b. 85%.
 - c. 90%.
 - d. 99%.
5. **After SPECT MPI was incorporated into the initial triage decision, there was**
 - a. a 32% reduction in unnecessary hospitalizations.
 - b. an overall decrease in hospitalizations, but more cases of ACS went undiagnosed.
 - c. an improvement in the diagnosis of ACS, but no change in the number of hospitalizations.
 - d. an improvement in ACS diagnosis, but a significant increase in cost due to an increase in the number of unnecessary hospitalizations.
6. **Clinically, one of the greatest advantages in using rest SPECT MPI is that it is**
 - a. less expensive than testing for serum markers.
 - b. much easier to perform than testing for serum markers.
 - c. able to detect myocardial ischemia/injury before markers appear in the serum.
 - d. more universally available than tests for serum markers.
7. **What percentage of patients presenting to the ED with chest pain will NOT be able to perform physical stress testing?**
 - a. 5
 - b. 10
 - c. 25
 - d. 33
8. **All of the following are agents used to provide the pharmacological stress used with MPI EXCEPT**
 - a. dipyridamole.
 - b. fluorodeoxyglucose.
 - c. adenosine.
 - d. dobutamine.
9. **Practical considerations in the use of rest SPECT imaging in the ED setting include**
 1. coordinating the efforts of many hospital staff members.
 2. ensuring the availability of radiopharmaceuticals.
 3. arranging for expert interpretation of images during off-hours.
 - a. 1 only
 - b. 2 only
 - c. 3 only
 - d. 1, 2, and 3
10. **Rest SPECT MPI can be limited to patients who have**
 - a. known coronary artery disease.
 - b. diabetes mellitus.
 - c. a history of stroke.
 - d. emphysema.
11. **A radionuclide that specifically detects acute myocardial infarction or ischemia by only showing uptake or accumulation in myocardium that is ischemic or necrotic is described as**
 - a. positron-emitting.
 - b. plasma binding.
 - c. cardiac binding.
 - d. infarct-avid.
12. **Immunoscintigraphy is most commonly used in**
 - a. tumor oncology.
 - b. orthopedics.
 - c. rheumatology.
 - d. trauma medicine.
13. **What factor limits the use of indium-111-antimyosin?**
 - a. It does not permit imaging earlier than 18 hours after administration.
 - b. There is a high rate of allergic reaction after administration.
 - c. It is highly cardiotoxic.
 - d. It cannot detect non-Q-wave infarcts.
14. **Tc-99m-labeled annexin-V binds to**
 - a. nuclear histones exposed in recently damaged myocytes.
 - b. antimyosin.
 - c. the plasma membrane of myocytes undergoing apoptosis due to infarction or repetitive ischemia.
 - d. calcium.

15. Advantages of Tc-99m-glucarate are

1. early visualization of both reperfused and non-reperfused infarcts with in vivo imaging, but lack of accumulation in models of ischemia or chronic infarction.
2. short biologic half-life.
3. favorable target-to-background ratio and rapid blood pool clearance.
4. extensive clinical studies documenting its usefulness in all risk levels of patients with acute chest pain.
 - a. 1 and 2
 - b. 1 and 4
 - c. 1, 2, and 3
 - d. 1, 3, and 4

16. Planar imaging of Tc-99m-glucuric acid localized acute myocardial injury when injected within ____ hours of chest pain onset.

- a. 2
- b. 6
- c. 9
- d. 48

17. Nitroimidazoles are a class of compounds that have been used as adjuvants to

- a. oral hypoglycemics for type II diabetics.
- b. blood-pressure-lowering medications in patients with hypertension.
- c. tissue plasminogen activators for the treatment of acute ischemic stroke.
- d. chemotherapy to sensitize tumors.

18. Which of the following is a positron-emitter that has been widely used for the determination of myocardial viability?

- a. Oxygen-15
- b. ^{18}F -FDG
- c. Tc-99m HL-91
- d. Fluorine-18

19. The main goals of the evaluation of patients with acute chest pain and nondiagnostic ECG findings are to

1. exclude acute infarction.
2. exclude ischemia.
3. detect ongoing or impending myocardial injury and ischemia.
 - a. 1 only
 - b. 2 only
 - c. 3 only
 - d. 1, 2, and 3

20. All of the following are characteristics of an optimal imaging agent EXCEPT

- a. slow blood pool clearance.
- b. very high sensitivity for ongoing low levels of ischemia.
- c. good specificity for acute injury.
- d. ability to image with standard conventional equipment.



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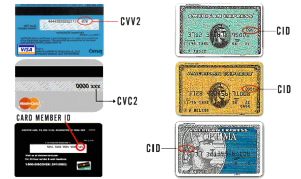
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