Review Article

Primary Care

Evaluation of the Patient with Acute Chest Pain

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THE evaluation of acute chest pain remains challenging, despite many insights and innovations over the past two decades. The percentage of patients who present at the emergency department with acute chest pain and are admitted to the hospital may actually be increasing.[1-6] The reasons for clinical caution are familiar to most physicians. Patients with acute myocardial infarction who are mistakenly discharged from the emergency department have short-term mortality rates of about 25 percent, at least twice what would be expected if they were admitted.[7] The legal costs that can result from such cases constitute the largest category of losses from malpractice litigation in the emergency department.[8] However, the admission of a patient with chest pain who is at low risk for acute myocardial infarction costs an average of $2,000 to $5,000 at many institutions and can lead to unnecessary tests and procedures, with their attendant costs and complications. Therefore, with increasing economic pressures on health care, most physicians, health plans, and medical centers are interested in improving the efficiency of care for patients with acute chest pain.

Clinicians can use validated decision aids (algorithms designed to improve decision making by physicians)[1-6] and newly identified markers of myocardial injury to improve the accuracy of diagnosis and the determination of risk.[9-13] The use of exercise testing soon or immediately after admission to the hospital can help establish the safety of discharge for patients at low risk.[14,15] Special chest-pain units and critical pathways (guidelines describing key steps for care of the patient) can standardize and expedite these evaluations.[16,17] Progress can be achieved by integrating clinical data[18] with information from new forms of technology.

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Clinical Evaluation

The evaluation of acute chest pain should begin with a clinical history taking that focuses on the characteristics of pain, the time of onset, and the duration of symptoms and an examination that emphasizes vital signs and cardiovascular status. The most important single source of data, the electrocardiogram, should be obtained within five minutes after presentation. In our recent experience with more than 2000 patients with acute chest pain, the prevalence of acute myocardial infarction was 80 percent among patients with 1 mm or more of new ST-segment elevation and 20 percent among patients with ST-segment depression or T-wave inversion not known to be old. In the absence of electrocardiographic changes consistent with the presence of ischemia, the risk of acute myocardial infarction was 4 percent among patients with a history of coronary artery disease and 2 percent among patients with no such history (unpublished data).

Malpractice cases often focus on the performance and use of electrocardiography. Some of the most common causes of losses from malpractice litigation related to acute chest pain are the failure to perform electrocardiography, misinterpretation of an electrocardiogram, and failure to record data from the clinical evaluation. When the electrocardiogram shows ST-segment changes or T-wave abnormalities that are consistent with the presence of ischemia and are not known to be old, discharge home without further evaluation is hazardous both clinically and legally.

In the evaluation of these data, the initial focus should be on the possibility of acute life-threatening conditions, including acute ischemic heart disease, aortic dissection, and pulmonary embolism. In a typical population of patients with acute chest pain who present at the emergency department, approximately 15 percent have acute myocardial infarction and about 30 to 35 percent have unstable angina. In the 1980s, about 4 percent of patients with acute myocardial infarction were mistakenly sent home from the emergency department, but more recently, Pope et al. found that only 2.1 percent of patients with acute myocardial infarction were discharged from the emergency department.[19] In that population, the risk-adjusted mortality was approximately double that of patients who had been admitted. If acute ischemic heart disease seems unlikely to be the cause of the chest pain, the possibility of pulmonary, gastrointestinal, and musculoskeletal conditions as well as pericarditis and other cardiovascular causes should be investigated, often in

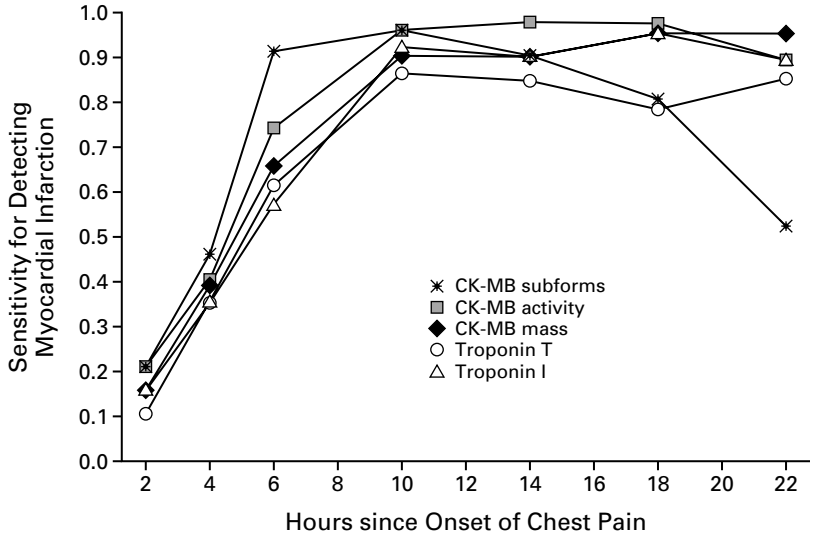

Figure 1. Diagnostic Sensitivity of Macromolecular Markers of Myocardial Infarction According to the Length of Time from the Onset of Chest Pain.

Data are from Zimmerman et al.[24] CK-MB denotes creatine kinase MB isoenzyme.

the outpatient setting by the patient's regular physician. Evidence suggests that esophageal spasm and gastroesophageal reflux disease account for a substantial number of cases of acute noncardiac chest pain.[20]

EMERGENCY TREATMENT

Patients with circulatory instability due to shock or with serious arrhythmias require urgent therapy and rapid transfer to an intensive care unit. If aortic dissection is suspected on the basis of radiologic or echocardiographic studies, arrangements should be made for the transfer of the patient to a facility with the capability to perform the surgical repair even as blood pressure is being controlled with such agents as intravenous nitroprusside or labetalol.[21]

For most patients with acute chest pain, however, the electrocardiogram is critical for guiding initial therapy and decisions with regard to admission. For patients who present within a few hours after the onset of symptoms and have ST-segment elevation of more than 1 mm in two or more leads, urgent coronary recanalization with primary percutaneous transluminal coronary angioplasty or intravenous thrombolytic agents should be performed unless there are contraindications.[22] For patients with other electrocardiographic changes that are indicative of ischemia, such as flat or down-sloping ST-segment depression or T-wave inversions, the presumptive diagnosis, until proved otherwise, must be an ongoing acute coronary syndrome with no ST-segment elevation. Treatment such as aspirin, intravenous heparin, or a platelet glycoprotein IIb/IIIa receptor antagonist (and commonly, in addition, nitrates, beta-blockers, or both) should be instituted while the diagnostic evaluation is beginning.[23]

The cases of patients without such electrocardiographic changes represent more of a diagnostic challenge than a therapeutic imperative. To guide decision making with regard to these patients at intermediate or low risk, attention has focused on the use of macromolecular markers, management guidelines, hospital units for the evaluation of chest pain, and noninvasive diagnostic tests.

MACROMOLECULAR MARKERS OF MYOCARDIAL INJURY

The availability of newly identified markers of myocardial injury has permitted new strategies to be used for evaluating patients with acute chest pain, but there is confusion about the optimal use of these tests. Levels of creatine kinase MB isoenzyme (CK-MB) usually rise above the normal range within 4 hours after the onset of myocardial infarction, and serial sampling of CK-MB over a period of 12 to 24 hours permits the detection of virtually all acute myocardial infarctions (Fig. 1). However, CK-MB elevations can result from causes other than myocardial injury. Furthermore, a knowledge of CK-MB levels is not helpful for determining the prognosis in patients with unstable angina.[25]

The cardiac troponins, T and I,[10-13] are encoded by different genes in cardiac muscle, slow skeletal muscle, and fast skeletal muscle; hence, these markers are more specific than CK-MB for myocardial injury. After myocardial injury, the levels of cardiac troponins rise after approximately the same amount of time as CK-MB levels and remain elevated for several days. Once elevated, however, the cardiac troponins are not useful in detecting repeated episodes of myocardial

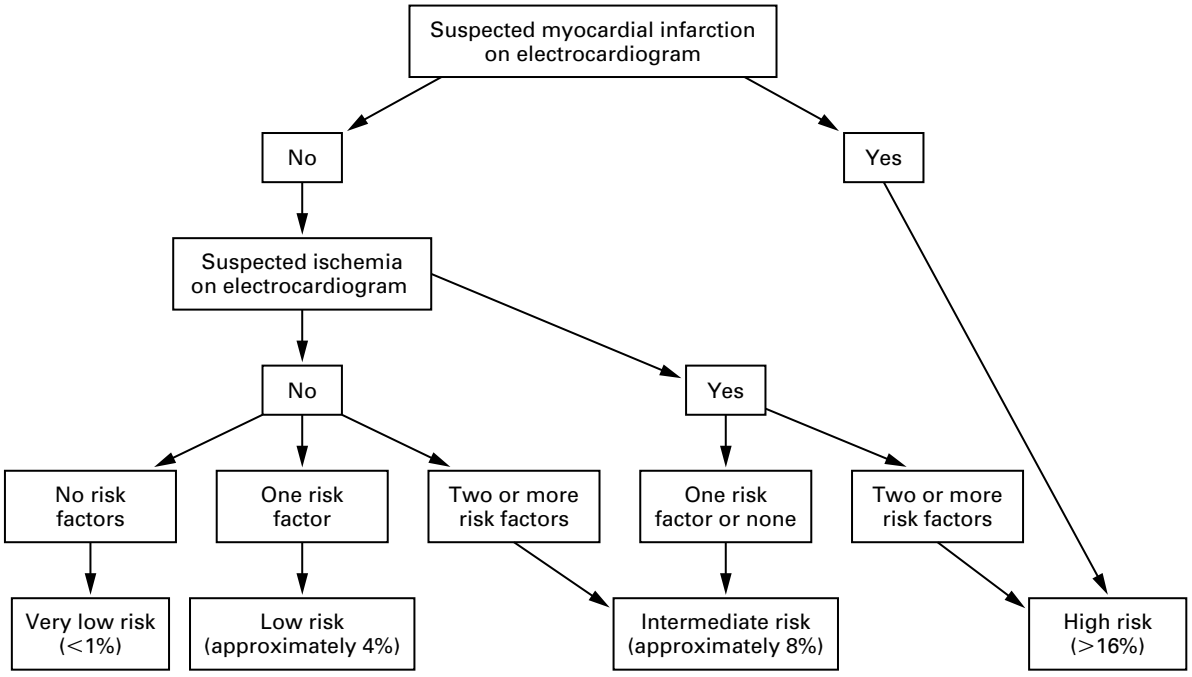

Figure 2. Derivation and Validation of Four Groups into Which Patients Can Be Categorized According to Risk of Major Cardiac Events within 72 Hours after Admission.

The categorization was based on the data available at the time of presentation in the emergency department. Myocardial infarction was suspected if the electrocardiogram showed ST-segment elevation of 1 mm or more or pathologic Q waves in two or more leads and if these findings were not known to be old. Ischemia was suspected if the electrocardiogram showed ST-segment depression of 1 mm or more or T-wave inversion in two or more leads and if these findings were not known to be old. Risk factors included systolic blood pressure below 110 mm Hg, bilateral rales heard above the bases on physical examination, and known unstable ischemic heart disease (defined as a worsening of previously stable angina, a new onset of angina after infarction or after a coronary revascularization procedure, or pain that was the same as that associated with a prior myocardial infarction). Data are from Goldman et al.[5]

injury. Multiple studies have shown that elevated levels of cardiac troponins indicate an increased risk of complications in patients who do not meet other clinical criteria for acute myocardial infarction.[10-12,26]

Bedside assays in which whole blood is used for the qualitative assessment of cardiac troponins T and I are now used in some emergency departments to obtain rapid information on whether these markers are elevated.[11,27] In one study of patients admitted to the coronary care unit, the sensitivity of the rapid assay for detecting myocardial infarction ranged from 33 percent for patients who presented within two hours after the onset of symptoms to 86 percent for patients who presented after having symptoms for eight hours; specificity ranged from 86 percent to 100 percent.[27] In a study of rapid assays for troponins T and I in 773 consecutive patients with acute chest pain but no ST-segment elevation, 94 percent of the patients with myocardial infarction had a positive result for troponin T and all patients had a positive result for troponin I within six hours after the onset of chest pain.[11] The specificity of the two assays was 89 percent and 83 percent, respectively. Hence, these assays seem to have approximately the same diagnostic performance.

Despite the advantages offered by the cardiac troponin assays, the interpretation of results is not always straightforward. Results for troponin that are falsely positive in patients with no evidence of ischemia are generally attributed to nonischemic or subclinical ischemic myocardial injury. False negative results may occur in patients who subsequently have life-threatening complications due to rupture of plaque or arrhythmia.

In the first six hours after acute myocardial infarction, CK-MB subforms appear to be both more sensitive and more specific than CK-MB mass or activity or even the troponins (Fig. 1).[13,24] However, the sensitivity for acute myocardial infarction of single values on all these tests is limited even for patients whose pain began more than 12 hours before presentation; thus, single values should not be used to rule out acute myocardial infarction.

The most appropriate strategy for the combined use of available markers remains uncertain. At many hospitals, assays for both CK-MB and cardiac troponins are routinely ordered for all patients with acute chest pain. The assay for CK-MB is inexpensive and permits the detection of reinfarction; hence, CK-MB

TABLE 1. EVALUATION OF ACUTE CHEST PAIN: EXCERPTS FROM THE CLINICAL POLICY OF THE AMERICAN COLLEGE OF EMERGENCY PHYSICIANS (ACEP).*

VARIABLE	FINDING	ACTION	
		RULE†	GUIDELINE‡
Pain	Ongoing and severe and crushing and substernal or same as previous pain diagnosed as MI	IV access Supplemental oxygen Cardiac monitor ECG Aspirin Nitrates Management of ongoing pain Admit	Serum cardiac markers CXR Anticoagulation
	Severe or pressure or substernal or exertional or radiating to jaw, neck, shoulder, or arm	ECG	IV access Supplemental oxygen Cardiac monitor Serum cardiac markers CXR Nitrates Management of ongoing pain Admit
	Tearing, severe, and radiating to back	Large-bore IV access Supplemental oxygen Cardiac monitor CXR ECG	Differential upper-extremity blood pressures Aortic imaging Management of ongoing pain Admit
	Similar to that of previous pulmonary embolus	IV access Supplemental oxygen Cardiac monitor ABG/oximetry Anticoagulation/pulmonary vascular imaging ECG	CXR Admit
	Ingestion or burning epigastric	None	ECG
	Pleuritic	None	CXR ECG
Age	Male, >33 years Female, >40 years	None	ECG
Associated symptoms	Syncope or near-syncope	ECG	Cardiac monitor Hematocrit
	Shortness of breath, dyspnea on exertion, paroxysmal nocturnal dyspnea, or orthopnea	ECG	ABG/oximetry CXR
Medical history	Previous MI, coronary-artery bypass graft/angioplasty, cocaine use within last 96 hours, previous positive cardiac diagnostic studies	ECG	
	Major risk factors for coronary artery disease		ECG

measurement is unlikely to disappear completely from diagnostic strategies. One recent analysis suggests that CK-MB should continue to be the first-line test for patients with suspected ischemic heart disease, with an assay for cardiac troponin I or T reserved for intermediate-risk patients who have normal CK-MB levels but electrocardiographic changes consistent with the presence of ischemia.[28]

THE DECISION TO ADMIT: AIDS AND GUIDELINES

Multivariate algorithms have been developed and prospectively validated with the goal of improving the stratification of risk in patients with possible acute ischemic heart disease. These algorithms can be used to estimate the probability of acute myocardial infarction[2,4] or acute ischemic heart disease[1,3,6] or the risk of major cardiac complications[5] in individual patients. Although such algorithms can, in theory, improve the identification of patients who are at high risk for complications or who might benefit from thrombolysis, they have been used mainly to identify patients who are at low risk for complications and who therefore do not require admission to the hospital or coronary care unit.

Goldman et al.[4] have published a prospectively validated decision protocol in the form of a flowchart; the electrocardiographic findings and other clinical data are incorporated into the flowchart, which is used to predict the patient's risk of acute myocardial in-

TABLE 1. CONTINUED.*

VARIABLE	FINDING	ACTION	
		RULE†	GUIDELINE‡
Assessment	Unstable angina — new-onset, exertional	ECG Aspirin	IV access Supplemental oxygen Cardiac monitor Nitrates Consult/admit
	Unstable angina — ongoing or recurrent ischemia	IV access Supplemental oxygen Cardiac monitor ECG Anticoagulation Aspirin Nitrates Management of ongoing pain Admit	Serial serum cardiac markers CXR Cardiac imaging Serial ECG Beta-blockers
	High clinical suspicion of MI with nondiagnostic ECG	IV access Supplemental oxygen Cardiac monitor Anticoagulation Aspirin Nitrates Management of ongoing pain Admit	Serial serum cardiac markers CXR Cardiac imaging Serial ECG Magnesium therapy Beta-blockers
	High clinical suspicion of MI with bundle-branch block or Acute MI with diagnostic ECG	IV access Supplemental oxygen Cardiac monitor Assessment for thrombolytic therapy or other reperfusion techniques Anticoagulation Aspirin Nitrates Management of ongoing pain Admit	Serial serum cardiac markers CXR Cardiac imaging Serial ECG Magnesium therapy if not given thrombolytics Beta-blockers
	Aortic dissection	Large-bore IV access Supplemental oxygen Cardiac monitor Blood type and crossmatch ECG Management of blood pressure/cardiac contractility Management of ongoing pain Immediate surgical consultation Admit	Aortic imaging
	Pericarditis/myocarditis	ECG	Serum cardiac markers CXR Echocardiography Consult/admit

*Data are from the American College of Emergency Physicians.[32] MI denotes myocardial infarction, IV intravenous, ECG electrocardiography, CXR chest radiography, and ABG arterial-blood gases.

†A rule is an action that reflects principles of good practice in most situations. There may be circumstances in which a rule does not need to be or cannot be followed; in these situations, it is advisable that the deviation from the rule be justified in writing. If a rule is not considered a standard of care at an institution, this fact should be documented as an institutional policy.

‡A guideline is an action that may be considered, depending on the patient, the circumstances, or other factors. Thus, guidelines are not always followed, and there is no implication that failure to follow a guideline is improper.

farction. In a prospective evaluation, this algorithm had a sensitivity for detecting myocardial infarction that was similar to that of the evaluating physicians' decisions with regard to admission to the coronary care unit (88 percent and 87.8 percent, respectively) and had a significantly higher specificity (74 percent vs. 71 percent). The authors have also used prospective data on 15,358 patients to describe and validate clinical factors that can be used to predict the risk of complications that require intensive care and to place patients into one of four groups in which the risk of major complications within the first 72 hours after admission ranges from 0.7 percent to 20 percent (Fig. 2).[5]

Pozen et al. developed a model that uses similar

TABLE 2. DETERMINATION OF SHORT-TERM RISK OF FATAL OR NONFATAL MYOCARDIAL INFARCTION.*

HIGH RISK†	INTERMEDIATE RISK‡	LOW RISK§
Prolonged (>20 min) ongoing pain at rest	Prolonged (>20 min) angina at rest, now resolved, with moderate or high likelihood of coronary artery disease	Increased frequency, severity, or duration of angina
Pulmonary edema, most likely related to ischemia	Angina at rest (>20 min or relieved with rest or sublingual nitroglycerin)	Angina provoked at a lower threshold
Angina at rest, with dynamic ST-segment changes of ≥1 mm	Nocturnal angina	New-onset angina with onset 2 wk to 2 mo before presentation
Angina with new or worsening mitral regurgitant murmur	Angina with dynamic T-wave changes	Normal or unchanged electrocardiogram
Angina with S_3 or new or worsening rales	New-onset Canadian Cardiovascular Society class III or IV angina in the previous 2 wk with a moderate or high likelihood of coronary artery disease	
Angina with hypotension	Pathologic Q waves or ST-segment depression of ≤1 mm in multiple lead groups (anterior, inferior, lateral) at rest	
	Age >65 yr	

*Data are from the AHCPR guidelines for unstable angina in Braunwald et al.[33]

†To be considered at high risk, a patient must have at least one of the features described.

‡To be considered at intermediate risk, a patient must have no high-risk features and at least one of the features described.

§To be considered at low risk, a patient must have no features of the high-risk or intermediate-risk patient and have at least one of the features described.

data to predict the risk of acute ischemic heart disease.[1,3] More recently, Selker and colleagues have adapted this aid to decision making by incorporating it into computerized reports of electrocardiograms to help clinicians make decisions about admission[6] and to help them assess the risks and benefits of using thrombolytic therapy in individual cases.

However, prospective trials have shown that these algorithms have little effect in the routine clinical practice of clinicians who have not received training in their use.[6,29-31] These studies indicate that practicing physicians often do not use algorithms because they are too busy, are unsure of their value, or are concerned about the legal and clinical consequences of inappropriately discharging patients who are subsequently found to have had myocardial infarction.[30]

The American College of Emergency Physicians[32] developed rules and guidelines about the data that should be recorded as part of the evaluation of patients with acute chest pain and the actions that should follow certain findings (Table 1). Actions that are general principles of good practice are termed rules; deviation from a rule should usually be justified in the record. Actions that should be considered are termed guidelines; failure to follow a guideline does not necessarily indicate improper care.

The Agency for Health Care Policy and Research (AHCPR)[33] and the National Heart Attack Alert Program[34] have also issued guidelines recommending that admission to the hospital be considered for patients with possible or probable acute myocardial infarction, but the AHCPR guidelines state that patients with unstable angina who are at low risk for acute myocardial infarction do not necessarily require admission (Table 2). These guidelines recommend that patients with unstable angina who are admitted be monitored electrocardiographically during their evaluation and that patients with ongoing pain at rest be placed on bed rest during the initial phase of stabilization.

WHERE TO ADMIT AND FOR HOW LONG

AHCPR guidelines indicate that patients with unstable angina who are at high risk for myocardial infarction should be admitted initially to a bed in the intensive care unit whenever possible and that patients with unstable angina who are at intermediate risk should be admitted to a bed in the intensive care unit or to a bed with electrocardiographic-monitoring capacity (Table 2).[33] Low-risk patients can usually be cared for in beds that are not in the intensive care unit if they do not have other indications for intensive care, such as possible aortic dissection or pulmonary embolism. We have developed recommendations that reflect cost-effectiveness analyses that support the routine use of the coronary care unit for patients whose initial electrocardiograms show changes consistent with ischemia not known to be old (Table 3).[35] According to these analyses, most other patients are at sufficiently low risk of complications that they can be observed safely in other monitored settings, undergo early exercise testing, or be discharged to their homes.[5,17]

TABLE 3. RECOMMENDED STRATEGIES FOR DETERMINING WHERE TO ADMIT PATIENTS WITH ACUTE CHEST PAIN FOR THE TREATMENT OF ONGOING, LIFE-THREATENING CONDITIONS.

LOCATION	INDICATION
Intensive care unit	One of the following: Substantial ischemic electrocardiographic changes in two or more leads that are not known to be old: ST-segment elevation ≥1 mm or Q waves of 0.04 sec or more ST-segment depression ≥1 mm or T-wave inversion consistent with presence of ischemia Any two of the following conditions, with or without substantial electrocardiographic changes: Coronary artery disease known to be unstable (in terms of frequency, duration, intensity, or failure to respond to usual measures) Systolic blood pressure <100 mm Hg Serious new arrhythmias (new-onset atrial fibrillation, atrial flutter, sustained supraventricular tachycardia, second-degree or complete heart block, or sustained or recurrent ventricular arrhythmias) Rales above the bases
Intermediate-care unit	Any of the following conditions but meeting no criteria for intensive care: Coronary artery disease known to be unstable Systolic blood pressure <110 mm Hg Rales above the bases Major arrhythmias (new-onset atrial fibrillation, atrial flutter, sustained supraventricular tachycardia, second-degree or complete heart block, or sustained or recurrent ventricular arrhythmias) New onset of typical ischemic heart disease that meets the clinical criteria for unstable angina and that occurs at rest or with minimal exertion
Evaluation or observation unit	New-onset symptoms that may be consistent with ischemic heart disease but are not associated with electrocardiographic changes or a convincing diagnosis of unstable ischemic heart disease at rest or with minimal exertion Known coronary artery disease whose presentation does not suggest a true worsening but for which further observation is thought to be beneficial
Home with office follow-up in 7 to 10 days to determine whether further testing is needed	Other conditions

Units for the Evaluation of Chest Pain

The installation of chest-pain units in medical centers has emerged as an important approach to improving the quality and efficiency of care.[16,36-40] These units are often adjacent to or in emergency departments and serve a diagnostic function for patients with no ongoing pain, circulatory instability, or serious coexisting illnesses. Patients who are found to have myocardial infarction, who have ongoing or recurrent ischemic pain, or who have complications are transferred promptly to settings in which the care is more intensive. In most chest-pain units, the rate of myocardial infarction has been about 1 to 2 percent. These units have proved safe for patients in terms of both the initial admission and longer-term follow-up; as a result, they are very cost effective.[36,37] In such units, management guidelines can be implemented readily, in part because fewer personnel are involved than in coronary-care units and there is an explicit emphasis on a protocol-driven approach.

A recent trend has been to admit moderate-risk patients (that is, those with known coronary artery disease) to the chest-pain unit. In a randomized trial of selected patients with unstable angina, admission to a chest-pain unit reduced costs without compromising patients' outcomes over a six-month follow-up period.[16]

Reducing the Length of Stay

Using an intervention in which a utilization reviewer (a clinician seeking to improve efficiency) telephoned physicians responsible for patients who were at low risk for complications and who remained in the hospital for more than 24 hours, Weingarten et al. achieved a 26 percent reduction in the length of stay.[41] Nichol et al. have described management guidelines that use exercise testing for low-risk patients after an observation period that ends six hours after the onset of their symptoms.[17] These approaches, though still preliminary, are an attractive adjunct to newer tests and aids to decision making.

EXERCISE TESTS, SCINTIGRAPHY, ECHOCARDIOGRAPHY, AND EARLY CORONARY ANGIOGRAPHY

Because of concern about the safety of the patient, exercise testing, with either electrocardiography or other techniques for detecting ischemic myocardium, has traditionally been used only after the patient has been observed for a day or more and has been found to be free of pain and abnormalities of cardiac enzymes. However, studies have shown that patients who have a low clinical risk of complications can safely undergo exercise testing within 6 to 12 hours after presentation at the hospital[17,42] or even immediately[14,15] and that patients with negative tests have excellent outcomes at six months.[43] In general, protocols for early or immediate exercise testing do not apply to patients with electrocardiographic changes consistent with ischemia or those who have infarction not known to be old, ongoing chest pain, or evidence of congestive heart failure.

At some medical centers, imaging of myocardial perfusion is used to improve risk stratification.[43] Ideally, the injection of the radionuclide tracer should take place while pain is occurring[44]; relatively few facilities have the capacity to provide the staff necessary to perform this service on a 24-hour basis. Echocardiography, with or without stress to induce ischemia, can also detect wall-motion abnormalities consistent with substantial myocardial ischemia.[45] However, old myocardial infarctions can cause similar abnormalities, and lesser degrees of infarction may not cause echocardiographic changes that are detectable. A newer approach is to consider prompt coronary angiography in patients who do not meet criteria for acute myocardial infarction despite suggestive symptoms. Recent analyses indicate that this strategy is particularly cost effective in patients with a high probability of coronary artery disease.[46] At some medical centers, catheterization through the radial artery is used to reduce the length of stay and to minimize the risk of postprocedural hemorrhage.

Radionuclide imaging, stress echocardiography, and prompt coronary angiography may all be useful for diagnosing coronary artery disease in some subgroups of patients.[46,47] Nevertheless, exercise electrocardiography remains the most readily available tool for risk stratification in patients without ongoing chest pain who have ST segments that can be interpreted during exercise testing.

CONCLUSIONS

Recent advances offer the potential for improving the quality and efficiency of the evaluation of patients with acute chest pain, but realizing these opportunities will require an integrated approach. Clinicians should use validated aids to decision making to help them make decisions with regard to the admission and care of patients. Management guidelines should be used to hasten the implementation of therapy for patients with acute ischemic syndromes and to expedite the evaluation of low-risk patients. Low-cost locations such as chest-pain centers should be used for the brief observation of patients for whom discharge is not appropriate but who are not likely to benefit from admission to the hospital. Clinicians should take advantage of tests to refine the stratification of risk at the time of presentation (macromolecular markers) or shortly thereafter (exercise testing). Finally, follow-up must be arranged for patients who are discharged to their homes from the emergency department or hospital, with appropriate communication to the patient's primary care physician.

REFERENCES

1. Pozen MW, D'Agostino RB, Mitchell JB, et al. The usefulness of a predictive instrument to reduce inappropriate admission to the coronary care unit. Ann Intern Med 1980;92:238-42.
2. Goldman L, Weinberg M, Weisberg M, et al. A computer-derived protocol to aid in the diagnosis of emergency room patients with acute chest pain. N Engl J Med 1982;307:588-96.
3. Pozen MW, D'Agostino RB, Selker HP, Sytkowski PA, Hood WB Jr. A predictive instrument to improve coronary-care unit admission practices in acute ischemic heart disease: a prospective multicenter clinical trial. N Engl J Med 1984;310:1273-8.
4. Goldman L, Cook EF, Brand DA, et al. A computer protocol to predict myocardial infarction in emergency department patients with chest pain. N Engl J Med 1988;318:797-803.
5. Goldman L, Cook EF, Johnson PA, Brand DA, Rouan GW, Lee TH. Prediction of the need for intensive care in patients who come to emergency departments with acute chest pain. N Engl J Med 1996;334:1498-504.
6. Selker HP, Beshansky JR, Griffith JL, et al. Use of the acute cardiac ischemic time-insensitive predictive instrument (ACI-TIPI) to assist with triage of patients with chest pain or other symptoms suggestive of acute cardiac ischemia: a multicenter, controlled clinical trial. Ann Intern Med 1998;129: 845-55.
7. 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.
8. Rusnak RA, Stair TO, Hansen K, Fastow JS. Litigation against the emergency physician: common features in cases of missed myocardial infarction. Ann Emerg Med 1989;18:1029-34.
9. Antman EM, Tanasijevic MJ, Thompson B, et al. Cardiac-specific troponin I levels to predict the risk of mortality in patients with acute coronary syndromes. N Engl J Med 1996;335:1342-9.
10. Newby LK, Christenson RH, Ohman EM, et al. Value of serial troponin T measures for early and late risk stratification in patients with acute coronary syndromes. Circulation 1998;98:1853-9.
11. Hamm CW, Goldmann BU, Heeschen C, Kreymann G, Berger J, Meinertz T. Emergency room triage of patients with acute chest pain by means of rapid testing for cardiac troponin T or troponin I. N Engl J Med 1997;337:1648-53.
12. Luscher MS, Thygesen K, Ravkilde J, Heickendorff L. Applicability of cardiac troponin T and I for early risk stratification in unstable coronary artery disease. Circulation 1997;96:2578-85.
13. Puleo PR, Meyer D, Wathen C, et al. Use of a rapid assay of subforms of creatine kinase MB to diagnose or rule out acute myocardial infarction. N Engl J Med 1994;331:561-6.
14. Lewis WR, Amsterdam EA, Turnipseed S, Kirk JD. Immediate exercise testing of low risk patients with known coronary artery disease presenting to the emergency department with chest pain. J Am Coll Cardiol 1999;33:1843-7.
15. Lewis WR, Amsterdam EA. Utility and safety of immediate exercise testing of low-risk patients admitted to the hospital for suspected acute myocardial infarction. Am J Cardiol 1994;74:987-90.
16. Farkouh ME, Smars PA, Reeder GS, et al. A clinical trial of a chest-pain observation unit for patients with unstable angina. N Engl J Med 1998;339:1882-8.
17. Nichol G, Walls R, Goldman L, et al. A critical pathway for management of patients with acute chest pain who are at low risk for myocardial ischemia: recommendations and potential impact. Ann Intern Med 1997; 127:996-1005.

18. Panju AA, Hemmelgarn BR, Guyatt GH, Simel DL. Is this patient having a myocardial infarction? JAMA 1998;280:1256-63.
19. 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.
20. Goyal RK. Changing focus on unexplained esophageal chest pain. Ann Intern Med 1996;124:1008-11.
21. Prêtre R, Von Segesser LK. Aortic dissection. Lancet 1997;349:1461-4.
22. Ryan TJ, Antman EM, Brooks NH, et al. 1999 Update: ACC/AHA guidelines for the management of patients with acute myocardial infarction: executive summary and recommendations: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). Circulation 1999;100:1016-30.
23. The Platelet Receptor Inhibition in Ischemic Syndrome Management in Patients Limited by Unstable Signs and Symptoms (PRISM-PLUS) Study Investigators. Inhibition of the platelet glycoprotein IIb/IIIa receptor with tirofiban in unstable angina and non–Q-wave myocardial infarction. N Engl J Med 1998;338:1488-97. [Erratum, N Engl J Med 1998;339:415.]
24. Zimmerman J, Fromm R, Meyer D, et al. Diagnostic marker cooperative study for the diagnosis of myocardial infarction. Circulation 1999;99: 1671-7.
25. Adams JE III, Abendschein DR, Jaffe AS. Biochemical markers of myocardial injury: is MB creatine kinase the choice for the 1990s? Circulation 1993;88:750-63.
26. Polanczyk CA, Lee TH, Cook EF, et al. Cardiac troponin I as a predictor of major cardiac events in emergency department patients with acute chest pain. J Am Coll Cardiol 1998;32:8-14.
27. Antman EM, Grudzien C, Sacks DB. Evaluation of a rapid bedside assay for detection of serum cardiac troponin T. JAMA 1995;273:1279-82.
28. Polanczyk CA, Johnson PA, Cook EF, Lee TH. A proposed strategy for utilization of creatine kinase-MB and troponin I in the evaluation of acute chest pain. Am J Cardiol 1999;83:1175-9.
29. Corey GA, Merenstein JH. Applying the acute ischemic heart disease predictive instrument. J Fam Pract 1987;25:127-33.
30. Pearson SD, Goldman L, Garcia TB, Cook EF, Lee TH. Physician response to a prediction rule for the triage of emergency department patients with chest pain. J Gen Intern Med 1994;9:241-7.
31. Lee TH, Pearson SD, Johnson PA, et al. Failure of information as an intervention to modify clinical management: a time-series trial in patients with acute chest pain. Ann Intern Med 1995;122:434-7.
32. American College of Emergency Physicians. Clinical policy for the initial approach to adults presenting with a chief complaint of chest pain, with no history of trauma. Ann Emerg Med 1995;25:274-99.
33. Braunwald E, Jones RH, Mark DB, et al. Unstable angina: diagnosis and management. Clinical practice guideline number 10. Rev. Rockville, Md.: Agency for Health Care Policy and Research, National Heart, Lung, and Blood Institute, May 1994. (AHCPR publication no. 94-0602.)
34. National Heart Attack Alert Program Coordinating Committee 60 Minutes to Treatment Working Group. Emergency department: rapid identification and treatment of patients with acute myocardial infarction. Washington, D.C.: National Heart, Lung, and Blood Institute, September 1993. (NIH publication no. 93-3278.)
35. Tosteson ANA, Goldman L, Udvarhelyi IS, Lee TH. Cost-effectiveness of a coronary care unit versus an intermediate care unit for emergency department patients with chest pain. Circulation 1996;94:143-50.
36. Gaspoz JM, Lee TH, Weinstein MC, et al. Cost-effectiveness of a new short-stay unit to "rule out" acute myocardial infarction in low risk patients. J Am Coll Cardiol 1994;24:1249-59.
37. Roberts RR, Zalenski RJ, Mensah EK, et al. Costs of an emergency department-based accelerated diagnostic protocol vs. hospitalization in patients with chest pain: a randomized controlled trial. JAMA 1997;278: 1670-6.
38. Gibler WB, Runyon JP, Levy RC, et al. A rapid diagnostic and treatment center for patients with chest pain in the emergency department. Ann Emerg Med 1995;25:1-8.
39. Graff L, Joseph T, Andelman R, et al. American College of Emergency Physicians information paper: chest pain units in emergency departments — a report from the Short-Term Observation Services Section. Am J Cardiol 1995;76:1036-9.
40. Gomez MA, Anderson JL, Karagounis LA, Muhlestein JB, Mooers FB. An emergency department-based protocol for rapidly ruling out myocardial ischemia reduces hospital time and expense: results of a randomized study (ROMIO). J Am Coll Cardiol 1996;28:25-33.
41. Weingarten SR, Riedinger MS, Conner L, et al. Practice guidelines and reminders to reduce duration of hospital stay for patients with chest pain: an interventional trial. Ann Intern Med 1994;120:257-63.
42. Gaspoz JM, Lee TH, Cook EF, Weisberg MC, Goldman L. Outcome of patients who were admitted to a new short-stay unit to "rule-out" myocardial infarction. Am J Cardiol 1991;68:145-9.
43. Polanczyk CA, Johnson PA, Hartley LH, Walls RM, Shaykevich S, Lee TH. Clinical correlates and prognostic significance of early negative exercise tolerance test in patients with acute chest pain seen in the hospital emergency department. Am J Cardiol 1998;81:288-92.
44. Kontos M, Jesse RL, Anderson P, et al. Comparison of myocardial perfusion imaging and cardiac troponin I in patients admitted to the emergency department with chest pain. Circulation 1999;99:2073-8.
45. Colon PJ III, Mobarek SK, Milani RV, et al. Prognostic value of stress echocardiography in the evaluation of atypical chest pain patients without known coronary artery disease. Am J Cardiol 1998;81:545-51.
46. Kuntz KM, Fleischmann KE, Hunink MG, Douglas PS. Cost-effectiveness of diagnostic strategies for patients with chest pain. Ann Intern Med 1999;130:709-18.
47. Garber AM, Solomon NA. Cost-effectiveness of alternative test strategies for the diagnosis of coronary artery disease. Ann Intern Med 1999; 130:719-28.