

## Is This Patient Having a Myocardial Infarction?

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When faced with a patient with acute chest pain, clinicians must distinguish myocardial infarction (MI) from all other causes of acute chest pain. If MI is suspected, current therapeutic practice includes deciding whether to administer thrombolysis or primary percutaneous transluminal coronary angioplasty and whether to admit patients to a coronary care unit. The former decision is based on electrocardiographic (ECG) changes, including ST-segment elevation or left bundle-branch block, the latter on the likelihood of the patient's having unstable high-risk ischemia or MI without ECG changes. Despite advances in investigative modalities, a focused history and physical examination followed by an ECG remain the key tools for the diagnosis of MI. The most powerful features that increase the probability of MI, and their associated likelihood ratios (LRs), are new ST-segment elevation (LR range, 5.7-53.9); new Q wave (LR range, 5.3-24.8); chest pain radiating to both the left and right arm simultaneously (LR, 7.1); presence of a third heart sound (LR, 3.2); and hypotension (LR, 3.1). The most powerful features that decrease the probability of MI are a normal ECG result (LR range, 0.1-0.3), pleuritic chest pain (LR, 0.2), chest pain reproduced by palpation (LR range, 0.2-0.4), sharp or stabbing chest pain (LR, 0.3), and positional chest pain (LR, 0.3). Computer-derived algorithms that depend on clinical examination and ECG findings might improve the classification of patients according to the probability that an MI is causing their chest pain.

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### CLINICAL SCENARIOS

#### Are These Patients Having a Myocardial Infarction?

**Case 1.**—A 57-year-old man presents to the emergency department (ED) with squeezing retrosternal pain that started 1 hour ago. He is diaphoretic. His blood pressure is 110/70 mm Hg, his heart rate is 74/min, and he has an audible fourth heart sound. The electrocardiogram (ECG) reveals 2-mm ST-segment elevation in leads V<sub>1</sub> to V<sub>4</sub>.

**Case 2.**—A 70-year-old man, with a history of myocardial infarction (MI) 5 years previously, presents to the ED with severe tightness in the neck. The discom-

fort started 30 minutes ago and was associated with diaphoresis. His blood pressure is 90/60 mm Hg, his heart rate is 50/min, and the ECG reveals Q waves in V<sub>1</sub> to V<sub>4</sub> (present in the old ECG).

**Case 3.**—A 50-year-old woman presents to the ED with retrosternal burning of 1 hour's duration and nausea. Antacids provided no relief. The findings of the clinical examination were unremarkable. The ECG reveals 3-mm ST-segment elevation in leads II, III, and aVF and 1-mm ST-segment depression in I and aVL.

**Case 4.**—A 40-year-old woman presents to the ED with a 24-hour history of left-sided chest pain. The pain is worsened by exertion and movement. Prior history is unremarkable. Examination reveals normal vital signs and tenderness with palpation of the left lower costal cartilages. The ECG result is normal.

#### Why Is This an Important Question to Answer With a Clinical Examination?

There have been numerous technological advancements made in the assess-

ment of patients with symptoms suggestive of acute MI. These include evaluation of time-dependent changes in cardiac enzymes including creatine kinase, creatine kinase isoenzyme, and, more recently, myoglobin and troponin, as well as an assessment of wall-motion abnormality using echocardiography, radionuclide angiography, or nuclear imaging.

Despite this progress, a carefully conducted history and a physical examination remain the first component, and the cornerstone, in the initial assessment of patients presenting with suspected MI. The history and physical examination are critical in guiding the selection of further diagnostic and therapeutic interventions. Clinicians complement their clinical examination with a 12-lead ECG and cardiac enzymes, which are additional data that provide the most definitive diagnosis of MI. We will focus on features of history, physical examination, and ECG that aid in increasing or decreasing the likelihood of acute MI. We include the ECG in our review because the clinician often interprets the results at the patient's bedside as part of a prompt initial clinical evaluation.

For the purpose of clarification, we begin by describing the 3 diagnostic groupings of patients with acute chest pain currently used by clinicians and then we contrast these with the categorization of chest pain as presence or absence of MI, as is evident in the literature. We then briefly describe signs and symptoms of MI, mechanisms of chest pain, and conditions that may present with symptoms suggestive of MI. Following these introductory topics, a detailed account of the precision and accuracy of the history, physical examination, and ECG in the diagnosis of MI is provided. Having presented multiple clinical examination items and their associated likelihood ratios (LRs), we conclude by noting the

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Table 1.—Grading of Angina of Effort by the Canadian Cardiovascular Society

Grade	Description
I	"Ordinary physical activity does not cause angina," such as walking or climbing stairs. Angina with strenuous or rapid or prolonged exertion at work or recreation.
II	"Slight limitation of ordinary activity." Walking or climbing stairs rapidly, walking uphill, or walking or stair climbing after meals, in cold, in wind, or under emotional stress, or only during the few hours after awakening. Walking more than 2 blocks on the level and climbing more than 1 flight of ordinary stairs at a normal pace and in normal conditions.
III	"Marked limitation of ordinary physical activity." Walking 1 or 2 blocks on the level and climbing 1 flight of stairs in normal conditions and at a normal pace.
IV	"Inability to carry on any physical activity without discomfort—angina syndrome may be present at rest."

clinical relevance of this information and by discussing the role of combined findings and clinical prediction rules in the setting of acute MI.

## DEFINITIONS

Cardiac ischemic chest pain presents in a spectrum of conditions including angina, unstable angina, and MI. Angina is defined as a discomfort in the chest or adjacent areas caused by myocardial ischemia, usually brought on by exertion, and associated with a disturbance of myocardial function, but without myocardial necrosis.<sup>1</sup> Various grading systems of the severity of angina pectoris have been developed. The classification proposed by the Canadian Cardiovascular Society,<sup>2</sup> outlined in Table 1, is a practical one adopted in a variety of settings.

Unstable angina encompasses a spectrum of symptomatic manifestations of ischemic heart disease intermediate between stable angina and acute MI. Based on historical features, ECG findings (with and without pain), and hemodynamic changes (low blood pressure, third heart sound, mitral regurgitation, and pulmonary crackles), guidelines have been developed to stratify patients with suspected unstable angina into high, intermediate, or low risk of complications after initial evaluation.<sup>3</sup> These guidelines also recommend disposition based on initial assessment of risk.

The diagnosis of MI used in most studies is based on criteria proposed by the World Health Organization. In an attempt to standardize the diagnosis of acute MI, the World Health Organization requires evolutionary changes on serially obtained ECG tracings or a rise and fall in serum cardiac markers either with typical ischemic-type chest discomfort and an ECG result that was not nor-

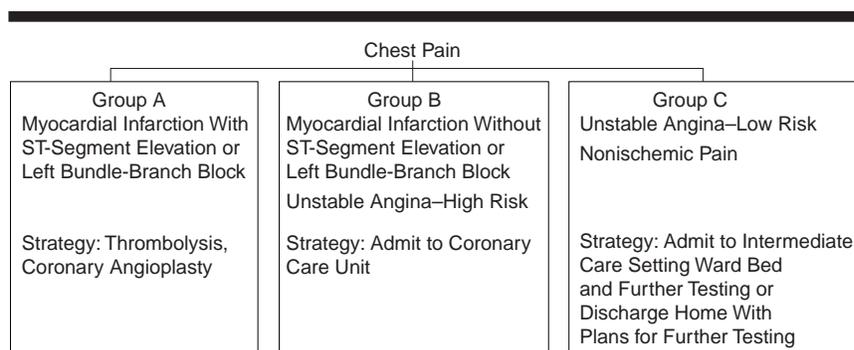


Figure 1.—Diagnostic groupings of acute chest pain based on management strategies.

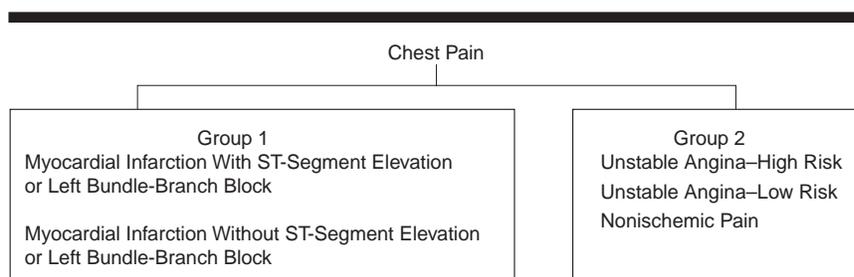


Figure 2.—Categorization of patients with acute chest pain in studies ascertaining test properties of history, physical examination, and electrocardiogram.

mal or with an ECG progression labeled probable and lesser symptoms.<sup>4</sup>

## Diagnosis in Acute Chest Pain

Determining the correct diagnosis is imperative to administering the appropriate therapy. The available therapeutic options create the categories for patients presenting to the ED with chest pain or other symptoms suggesting cardiac ischemia. Three distinct management strategies determine the diagnostic groupings clinicians use currently (Figure 1).

For the first group of patients, which includes those with MI and ST-segment elevation or left bundle-branch block (LBBB) (Figure 1, group A), current therapy consists of early thrombolytic therapy and/or emergency percutaneous transluminal coronary angioplasty. A second group of patients includes those with MI, but without ST-segment elevation or LBBB, or those with high-risk unstable angina (Figure 1, group B). These patients require intensive monitoring, immediate administration of aspirin, early administration of  $\beta$ -blockers, and possibly heparin therapy. The third group includes patients with low-risk unstable angina or nonischemic chest pain (Figure 1, group C). Clinicians may consider either admitting these patients to an intermediate care setting or ward bed or discharging them home with plans for subsequent diagnostic testing

to establish the cause of their symptoms. Recent economic pressures on the health care system have highlighted the importance of distinguishing the second from the third group of patients.

Ideally, we should have information that allows us to classify patients into 1 of these 3 groups. Importantly, this is not, however, the issue addressed by most studies of the history and physical examination in the setting of acute chest pain. Rather, as shown in Figure 2, studies reviewed classified patients with acute chest pain into 2 groups based on the presence (group 1) or absence (group 2) of MI. Specifically, all patients with MI (Figure 1, groups A and B) are compared with all those without MI (Figure 1, group C).

The results of studies that used the Figure 2 design may mislead clinicians who need to discriminate between the 3 groups of patients as shown in Figure 1. Clinical features that fail to distinguish patients with infarct or high-risk unstable angina from those with low-risk unstable angina or nonischemic chest pain might still be useful in the decision about whether to admit to a monitored bed in an acute care hospital. The study design that most investigators have chosen, depicted in Figure 2, does not correlate with the current triage of chest pain patients based on the therapeutic options available. Current therapeutic interventions for MI require the presence of ECG changes. It will, however,

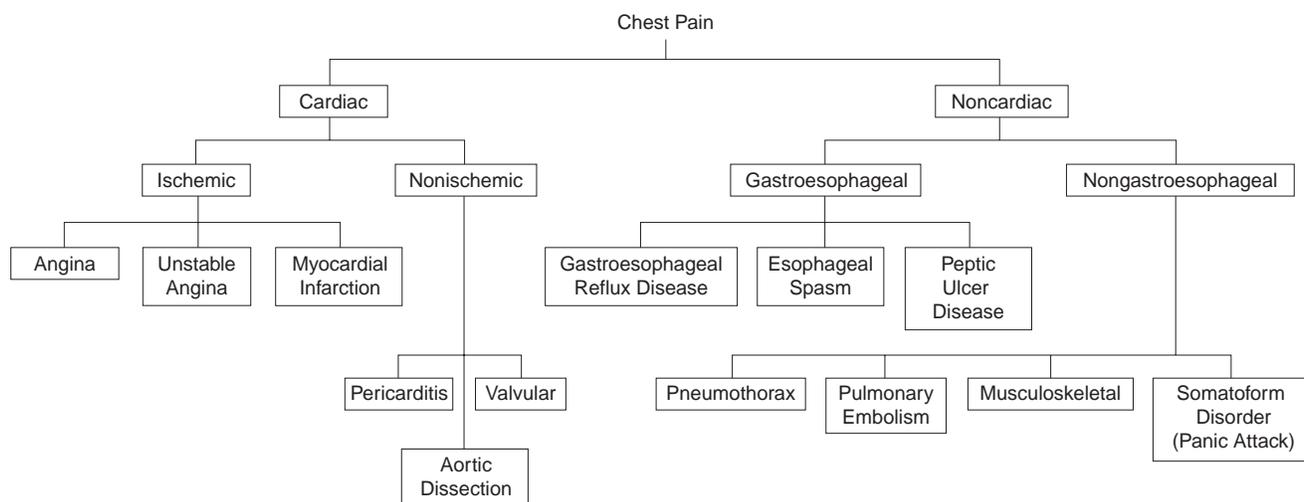


Figure 3.—Cardiac and noncardiac conditions presenting with chest pain.

provide clinically important information when we have interventions that are clearly useful in acute MI both with and without ECG changes. In the interim, this review will aid the reader in identifying features of the history, physical examination, and ECG that help differentiate acute MI, both with and without ECG changes, from non-MI patients. Clinicians must avoid misinterpreting the diagnostic information we will present as if it were useful in differentiating between the 3 groups in Figure 1.

### Relevant Signs and Symptoms

Patients with acute MI typically present with a characteristic combination of signs and symptoms, as outlined in standard textbooks of medicine. Pain is described as being the most common presenting complaint, and considerable emphasis is placed on the characteristics of the pain, including its location, duration, radiation, and quality. Location of the pain includes the central portion of the chest or epigastrium, with potential radiation to the arms, neck, jaw, or less commonly to the abdomen and back. Quality of the chest pain is characteristically described using adjectives such as squeezing, crushing, and pressure.

Other symptoms also may be present, including diaphoresis, nausea, vomiting, weakness, and syncope. While certain features have been identified as being important in recognizing MI, follow-up data from the Framingham Study cohort estimate that approximately 25% of infarcts may go unrecognized due to either lack of chest pain or atypical symptoms.<sup>5</sup>

### Mechanism of Chest Pain in MI

Three quarters of all patients with recognized acute MI present with chest

pain.<sup>6</sup> Cardiac ischemic pain originates in the myocardium, where free nerve endings are the sensory receptors. Cardiac afferent impulses travel through fibers in the cardiac sympathetic nerves, the upper 5 sympathetic ganglia, the white rami communicants, the gray rami, and then via the upper 4 or 5 thoracic roots. Cardiac afferent impulses project to the dorsal horn convergent neurons and subsequently travel via the spinothalamic tract to the thalamus and subsequently to the cortex, where the cardiac stimuli are decoded.

Afferent impulses also travel in the cholinergic fibers of the vagus nerve, many of which arise from the inferior cardiac wall. The signs and symptoms of nausea, bradycardia, and hypotension, which appear to be more prevalent in patients with inferior wall MI, are believed to be related to the larger number of vagal afferent fibers located in the inferior cardiac wall.<sup>7</sup>

Like other visceral sensations, myocardial pain is poorly and variably localized. In addition, sensations originating in other intrathoracic structures (particularly the esophagus) can cause pain that is indistinguishable from cardiac pain.

### Conditions That May Present With Symptoms Suggestive of MI

There are many other clinical conditions that can present with symptoms suggestive of acute MI, which can be broadly divided into cardiac and noncardiac disorders. The noncardiac causes of chest pain are further divided into gastroesophageal diseases and nongastroesophageal diseases, while the cardiac causes are grouped into ischemic and nonischemic conditions. Figure 3 illus-

trates the most common of these conditions, but is not all-inclusive.

Given the diversity of the conditions presenting with chest pain, and the extent of the diagnostic testing that would be required, it is difficult to determine the relative frequency of each of these conditions occurring in the setting of chest pain. Pozen et al.<sup>8</sup> in an evaluation of 1032 patients presenting to the ED with a chief symptom of chest pain, including follow-up ECG and cardiac enzyme tests for both hospitalized and nonhospitalized patients, reported an overall incidence of acute ischemia of 29% (ischemia included new-onset or unstable angina and MI). In an attempt to determine the etiology of noncardiac chest pain, Panju et al.<sup>9</sup> conducted further cardiac and gastrointestinal investigations in 100 patients discharged from the coronary care unit (CCU) with chest pain not yet diagnosed (8.1% of the CCU admissions for chest pain). More than 75% of these patients had evidence of esophageal disorders by objective testing, including 24-hour intraesophageal pH monitoring, upper gastrointestinal tract endoscopy with biopsy, esophageal motility studies, or upper gastrointestinal tract barium series. These results are generalizable to patients discharged from the CCU with chest pain not yet diagnosed, a distinct subset of the patients with noncardiac chest pain presenting to the ED.

### METHODS

#### Inclusion Criteria of Tests for Precision and Accuracy

Given the limited number of studies that have focused on the precision of the history, physical examination, and ECG

Table 2.—Interobserver Agreement in Recording Chest Pain Histories\*

Attribute	Inpatients (N = 197)		Outpatients (N = 112)	
	Two Internists, $\kappa$	Internist and Questionnaire, $\kappa$	Nurse and Internist, $\kappa$	Nurse and Questionnaire, $\kappa$
Pain radiates to left arm	0.89	0.58	0.43	0.41
Pain relieved by nitroglycerin	0.79	0.51	0.94	0.77
History of myocardial infarction	0.78	0.81	0.70	0.81
Pain in substernal location	0.74	0.50	0.38	0.19
Pain brought on by exertion	0.63	0.51	0.42	0.22
Pain described as "pressure"	0.57	0.37	0.49	0.50
Patient must stop activities when pain occurs	0.50	0.47	0.44	0.40
Pain brought on by cough or deep breath	0.44	0.30	0.55	0.62
Pain described as "sharp"	0.30	0.26	0.33	0.31
Pain brought on by moving arms or torso	0.27	0.44	0.52	0.54

\*Adapted, with permission, from Hickman et al.<sup>12</sup>

in the diagnosis of MI, we developed a broad set of inclusion criteria. We included studies that consisted of an assessment of the interobserver and/or intraobserver variation, of features of the history, physical examination, and ECG among patients with chest pain or a diagnosis of MI.

For the accuracy of the history, physical examination, and ECG, we included studies that met the following criteria: (1) patients: those with chest pain thought to be ischemic in nature; (2) test: history, physical examination, or ECG described in adequate detail; (3) outcome: MI or no infarction using the definition described above; (4) sample size: studies with a sample size of at least 200 patients.

### Search Strategy

For both precision and accuracy of the history, physical examination, and ECG we performed an English-language MEDLINE search from 1980 using the following Medical Subject Heading (MeSH) terms and search strategy: (1) *medical history taking or physical examination and myocardial infarction or chest pain* and (2) *reproducibility of results or observer variation and myocardial infarction or chest pain*. A textword search was also performed using *interobserver, intraobserver, accuracy, precision, reliability, sensitivity, specificity, and myocardial infarction or chest pain*. Additional search strategies for accuracy included the term *myocardial infarction, diagnosis* (subheading). For all strategies, references from appropriate articles were reviewed to provide additional references for this article. Of the 14 references used to assess the precision and accuracy of the history, physical examination, and ECG in the diagnosis of acute MI, 12 were obtained from the MEDLINE search strategy outlined and 2 from the review of reference lists.

### Selection of Articles

One author (B.R.H.) initially screened the titles and abstracts. If she felt the

articles might be relevant, she and another author (A.A.P.) reviewed the articles in detail and determined their eligibility.

### Methodologic Quality Assessments

We evaluated the methodologic quality of articles addressing the accuracy of history, physical examination, or ECG using criteria adapted from Sackett and Goldsmith and previously used in this series.<sup>10</sup> A grade A designation meant an independent, blind comparison of sign or symptom with a "gold standard" among 500 or more consecutive patients suspected of having the target condition; grade B meant an independent, blind comparison of sign or symptom with a gold standard among fewer than 500 consecutive patients suspected of having the target condition; grade C meant an independent, blind comparison of sign or symptom with a standard of uncertain validity; or independent, blind comparison of sign or symptom with a gold standard among nonconsecutive patients suspected of having the target disorder.

### Analysis

To calculate LRs for features of the history, physical examination, and ECG, we considered studies suitable for combination if the sensitivity and specificity met 1 of the following criteria: (1)  $\chi^2$  test of sensitivity and specificity excluding statistically significant heterogeneity ( $P > .05$ ) or (2) range of sensitivity and specificity across studies of 15% or less. We pooled studies satisfying at least 1 criterion and calculated LRs by simple combination of results across studies. The 95% confidence intervals were calculated according to the method of Simel et al.<sup>11</sup>

## RESULTS

### Precision of the History and Physical Examination

Precision refers to the degree of variation between observers (interobserver

Table 3.—Interobserver Agreement in Assessment of Physical Symptoms and Signs of Heart Failure in Myocardial Infarction Patients\*

Physical Sign	Range, $\kappa$
Dyspnea	0.62-0.75
Displaced apex beat	0.53-0.73
S <sub>3</sub> gallop	0.14-0.37
Rales	0.12-0.31
Neck vein distention	0.31-0.51
Hepatomegaly	0.00-0.16
Dependent edema	0.27-0.64

\*Adapted, with permission, from Gadsboll et al.<sup>14</sup>

variation) or within observers (intraobserver variation) regarding a particular clinical finding. Hickman and colleagues<sup>12</sup> studied the precision of an important aspect of the history, namely that of chest pain. They assessed the interobserver agreement in chest pain histories obtained by general internists, nurse practitioners, and self-administered questionnaires for 197 inpatients and 112 outpatients with chest pain. As outlined in Table 2, the 2 internists, who each independently interviewed 47 of 197 inpatients, showed high agreement for 7 of the 10 items, including location and description of the pain, as well as aggravating and relieving factors. Agreement was slightly lower between internist and questionnaire and between the nurse practitioners and internist, with the lowest level of agreement between nurse and questionnaire. Features of the chest pain associated with a lower probability of MI, namely pleuritic, positional, and sharp chest pain, typically showed a lower level of agreement for all comparisons.

The precision of the history obtained is also dependent on the reliability of the sources themselves. Kee and colleagues<sup>13</sup> assessed the reliability of a reported family history of MI from patients who had recently survived MI with that of other documented sources including hospital charts and death certificates. They reported a moderate level of agreement with a  $\kappa$  of 0.65.

Few studies have evaluated the precision of features of the physical examination in the assessment of patients with suspected MI. One study did evaluate the interobserver agreement between 3 clinicians in the assessment of physical symptoms and signs of heart failure in 102 MI patients.<sup>14</sup> As shown in Table 3, agreement was high for dyspnea, as well as for the displaced apex beat. However, the level of agreement for the other physical symptoms and signs of heart failure, particularly the assessment of pulmonary rales and hepatomegaly, was considerably lower.

### Precision of the ECG Interpretation

Unfortunately, most studies that have assessed the precision of ECG interpretation have simply reported the percent-

Table 4.—Features of Studies Used to Determine Accuracy of the History, Physical Examination, and Electrocardiogram

Source, y	Methodologic Quality*	Inclusion Criteria	Incidence of Myocardial Infarction (MI), %	No. of Patients (% Women)	Age, y	Country
Rude et al, <sup>21</sup> 1983	A	Consecutive patients admitted to coronary care unit (CCU) with suspected MI	48.9	3697 (38)	Mean = 61	United States
Yusuf et al, <sup>22</sup> 1984	B	Consecutive patients admitted to CCU with suspected MI	85.1	475 (15.4)	Mean = 56.2	United Kingdom
Pozen et al, <sup>8</sup> 1984	A	Consecutive patients presenting to emergency department (ED) with chest pain	NR	2801 (NR)	Males $\geq$ 30 Females $\geq$ 40	United States
Lee et al, <sup>23</sup> 1985	A	Consecutive patients presenting to ED with chest pain	17.4	596 (52.0)	$\geq$ 25	United States
Tierney et al, <sup>24</sup> 1986	B	Consecutive patients presenting to ED with chest pain	12.4	492 (NR)	Males $\geq$ 30 Females $\geq$ 40	United States
Herlihy et al, <sup>25</sup> 1987	B	Consecutive patients admitted to CCU with suspected MI	44.5	265 (NR)	Not reported	United States
Klaeboe et al, <sup>26</sup> 1987	B	Consecutive patients admitted to CCU with suspected MI	59.1	237 (35.8)	Range = 29-90	Norway
Rouan et al, <sup>27</sup> 1989	A	Consecutive patients presenting to ED with chest pain	14.4	7115 (50.0)	$\geq$ 30	United States
Solomon et al, <sup>28</sup> 1989	A	Consecutive patients presenting to ED with chest pain	14.5	7734 (50.3)	$\geq$ 30	United States
Berger et al, <sup>29</sup> 1990	B	Consecutive patients admitted to hospital with chest pain	36.0	278 (30.9)	57.2	Switzerland
Weaver et al, <sup>30</sup> 1990	C	Patients with chest pain brought to ED by paramedics	18.3	2472 (NR)	<75	United States
Jonsbu et al, <sup>31</sup> 1991	B	Consecutive patients admitted to hospital with suspected MI	36.5	200 (NR)	Not reported	Norway
Karlson et al, <sup>32</sup> 1991	A	Consecutive patients admitted to hospital with suspected MI	19.6	4690 (NR)	Not reported	Sweden
Kudenchuk et al, <sup>33</sup> 1991	C	Patients brought to ED by paramedics	32.9	1189 (34)	$\leq$ 74	United States

\*See "Methodologic Quality Assessments" subsection of the text for an explanation of these grades.

age agreement between clinicians, without taking into account chance agreement through the use of  $\kappa$  or other statistical measures.<sup>15</sup> Precise interpretations are important because they are made at the bedside and set off immediate management strategies. There are several factors that may influence the interpretation of the ECG, including the clinical observation of the patient and clinical data (expectation bias), as well as the training and experience of the individual reading the ECG. Although they must be interpreted with caution, the results of earlier studies suggest appreciable variability in precision in the interpretation of ECGs.

In one of the earlier studies,<sup>16</sup> 10 clinicians with experience in cardiology read 100 ECGs on 2 separate occasions and classified the tracings as normal, abnormal, or infarction. The 3 clinicians agreed completely in only one third of the ECGs. Following a second reading, the clinicians disagreed with 1 of 8 of their original reports. Gjorup et al<sup>17</sup> had 16 residents in internal medicine read 107 ECGs of suspected MI patients and assessed whether signs indicative of acute infarction were present. There was disagreement in approximately 70% of the cases.

Brush et al<sup>18</sup> reported much higher agreement in a study in which 2 clinicians classified 50 ECGs according to evidence of infarction, ischemia or strain, left ventricle hypertrophy, LBBB, or paced rhythm. They obtained agreement in 45 of the 50 cases ( $\kappa = 0.69$ ).

The precision in the interpretation of ECGs appears to increase with experience. Eight cardiologists interpreted ECGs of 1220 clinically validated cases of various cardiac disorders including anterior, inferior, or combined MI, as well as right, left, or biventricular hypertrophy.<sup>19</sup> The interobserver agreement between cardiologists was reasonably high, with an average  $\kappa$  of 0.67. For the 125 selected ECGs that were read twice by each cardiologist, different diagnoses were given for 10% to 23% of the ECGs (intraobserver reproducibility, 76.8%-90.4%).

Sgarbossa et al<sup>20</sup> have assessed the precision of features of the ECG that may aid in the diagnosis of acute MI in the presence of LBBB. In this study, 4 investigators read 2600 ECGs and achieved a  $\kappa$  of more than 0.85 for QRS-complex and T-wave polarities, with a high degree of correlation among the investigators for interpretation of ST-segment deviation (Pearson product moment correlation coefficient,  $>0.9$ ).

#### Studies Used to Determine Accuracy of the History, Physical Examination, and ECG

Table 4 summarizes features of the 14 studies<sup>8,21-33</sup> used to determine the accuracy of the history, physical examination, and ECG in the diagnosis of acute MI. Five of the studies included consecutive patients presenting to the ED with chest pain,<sup>8,23,24,27,28</sup> 7 included patients admitted to the hospital or CCU for suspected MI,<sup>21,22,25,26,29,31,32</sup> and 2 included pa-

tients with chest pain brought to the ED by paramedics.<sup>30,33</sup>

The studies examined a variety of features of the clinical examination and ECG. For the sake of relevance and clarity we have chosen to present only the results of those variables in which an LR of 2.0 or more or 0.5 or less was obtained. These studies provide the best available evidence for identifying those features that aid in the diagnosis of MI.

#### Accuracy of the History and Physical Examination

Nine of the studies outlined in Table 4 reported the relation between features of the clinical examination of patients presenting to the ED with chest pain, as determined by physicians, with that of the final diagnosis of MI. In all studies, the gold standard for the diagnosis of MI was based on cardiac enzyme and ECG changes, except for the study by Weaver et al<sup>30</sup> in which the discharge diagnosis was used to define acute MI. Although features of the clinical examination are extremely insensitive in diagnosing MI, they are reasonably specific and their presence is more likely to occur in patients with MI.

As noted in Table 5, chest pain radiation was the clinical feature that increased the probability of MI the most, with a wider extension of pain associated with the highest likelihood of MI. In particular, chest pain radiating to the left arm was twice as likely to occur in patients with, as opposed to those without, MI, while ra-

diation to the right shoulder was 3 times as likely and radiation to both the left and right arm was 7 times as likely to occur in such patients. Chest pain radiating to the right arm alone has been reported to be an extremely specific, but insensitive, marker of MI (LR, 8.9; 95% confidence interval, 1.1-75.1).<sup>29</sup> However, as reflected by the width of the confidence interval, these results were based on a small number of subjects (6 of the 100 patients with MI) and must therefore be interpreted with caution.

Further aspects of the chest pain, including presence of pain in the chest or left arm, and chest pain described as the most important symptom were associated with LRs of 2.7 and 2.0, respectively. Other items of the history that aided in the diagnosis of MI included history of MI, nausea and vomiting, and diaphoresis (LRs  $\leq 3.0$  past history and a combined LR of 1.9 and 2.0 for nausea and vomiting and diaphoresis).

A number of features from the history and clinical examination thought to be useful in determining the presence of MI were in fact of little value in establishing such a diagnosis. Features of the history, including age above 60 years, male sex, history of angina or coronary artery disease, history of nitroglycerin use, duration of chest pain greater than 60 minutes, constant or episodic chest pain, and chest pain of sudden onset, were all associated with LRs of less than 2. Adjectives used to describe the quality of the chest pain, including that of pressure, aching, and squeezing, were also associated with LRs of less than 2. Therefore, none of these features carry information independently useful in establishing an MI diagnosis.

The 3 components of the physical examination associated with LRs higher than 2 included hypotension, presence of a third heart sound, and pulmonary crackles on auscultation (LRs of 3.1, 3.2, and 2.1, respectively). Dyspnea was not found to be an important component of the clinical examination. Other features frequently described in the assessment of the patient with chest pain, including bradycardia and tachycardia, were not evaluated.

Cardiac risk factors, including hypertension, smoking, obesity, hypercholesterolemia, diabetes, and a family history of cardiovascular disease, are frequently included in the history of a patient presenting with chest pain. However, current evidence provides little support for the diagnostic value of a history of these risk factors. In 3 large studies of patients presenting to the ED with chest pain, none of the classic cardiac risk factors emerged as independent predictors of acute MI.<sup>8,34,35</sup>

Table 5.—Clinical Features That Increase the Probability of a Myocardial Infarction in Patients Presenting With Acute Chest Pain

Clinical Feature	Likelihood Ratio (95% Confidence Interval)	Reference
Pain in chest or left arm	2.7*	8
Chest pain radiation		
Right shoulder	2.9 (1.4-6.0)	24
Left arm	2.3 (1.7-3.1)	29
Both left and right arm	7.1 (3.6-14.2)	29
Chest pain most important symptom	2.0*	8
History of myocardial infarction	1.5-3.0†	8, 24
Nausea or vomiting	1.9 (1.7-2.3)	24, 25, 29, 31
Diaphoresis	2.0 (1.9-2.2)	24, 28, 31
Third heart sound on auscultation	3.2 (1.6-6.5)	24
Hypotension (systolic blood pressure $\leq 80$ mm Hg)	3.1 (1.8-5.2)	30
Pulmonary crackles on auscultation	2.1 (1.4-3.1)	24

\*Data not available to calculate confidence intervals.

†In heterogeneous studies the likelihood ratios are reported as ranges.

Table 6.—Clinical Features That Decrease the Probability of a Myocardial Infarction in Patients Presenting With Acute Chest Pain

Clinical Feature	Likelihood Ratio (95% Confidence Interval)	Reference
Pleuritic chest pain	0.2 (0.2-0.3)	23, 24, 28
Chest pain sharp or stabbing	0.3 (0.2-0.5)	23, 24
Positional chest pain	0.3 (0.2-0.4)	23, 28
Chest pain reproduced by palpation	0.2-0.4*	23, 24, 28

\*In heterogeneous studies the likelihood ratios are reported as ranges.

Table 6 presents clinical features that decrease the probability of MI. Chest pain described as pleuritic, sharp, stabbing, or positional decreased the likelihood of MI significantly. In addition, chest pain reproduced by palpation on physical examination was associated with a low LR, ranging from 0.2 to 0.4.

### Accuracy of the ECG

Eight studies addressed the accuracy of the ECG in diagnosing MI. The results reported in this article are for interpretation of the ECGs by clinicians and not by computer algorithms. Interpretation of the ECG was by an independent physician blinded to the clinical data in 5 of the studies,<sup>8,21,22,32,33</sup> by the ED physician alone in 2 others,<sup>23,27</sup> and by the ED physician with a review by an independent physician blinded to the clinical data in 1.<sup>24</sup> In all studies the gold standard for the diagnosis of MI was based on cardiac enzymes, except for the study by Kudenchuk et al,<sup>33</sup> in which the hospital discharge diagnosis was used to define MI.

Several features of the ECG have been used to assist in the diagnosis of acute MI. The most common characteristics include the presence of Q waves, ST-segment elevation or depression, and T-wave inversion. As noted in Table 7, there was a considerable degree of variability between studies for some of these features. New ST-segment elevation was the most powerful feature in increasing the probability of MI, with the LRs ranging from 5.7 to 53.9. The presence of a new Q wave was

also much more likely to occur in patients with, as opposed to those without, MI, with LRs ranging from 5.3 to 24.8, although the usefulness of this finding was reduced when patients with old Q waves were included.

ST-segment depression, whether new or known to have been present previously, and new T-wave peaking or inversion were all approximately 3 times as likely to occur in patients with, as opposed to those without, MI. In addition, conduction defects, particularly those reported to be new, also increased the probability of MI.

A normal ECG decreased the probability of MI the most and was associated with LRs of 0.1 to 0.3.<sup>19,20,26,31</sup>

### The Role of Combined Findings and Clinical Prediction Rules for MI

Clinicians are frequently presented with multiple clinical examination items, each of which can be considered a separate diagnostic test for establishing the diagnosis of MI. The challenge in situations such as this is in knowing how to combine the LRs from these multiple tests to obtain an accurate estimate of the posttest probability of MI. The simple serial multiplication of LRs that has been proposed assumes that the tests are conditionally independent,<sup>15</sup> that is, that the patient's results on one test bear no relationship to the results on any of the other tests. As demonstrated by Holleman and Simel,<sup>36</sup> violation of the conditional independence as-

Table 7.—Features of the Electrocardiogram That Increase the Probability of a Myocardial Infarction in Patients Presenting With Acute Chest Pain

Feature of the Electrocardiogram	Likelihood Ratio (95% Confidence Interval)	Reference(s)
New ST-segment elevation $\geq 1$ mm	5.7-53.9*	21-24, 32, 33
New Q wave	5.3-24.8*	21, 24, 32, 33
Any ST-segment elevation	11.2 (7.1-17.8)	24
New conduction defect	6.3 (2.5-15.7)	24
New ST-segment depression	3.0-5.2*	21, 24, 32
Any Q wave	3.9 (2.7-5.7)	24
Any ST-segment depression	3.2 (2.5-4.1)	24
T-wave peaking and/or inversion $\geq 1$ mm	3.1†	8
New T-wave inversion	2.4-2.8*	24, 32, 33
Any conduction defect	2.7 (1.4-5.4)	24

\*In heterogeneous studies the likelihood ratios are reported as ranges.

†Data not available to calculate confidence intervals.

sumption can yield inaccurate posttest probabilities of disease. Unfortunately, the precision and accuracy of combination of findings were not reported in the studies included in this review. However, the combination of clinical findings are assessed in clinical prediction rules.

By combining findings from patients' history, physical examination, and ECG, investigators have developed probability-based decision aids, as well as computer-based protocols and guidelines, that categorize patients with chest pain into risk groups based on their probability of MI.<sup>34,35,37</sup> These tools have been devised to improve physician recognition and triage of patients with acute ischemic events.<sup>8,38</sup> Although these measures have helped clinicians make appropriate decisions, not all studies of probability-based risk assessment tools have demonstrated improvement in ED triage or reduction in resource utilization.<sup>39</sup> These clinical prediction rules conform to the methodological standards of clinical prediction rules initially proposed by Wasson et al,<sup>40</sup> and recently revised,<sup>41</sup> except for the validation of the rule by Tierney et al,<sup>34</sup> which was performed on a subset, rather than on a prospective sample of the population.

Tierney et al<sup>34</sup> developed an instrument for the prediction of MI. Based on multivariate analysis of 540 ED patients with chest pain, 4 variables with independent predictive value for infarction were identified. These included diaphoresis with chest pain, history of MI, ECG changes of a new Q wave, and ST-segment elevation either new or old.

Goldman et al<sup>35,37</sup> also developed a protocol to predict MI in ED patients with chest pain. The instrument was based on the history, physical examination, and ECG of more than 6000 patients presenting at an ED with a chief complaint of chest pain. Variables in Goldman's algorithm include patient's age above 40 years, history of angina or MI, chest pain that began less than 48 hours prior to arrival at the ED, longest pain episode 1

hour or more, pain worse than usual angina or the same as earlier MI, and radiation of pain to neck, left shoulder, or left arm as predictors of infarction. Features of the chest pain including radiation to the back, abdomen, or legs, stabbing pain, and pain reproduced by palpation included in the algorithm lower the probability of infarction. The ECG changes predictive of an acute MI included new ST-segment elevation or Q waves in 2 or more leads and new ST-T-segment changes of ischemia or strain. On the basis of the algorithm, patients can be assigned to 1 of 14 subgroups, with a probability of acute MI ranging from 1% to 77%.

These prediction rules included several of the common variables identified in univariate analysis and included in this review, namely the location and extent of the chest pain, chest pain with diaphoresis, and ECG changes including new Q-wave and ST-segment elevation. However, in situations in which the independence of features of the history and clinical examination has not been tested, as in these studies, clinicians must be cautious when interpreting and attempting to combine these multiple clinical findings. In these situations they may look to clinical prediction rules to help integrate and interpret the results.

#### Pretest Probability in the Diagnosis of MI

To determine the posttest probability, or likelihood, of disease based on the clinical features and their associated LRs, one must take into account the pretest probability, or likelihood, of that condition. Although much focus has been placed on the combination of multiple clinical variables and the development of prediction rules for MI, as described above, there has been little emphasis on establishing the pretest probability of MI based on standard clinical assessment. If an estimate of the pretest probability of MI is available, a diagnostic test, based on its sensitivity, specificity, and LR, can be used to establish a new estimate of disease likelihood.

A classic and widely used example of this concept was proposed by Diamond and Forrester.<sup>42</sup> Estimates of the pretest probability of coronary artery disease on the basis of age, sex, and chest pain description have been published and are easily used in the clinical setting. A more comprehensive attempt to consider all clinical characteristics has also been undertaken.<sup>43</sup>

The predictive value of the history, physical examination, and ECG presented also depends therefore on the pretest probability of MI. Even with a normal ECG result, for example, a high pretest probability of MI would result in a high posttest probability of this condition being present. Proper use of these findings must therefore incorporate the pretest probability of MI.

#### COMMENT

The diagnosis of MI in the setting of chest pain is a complex task. Clinicians categorize patients with chest pain into 3 groups based on current therapeutic interventions, while in the literature patients with chest pain are typically categorized into the presence or absence of MI. Based on this latter categorization, we have assessed the features of the history, physical examination, and ECG, which aid in increasing or decreasing the likelihood of acute MI. We have also addressed the use of clinical prediction rules, which use a number of clinical variables, to aid in the diagnosis of MI, as well as the need to take into account pretest probability of disease when assessing the predictive value of individual variables.

Referring back to the scenarios presented at the beginning of this article, the first 3 have features that increase the likelihood of acute MI. Patient 1 has chest pain, diaphoresis, and ST-segment elevation. Patient 2 has diaphoresis, hypotension, and history of an MI. Patient 3 has nausea and ST-segment elevation. In contrast, Patient 4 has features that decrease the likelihood of MI, namely, chest pain that is both positional and reproducible by palpation and a normal ECG.

Clinicians interested in distinguishing patients with acute MI from those with unstable angina and nonanginal chest pain can use either Goldman's algorithm or the individual clinical features that we summarize in Tables 5 to 7. However, the distinction between MI and non-MI chest pain may not be the most relevant initial clinical decision; it is more important to decide on appropriate immediate therapy.

#### THE BOTTOM LINE

The presence of any of the following clinical findings increases the likelihood of MI: patients presenting with chest pain radiating to the left arm, radiating

to the right shoulder, or radiating to both left and right arms; and patients presenting with chest pain diaphoresis, a third heart sound, or with hypotension.

The presence of any of the following clinical findings decreases the likelihood of MI: patients presenting with chest pain that is described as pleuritic, sharp or stabbing, positional, or reproduced by palpation.

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