

PREDICTION OF THE NEED FOR INTENSIVE CARE IN PATIENTS WHO COME TO EMERGENCY DEPARTMENTS WITH ACUTE CHEST PAIN

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Abstract Background. Patients who come to the emergency department with chest pain are a heterogeneous group. Some have ischemic heart disease that may lead to serious complications, whereas others have minor disorders. We performed a study to identify clinical factors that predict which patients will have complications requiring intensive care.

Methods. We first studied 10,682 patients with acute chest pain at seven hospitals between 1984 and 1986 (derivation set) to identify potential clinical predictors of the development of major complications. We then validated these predictors in a separate set of 4676 patients at one hospital between 1990 and 1994 (validation set).

Results. In the derivation set of patients, we identified the following clinical features, which, if present in the emergency department, were associated with an increased risk of complications: ST-segment elevation or Q waves on the electrocardiogram thought to indicate acute myocardial infarction, other electrocardiographic changes indicating myocardial ischemia, low systolic blood pressure, pulmo-

nary rales above the bases, or an exacerbation of known ischemic heart disease. On the basis of these criteria, the patients in the validation set were stratified into four groups, with the risk of major complications in the first 12 hours ranging from 0.15 to 8 percent. After 12 hours, the probability of a major complication could be updated on the basis of whether the patient had already had a complication of major severity, a complication of intermediate severity, or a myocardial infarction (independent relative risks, 18.9, 7.7, and 4.0, respectively, as compared with patients without prior complications or myocardial infarction).

Conclusions. The risk of major complications in patients with acute chest pain can be estimated on the basis of the clinical presentation and new clinical observations made during the hospital course. These estimates of risk help in making rational decisions about the appropriate level of medical care for patients with acute chest pain. (N Engl J Med 1996;334:1498-504.)

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CLINICAL factors used to predict whether patients who come to an emergency department with acute chest pain are having an acute myocardial infarction or have acute ischemic heart disease¹⁻⁷ serve as surrogate criteria for another important issue: deciding whether a patient will benefit from hospitalization and, if so, determining the appropriate level of care. The findings on the initial electrocardiogram recorded in the emergency department predict not only the presence of acute myocardial infarction¹⁻⁶ but also the subsequent development of life-threatening complications.⁷⁻⁹ Acute myocardial infarction develops in 75 to 86 percent of patients with classic electrocardiographic abnormalities,^{4,10} but only about 50 to 65 percent of patients with acute myocardial infarction present with these electrocardiographic findings.⁴

It may be appropriate to observe certain patients for 6 to 12 hours without admitting them to the hospital, and certain patients who are admitted may be moved safely from an intensive or intermediate care unit to

a general unit or even sent home within 12 to 24 hours.¹¹⁻¹⁵ Some patients with acute myocardial infarction may even be ready for discharge by the fourth hospital day.¹⁶

In this report from the Multicenter Chest Pain Study, we describe the derivation and validation of a straightforward clinical approach to assessing the risk of major complications in patients who present to the emergency department with chest pain and updating the risk periodically during the first 72 hours of hospitalization.

METHODS

The Multicenter Chest Pain Study^{2,4,12,13,17,18} assessed the risk of complications in patients who came to any of seven emergency departments with a primary symptom of chest pain unexplained by obvious local trauma or abnormalities on the chest radiograph. The three university hospitals and four community hospitals participating in the study and the enrollment periods were as follows: Brigham and Women's Hospital, Boston, January 1984 to November 1986; Yale-New Haven Hospital, New Haven, Connecticut, February 1984 to June 1986; University of Cincinnati Hospital, Cincinnati, July 1984 to October 1986; Milford Hospital, Milford, Connecticut, June 1984 to September 1986; Danbury Hospital, Danbury, Connecticut, January 1984 to August 1986; St. Mary's Hospital, Waterbury, Connecticut, April 1984 to April 1985; and William Beaumont Hospital, Royal Oak, Michigan, June 1985 to August 1985. A total of 10,682 patients were enrolled (the derivation set). An additional 4676 patients at Brigham and Women's Hospital who met the same entry criteria were enrolled between July 2, 1990, and February 18, 1994 (the validation set), to test the accuracy of risk estimates based on data from the earlier group. The protocol was approved by the institutional review board at each hospital.

Admitted patients underwent serial electrocardiography and cardiac-enzyme measurements at the discretion of their physicians. The physicians who examined the patient in the emergency department and the research nurse or other personnel who occasionally transcribed pertinent data onto our standard study form did so at a time when they had no knowledge of the patient's subsequent course.

A patient could be included in the study for each separate visit to the emergency department, up to a total of three visits. Patients who

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Supported in part by grants from the John A. Hartford Foundation (83102-2H), the Robert Wood Johnson Foundation (12543), and the Agency for Health Care Policy and Research (RO1-HS06452). Dr. Lee is the recipient of an Established Investigator Award (900119) from the American Heart Association. Dr. Rouan was a Teaching and Research Scholar of the American College of Physicians during the study. Dr. Johnson is the recipient of a Minority Faculty Development Award from the Robert Wood Johnson Foundation.

had a cardiac arrest in the emergency department or who left against medical advice were excluded.

Patients were enrolled in the study only if they were admitted or if they consented to return for follow-up within 24 to 72 hours, if requested. In the derivation set, which included 14,832 potentially eligible patients, 2140 did not consent to participate, and 1576 had incomplete study forms or insufficient clinical data for a meaningful assessment of the risk of major complications (primarily because of missing or insufficiently explicit interpretation of the electrocardiogram). For 434 patients, follow-up data were inadequate to allow the investigators, who were blinded to the initial data, to determine whether a myocardial infarction had occurred. The remaining 10,682 patients were included in all subsequent analyses. Of the 4637 patients (43 percent) who were not initially admitted to the hospital, 65 percent underwent subsequent serum cardiac-enzyme measurements or examinations by the investigators or other physicians. In the validation set, 292 (17 percent) of the discharged patients saw a physician within one month after discharge. Twenty-nine patients in the validation set were excluded because of insufficiently explicit interpretation of the electrocardiogram. For all patients in both sets, there were sufficient follow-up data from examinations by the patients' physicians or the study investigators or from telephone interviews or a review of medical records by the investigators to determine whether complications had occurred.

Definition of Events

We recorded all major events, defined as those thought on a clinical basis to require intensive care, and all intermediate events, defined as those that did not necessarily require intensive care but did require careful monitoring or active treatment (Table 1). All events were defined before any analyses were performed with data from the validation set. Complications that occurred during or after cardiac surgery were excluded.

A myocardial infarction was diagnosed according to the study's standard criteria, which included an elevated serum concentration of creatine kinase MB isoenzymes, an elevated concentration of lactate dehydrogenase isoenzyme 1 in the absence of another explanation, or new pathologic Q waves with a decrease in the amplitude of the following R wave.^{2,4,12,13,17} Patients with sudden cardiac arrest within 72 hours without another known cause were considered to have a myocardial infarction. This diagnosis was also made in patients who received intravenous thrombolytic agents or primary percutaneous angioplasty, if ST-segment elevation was present on the electrocardiogram and then resolved or evolved in the next 24 hours after therapy and if the patient also had complete occlusion of the infarct-related artery, echocardiographic wall-motion abnormalities corresponding to the acute electrocardiographic changes, or a creatine kinase MB level above 2.5 percent of an elevated total creatine kinase level that returned to a normal value. The time at which the myocardial infarction occurred was considered to be the time at which the patient met the enzymatic criteria (in over 98 percent of the patients) or other criteria (in less than 2 percent). Nine percent of the patients with myocardial infarction in the derivation set and 45 percent of those in the validation set underwent thrombolytic therapy or primary percutaneous angioplasty.

Statistical Analysis

All analyses of data from the derivation set were performed before the analyses of data from the validation set. The association between clinical data at the time of presentation and the risk of major events was analyzed by the chi-square test, with the appropriate degrees of freedom, for categorical variables, by Student's t-test for continuous variables, and by a univariate Cox proportional-hazards test for life-table analyses.¹⁹

Recursive-partitioning analysis was used to assess the ability of about 50 potential predictive variables from the history, physical examination, and electrocardiogram to discriminate between patients with major events within 24 hours and those without such events.^{2,4,20} For continuous variables, any cutoff point could theoretically be chosen, but we selected only those cutoff points that would be easy to apply clinically.

We used the Mantel-Haenszel test to determine whether any variables added statistically significant information across all strata of patients.²¹ On the basis of clinical judgment, we hypothesized that pa-

tients with a myocardial infarction or a prior intermediate or major event would be at increased risk for a subsequent major event. Because of the size of the data base and the large number of statistical tests performed, only two-tailed P values of less than 0.01 were considered to indicate statistical significance, except where otherwise noted.

We compared key results in the derivation set with those in the validation set by the chi-square test for association and the Mantel-Haenszel stratified test.²¹ The area under the receiver-operating-characteristic curve, which is a measure of overall discrimination, was calculated²² and compared²³ for various predictive models.

RESULTS

Timing and Type of Events

Of the 10,682 patients in the derivation set, 462 had a total of 947 major events within 72 hours after they had presented to the emergency department (Table 2). Except for cardiac catheterization followed by coronary-artery bypass surgery in patients with recurrent ischemic pain, the likelihood of each major event declined as the elapsed time after presentation to the emergency department increased, with 384 major events (41 percent) occurring within the first 12 hours and 585 (62 percent) occurring within 24 hours. Of the 462 patients in the derivation set who had major events within 72 hours, 190 (41 percent) had the first event within 12 hours, and 287 (62 percent) within 24 hours.

Among the patients in the validation set, major events were also more common in the first 24 hours than in any subsequent 24-hour period, but the overall event rate in the first 24 hours was lower than in the derivation set (1.8 percent vs. 2.8 percent, $P < 0.01$), and most of the individual events were also less frequent. Patients in the validation set were significantly more likely than those in the derivation set to undergo a revascularization procedure that met the study criteria

Table 1. Complications Defined as Major or Intermediate Events in Patients with Acute Chest Pain.

MAJOR EVENTS	INTERMEDIATE EVENTS
	ARRHYTHMIA
Ventricular fibrillation	Atrial flutter
Cardiac arrest	Atrioventricular dissociation
New complete heart block	Mobitz type I or II second-degree heart block not treated with a pacemaker
Insertion of a temporary pacemaker	Sinus bradycardia treated with medications to raise the heart rate
Emergency cardioversion	
	PUMP FAILURE
Cardiogenic shock	Pulmonary edema without hypotension
Use of an intraaortic balloon pump*	
Intubation	
	ISCHEMIA
Recurrent ischemic chest pain requiring CABG or PTCA within 72 hours after admission or cardiac catheterization followed by CABG or PTCA before discharge†	Infarct extension or reinfarction without a major event
	Recurrent ischemic pain not meeting the criteria for a major event
	OTHER
	Pulmonary embolism

*May also be used to treat ischemia.

†CABG denotes coronary-artery bypass grafting, and PTCA percutaneous transluminal coronary angioplasty.

for a major event in the first 24 hours and in the interval between 24 and 72 hours.

Risk of a Major Event

In the derivation set, the factors associated with the development of major events within 72 hours were older age, male sex, description of pain as the same as that during a prior myocardial infarction or worse than prior angina, systolic blood pressure below 110 mm Hg, rales above the bases on the initial physical examination, and initial electrocardiographic changes suggestive of acute myocardial infarction or ischemia (Table 3).

Event rates within 72 hours were much higher among the patients in the derivation set who met the diagnostic criteria for an acute myocardial infarction (23 percent) than among those with unstable angina (5 percent) or other cardiac diagnoses (2 percent). Of the 82 patients with unstable angina in whom major events developed, 43 (52 percent) met our criteria because they underwent revascularization after the development of recurrent ischemic pain but did not have another major event before the procedure was performed. Overall, 445 of the 483 patients (92 percent) with events within 72 hours were admitted by their physicians to intensive care units.

The factors that were correlated with the development of major events in the derivation set were predictive in the validation set. Although the overall complication rate was lower in the validation set than in the derivation set, the complication rates among the patients with myocardial infarction were similar in the two groups (22 percent in the validation set and 23 percent in the derivation set, $P=0.67$) and higher among the patients with unstable angina in the validation set (8 percent, vs. 5 percent in the derivation set; $P<0.001$), indicating that the patients in the validation set were at

lower risk because fewer of them met these diagnostic criteria. Of the events in the group of patients with unstable angina, 59 (74 percent) were procedures that followed recurrent ischemic pain.

As compared with patients in the derivation set, those in the validation set were significantly more likely to be admitted to an intermediate care unit (52 percent vs. 10 percent, $P<0.001$) and less likely to be admitted to an intensive care unit (10 percent vs. 43 percent, $P<0.001$). The proportion of patients with myocardial infarctions who were initially admitted to an intermediate care unit increased from 4 percent in the derivation set to 31 percent in the validation set. Along with the increased use of intermediate care, the frequency of documented myocardial infarction among patients admitted to an intensive care unit rose from 31 percent in the derivation set to 50 percent in the validation set ($P<0.001$), and the proportion of patients admitted to an intensive care unit without myocardial infarction or unstable angina fell from 41 percent to 22 percent ($P<0.001$). The rate of major complications remained low (3.3 percent) among patients in the validation set who were admitted to an intermediate care unit, though it was significantly higher than the rate in the derivation set (1.6 percent, $P<0.01$).

Multivariate Correlates of the Risk of an Event within 24 Hours

Patients were assigned to one of four groups according to the risk of an event within 24 hours, from very low (0.3 percent) to high (16 percent) (Fig. 1). Five factors were used to assign patients to a risk group: electrocardiographic evidence of an ST-segment elevation or Q waves, not known to be old, in two or more leads; ST-segment or T-wave changes, not known to be old, indicative of myocardial ischemia; pain worse than prior angina or the same as the pain associated with a prior myocardial infarction; systolic blood pressure of less than 110 mm Hg; or rales above the bases bilaterally.

The risk of complications associated with each of the four groups identified in the derivation set was remarkably consistent when applied to the validation set (Table 4). With the use of a systolic blood pressure of less than 100 mm Hg, which appeared to be a better univariate threshold for predicting complications in the validation set, the results were similar both clinically and statistically.

Updated Risk of a Major Event after the Initial Presentation

Among the patients in the derivation group, the relative risk of a major event more than 12 hours after presentation was associated with prior events (Table 5). Each prior event

Table 2. Major Events after Arrival at the Emergency Department.

EVENT*	≤24 HOURS			>24-72 HOURS		
	DERIVATION SET (N = 10,682)	VALIDATION SET (N = 4676)	P VALUE	DERIVATION SET (N = 10,682)	VALIDATION SET (N = 4676)	P VALUE
Total no. of events	585	129	<0.01	362	139	0.51
	<i>no. of patients (%)</i>			<i>no. of patients (%)</i>		
First event†	294 (2.8)	86 (1.8)	<0.01	189 (1.8)	82 (1.8)	0.61
Type of event						
Ventricular fibrillation or cardiac arrest	108 (1.0)	14 (0.3)	<0.001	50 (0.5)	8 (0.2)	0.01
Complete heart block or new Mobitz type II block treated with a pacemaker	41 (0.4)	8 (0.2)	0.03	25 (0.2)	3 (0.1)	0.02
Cardiogenic shock	73 (0.7)	6 (0.1)	<0.001	30 (0.3)	4 (0.1)	0.02
Emergency cardioversion	65 (0.6)	4 (0.1)	<0.001	15 (0.1)	5 (0.1)	0.60
Use of an intraaortic balloon pump	59 (0.6)	23 (0.5)	0.64	35 (0.3)	14 (0.3)	0.75
Intubation	94 (0.9)	15 (0.3)	<0.001	44 (0.4)	13 (0.3)	0.21
Insertion of a temporary pacemaker	100 (0.9)	10 (0.2)	<0.001	44 (0.4)	4 (0.1)	0.001
CABG without catheterization‡	3	11 (0.2)	<0.001	25 (0.2)	34 (0.7)	0.001
PTCA‡	16 (0.1)	14 (0.3)	0.05	26 (0.2)	24 (0.5)	0.01
Cardiac catheterization followed by CABG before discharge‡	26 (0.2)	24 (0.5)	<0.01	68 (0.6)	30 (0.6)	0.97

*CABG denotes coronary-artery bypass grafting, and PTCA percutaneous transluminal coronary angioplasty.

†The derivation set included 7 patients transferred to another hospital within 24 hours and another 14 transferred within 72 hours because of problems that could not be managed at the community hospital.

‡Performed in patients who also had one or more episodes of ischemia after admission and before the procedure.

Table 3. Relative Risk of a Major Event within 72 Hours in the Derivation and Validation Sets, According to Data on Presentation, the Ultimate Diagnosis, and Discharge or Admission.*

VARIABLE	MAJOR EVENT WITHIN 72 HOURS				P VALUE†
	DERIVATION SET (N = 10,682)		VALIDATION SET (N = 4676)		
	no./total no. (%)	RR (95% CI)	no./total no. (%)	RR (95% CI)	
Data on presentation					
Age (yr)					
30–39	15/1517 (1.0)	0.3 (0.15–0.46)	2/669 (0.3)	0.3 (0.01–0.47)	0.27
40–49	59/2078 (2.8)	0.8 (0.55–1.1)	21/961 (2.2)	0.8 (0.46–1.5)	0.85
50–59	89/2427 (3.7)	1.0	26/975 (2.7)	1.0	
≥60	320/4660 (6.9)	1.9 (1.5–2.4)	119/2071 (5.7)	2.2 (1.4–3.4)	0.56
Sex					
Male	304/5328 (5.7)	1.7 (1.4–2.1)	103/2303 (4.5)	1.6 (1.2–2.3)	0.78
Female	179/5354 (3.3)	1.0	65/2373 (2.7)	1.0	
Pain same as with prior infarction or worse than prior angina‡					
No	263/8244 (3.2)	1.0	74/3494 (2.1)	1.0	
Yes	196/2255 (8.7)	2.8 (2.3–3.4)	94/1091 (8.6)	4.2 (3.1–5.7)	0.03
Systolic blood pressure (mm Hg)§					
<100	38/223 (17.0)	5.0 (3.6–7.1)	9/132 (6.8)	2.0 (1.0–3.9)	0.02
100–109	39/422 (9.2)	2.5 (1.8–3.5)	10/293 (3.4)	1.0 (0.5–1.8)	0.01
110–119	53/894 (5.9)	1.6 (1.2–2.1)	17/529 (3.2)	0.9 (0.5–1.5)	0.07
≥120	344/8945 (3.8)	1.0	132/3699 (3.6)	1.0	
Rales					
None	350/9361 (3.7)	1.0	124/3968 (3.1)	1.0	
Basilar only	72/920 (7.8)	2.2 (1.7–2.8)	28/544 (5.1)	1.7 (1.1–2.5)	0.30
Above bases	61/401 (15.2)	4.5 (3.4–5.9)	16/164 (9.8)	3.3 (1.9–5.6)	0.30
Abnormality on ECG					
ST elevation or Q wave not known to be old	189/900 (21.0)	17 (13–21)	45/251 (18.0)	13 (8.5–19)	0.20
ST depression or T-wave inversion not known to be old	180/1921 (9.4)	6.8 (5.4–8.6)	65/823 (7.9)	5.1 (3.6–7.3)	0.18
Other	114/7861 (1.5)	1.0	58/3602 (1.6)	1.0	
Ultimate diagnosis					
Myocardial infarction	363/1574 (23.1)	165 (88–309)	75/341 (22.0)	156 (63–387)	0.90
Unstable angina	82/1709 (4.8)	30 (15–57)	80/988 (8.1)	51 (21–126)	0.34
Other cardiac condition	28/1379 (2.0)	12 (6–26)	8/340 (2.4)	14 (5–44)	0.83
Noncardiac condition	10/6020 (0.2)	1.0	5/3007 (0.2)	1.0	
Discharge or admission¶					
Home or general ward	21/5044 (0.4)	0.04 (0.03–0.06)	6/1776 (0.3)	0.02 (0.01–0.04)	0.07
Intermediate care	16/1031 (1.6)	0.15 (0.09–0.25)	81/2444 (3.3)	0.17 (0.12–0.23)	0.72
Intensive care	445/4598 (9.7)	1.0	81/456 (17.8)	1.0	

*RR denotes relative risk, CI confidence interval, and ECG electrocardiogram.

†For the comparison of the relative risks in the two sets of patients.

‡Data were missing for 183 patients in the derivation set and 91 in the validation set.

§Data were missing for 198 patients in the derivation set and 23 in the validation set.

¶Data were missing for 9 patients in the derivation set.

remained a significant predictor of a subsequent major event after adjustment for the patient's characteristics at presentation. After adjustment for the initial risk group, their constituent factors, and a prior major or intermediate event or myocardial infarction, no other factor in Table 2 for which data were available at the time of presentation was a significant correlate of a subsequent major event in any period.

The influence of a prior major or intermediate event or documented myocardial infarction on the risk of a subsequent major event was generally stronger in the validation set (Table 5), especially after adjustment for the patient's characteristics at presentation.

Overall Risk Assessment Based on Data at Presentation and Subsequent Events

By considering events that occurred during intervals after presentation, in addition to the data at the time of presentation, we assigned patients to one of four risk groups that accurately predicted the rates of major

events in the validation set (Table 6). The risk of a major event declined as the time after presentation increased, except among the patients with a major or intermediate event or a myocardial infarction diagnosed in a prior period. In both the derivation and the validation sets, after an initial period of 12 hours, the development of an event was more important than the patient's original risk factors in predicting the probability of a subsequent event.

The development of a major or intermediate event or a myocardial infarction after the first 12 hours increased the area under the receiver-operating-characteristic curve in the validation set as follows: >12 to 24 hours, from 0.77 to 0.85; >24 to 48 hours, from 0.77 to 0.91; and >48 to 72 hours, from 0.81 to 0.88 ($P < 0.001$ for all three comparisons).

DISCUSSION

Given substantial evidence from previous studies that electrocardiographic abnormalities recorded in the

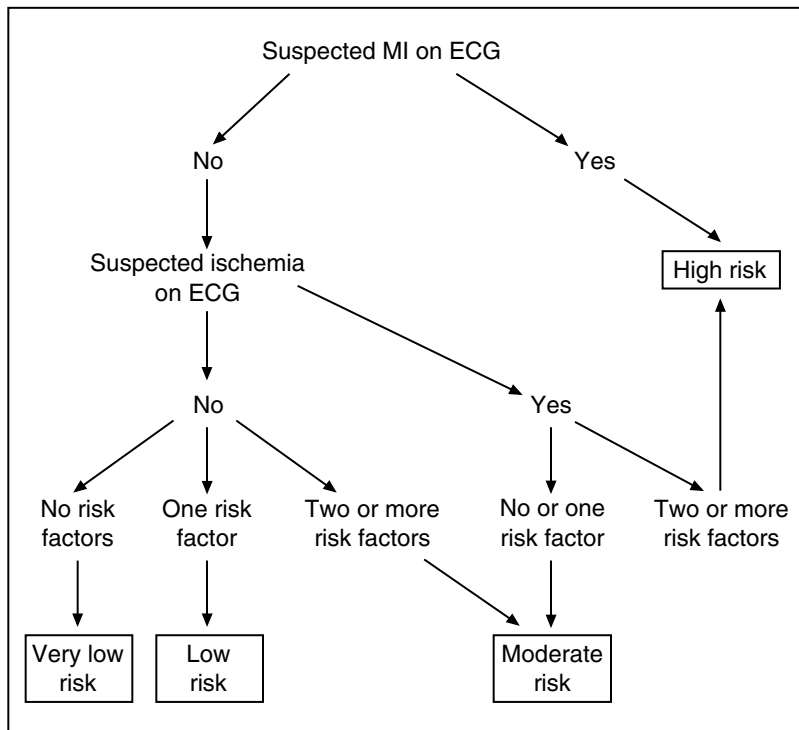


Figure 1. Derivation of the Four Initial Risk Groups on the Basis of Data Available at the Time of Presentation in the Emergency Department.

Myocardial infarction (MI) was suspected if the electrocardiogram (ECG) showed ST-segment elevation of 1 mm or more or pathologic Q waves in two or more leads, and these findings were not known to be old. Ischemia was suspected if the ECG showed ST-segment depression of 1 mm or more or T-wave inversion in two or more leads, and these findings were not known to be old. Risk factors included systolic blood pressure below 110 mm Hg, rales heard above the bases bilaterally on physical examination, and known unstable ischemic heart disease, defined as a worsening of previously stable angina, the new onset of postinfarction angina or angina after a coronary-revascularization procedure, or pain that was the same as that associated with a prior myocardial infarction. The difference between each adjacent pair of risk groups was significant ($P < 0.001$).

emergency room predict subsequent in-hospital complications, it is not surprising that in our study electrocardiographic abnormalities were the most important predictor of major complications within the first 24 hours after presentation. A systolic blood pressure below 110 mm Hg, and especially below 100 mm Hg, also

predicted complications, although we were not able to determine whether patients with chronically low blood pressure were at lower risk. Overall, our risk factors are similar to the original Killip criteria²⁴ and the predictors of mortality at 30 days among hospitalized patients with acute myocardial infarction in the era of thrombolytic therapy.²⁵

Updating the Risk during the Hospital Course

Previous studies have concentrated on the identification of patients at very low risk 12 hours¹³ or 24 hours^{11,12,14,15} after admission or even patients at low risk four days after an acute myocardial infarction.⁶ The large number of patients in our series permitted us to update the risk during the first 72 hours on the basis of the development of major events, intermediate events, or evidence of an acute myocardial infarction. After the first 12 hours, the early hospital course was more important than the original presenting characteristics in predicting the subsequent risk of complications. These observations, as well as the specific risk probabilities, should be helpful in decision making, even in the era of thrombolytic therapy.

Rational Use of Hospital Facilities

To date, decision-making aids in the management of acute chest pain have not been widely used by clinicians,²⁶ probably because these aids have focused on diagnoses rather than on the need for hospitalization or intensive care. Although there is interest in finding a way to predict the hospital course on the basis of the initial emergency department data alone,²⁷ our finding that the early in-

Table 4. Rate of First Major Event According to the Level of Risk Identified in the Emergency Department.

Risk*	FIRST MAJOR EVENT									
	≤12 HOURS		>12–24 HOURS		>24–48 HOURS		>48–72 HOURS		0–72 HOURS	
	Derivation Set	Validation Set	Derivation Set	Validation Set	Derivation Set	Validation Set	Derivation Set	Validation Set	Derivation Set	Validation Set
	<i>number of patients/total number (percent)</i>									
High	125/1034 (12.1)	24/317 (7.6)	36/909 (4.0)	10/293 (3.4)	39/873 (4.5)	9/283 (3.2)	22/834 (2.6)	8/273 (2.9)	222/1034 (21.5)	51/317 (16.1)
Moderate	55/1949 (2.8)	9/845 (1.1)	36/1894 (1.9)	18/836 (2.2)	32/1858 (1.7)	22/818 (2.7)	35/1826 (1.9)	17/795 (2.1)	158/1949 (8.1)	66/845 (7.8)
Low	11/1511 (0.7)	5/918 (0.5)	14/1500 (0.9)	11/912 (1.2)	11/1485 (0.7)	10/901 (1.1)	19/1473 (1.3)	10/891 (1.1)	55/1511 (3.6)	36/918 (3.9)
Very low	5/6188 (0.1)	4/2596 (0.2)	12/6182 (0.2)	5/2592 (0.2)	18/6170 (0.3)	5/2586 (0.2)	13/6152 (0.2)	1/2580 (0)	48/6188 (0.8)	15/2596 (0.6)
Area under the ROC curve†	0.89	0.84	0.79	0.77	0.77	0.77	0.75	0.81	0.82	0.80

*The derivation of the risk groups is shown in Figure 1.

†None of the differences between the derivation set and the validation set were significant, except that for the entire 72-hour period, the event rate among the high-risk patients differed significantly between the two sets ($P = 0.04$). ROC denotes receiver-operating-characteristic.

Table 5. Relative Risk of a Subsequent Major Event More Than 12 Hours after Presentation, According to the Prior Event.*

PRIOR EVENT	SUBSEQUENT MAJOR EVENT			
	UNADJUSTED ANALYSIS		ADJUSTED ANALYSIS†	
	Derivation Set	Validation Set	Derivation Set	Validation Set
	<i>relative risk (95% confidence interval)</i>			
Major event	68.9 (58.4–81.2)	55.9 (43.1–72.4)	18.9 (13.9–25.6)	26.5 (18.0–39.2)
Documented MI but no major or intermediate event	12.2 (9.2–16.3)	13.4 (9.3–19.4)	4.0 (2.7–5.9)	5.6 (3.2–9.7)
Intermediate event but no major event or documented MI	14.6 (11.3–18.9)	29.2 (22.1–38.4)	7.7 (5.7–10.4)	18.0 (13.3–24.4)
Documented MI or intermediate event but no major event	16.5 (13.4–20.4)	21.2 (16.3–27.5)	6.8 (5.3–8.7)	11.1 (8.1–15.3)

*Data shown are relative risks for each group as compared with patients without prior major or intermediate events or documented myocardial infarction (MI).

†The analysis was adjusted for stratification of the data according to the level of risk at the time of presentation.

hospital course is also a strong predictor of later in-hospital events confirms similar findings in other studies.^{11-13,16,28}

There is no universal consensus on the criteria for admitting patients with acute chest pain or for determining the optimal level of care for those who are admitted. Several analyses suggest that admission is appropriate for patients with a probability of acute myocardial infarction as low as 5 to 7 percent,²⁹ although the threshold for admission to an intensive care unit should probably be higher (e.g., closer to 20 percent) among patients who do not have other problems that require intensive care.³⁰ When beds are limited, physicians seem remarkably able to shift patients from intensive care units to less intensive facilities without any loss of safety.^{31,32} Since low-risk patients in initially stable condition who meet the diagnostic criteria for acute myocardial infarction seem to do well in intermediate care units, low-intensity care with continuous electrocardiographic monitoring has been developed as a cost-effective alternative to intensive care for low-risk patients with acute chest pain who have no other indications for admission.³³

Interventions relying on conferences, discharge-planning rounds, or utilization review have reduced the

length of stay for patients with cardiac conditions in intensive care units or other settings with monitoring,^{14,15,34} whereas the simple feedback of information has not.³⁵ The events and complications that formed the basis for the consensus recommendations in these intervention studies were generally consistent with those that were empirically identified in the current research.^{14,15}

There is no precise risk threshold that can uniformly dictate which patients should be admitted from the emergency department to a specific hospital unit or how long they should remain hospitalized. However, our prospectively derived and validated risk probabilities should

aid in decision making. There seems little doubt that admission to an intensive care unit is appropriate for patients in the emergency department who are considered to be at high risk according to our protocol and that if there is any evidence of major or intermediate complications or an acute myocardial infarction, such patients should probably remain in the intensive care unit for at least two or three days. Admission to an intensive care unit also appears to be appropriate for patients at moderate risk, whether the assessment is based on electrocardiographic criteria³⁰ or on the combination of unstable angina and abnormal pump function, as manifested by relative hypotension or substantial heart failure. Any patient in whom a major event develops is at high risk for a subsequent major event, whereas a patient with an intermediate event or evidence of an acute myocardial infarction has about a 3.5 to 7.5 percent risk of a major event per 24-hour period. Patients without initial complications who are at too high a risk to be sent home but who have a low probability of an acute myocardial infarction or a major event can be monitored in an intermediate care unit or in an area adjacent to or in the emergency department.^{18,30,33,36} Patients who have no complications and no recurrent chest pain at 24 hours are also at very low

Table 6. Rate of New Major Events, According to the Original Risk Group and as Updated on the Basis of the Occurrence of a Myocardial Infarction or Intermediate or Major Event after Admission.*

RISK GROUP	NEW MAJOR EVENT							
	≤12 HOURS		>12–24 HOURS		>24–48 HOURS		>48–72 HOURS	
	Derivation Set	Validation Set	Derivation Set	Validation Set	Derivation Set	Validation Set	Derivation Set	Validation Set
	<i>percentage of patients (number/total number)</i>							
Very low risk	0.1 (5/6188)	0.2 (4/2596)	0.2 (14/7065)	0.2 (7/3394)	0.1 (4/6957)	0.1 (2/3333)	0.1 (9/6888)	0.2 (6/3288)
Low risk	0.7 (11/1511)	0.5 (5/918)	1.1 (16/1475)	1.0 (9/872)	0.5 (7/1377)	1.3 (11/816)	0.7 (9/1309)	0.7 (5/768)
Moderate risk	2.8 (55/1949)	1.1 (9/845)	3.5 (63/1790)	7.6 (28/367)	4.4 (88/1980)	7.5 (33/439)	3.5 (71/2035)	5.2 (25/483)
High risk	12.1 (125/1034)	7.6 (24/317)	24.9 (45/181)	12.8 (5/39)	12.7 (30/237)	18.1 (13/72)	12.0 (37/309)	18.0 (18/100)

*For the first 12 hours, the risk groups correspond to those shown in Figure 1. For the other three intervals, the risk groups have been updated as follows. Patients at very low risk were those originally at very low or low risk who did not have a myocardial infarction or intermediate or major event before the period in question; patients at low risk were those originally at moderate or high risk who did not have a myocardial infarction or intermediate or major event before the period in question; patients at moderate risk were those who had a myocardial infarction or intermediate event but not a major event before the period in question, regardless of the original risk group; and patients at high risk were those who had a major event before the period in question, regardless of the original risk group. For both the derivation and the validation sets, all comparisons between risk groups for all periods were statistically significant (P<0.05), except for the comparison between the low- and moderate-risk groups in the first 12 hours and the comparison between the moderate- and high-risk groups at >12 to 24 hours in the validation set.

risk. An observation period of 12 hours or less seems sufficient for many low-risk patients.^{11-13,36,37}

In our approach to risk stratification, we did not consider other information, such as echocardiographic findings or the results of other diagnostic tests.^{28,37-40} Studies are needed to determine the extent to which such additional information can result in a cost-effective improvement in predictions based on simple clinical characteristics alone.

We are indebted to the investigators in the Multicenter Chest Pain Study, who gathered the data on the patients in the derivation set.

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