Impact of a Clinical Decision Rule on Hospital Triage of Patients With Suspected Acute Cardiac Ischemia in the Emergency Department

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Context Emergency department (ED) physicians often are uncertain about where in the hospital to triage patients with suspected acute cardiac ischemia. Many patients are triaged unnecessarily to intensive or intermediate cardiac care units.

Objective To determine whether use of a clinical decision rule improves physicians' hospital triage decisions for patients with suspected acute cardiac ischemia.

Design and Setting Prospective before-after impact analysis conducted at a large, urban, US public hospital.

Participants Consecutive patients admitted from the ED with suspected acute cardiac ischemia during 2 periods: preintervention group (n=207 patients enrolled in March 1997) and intervention group (n=1008 patients enrolled in August-November 1999).

Intervention An adaptation of a previously validated clinical decision rule was adopted as the standard of care in the ED after a 3-month period of pilot testing and training. The rule predicts major cardiac complications within 72 hours after evaluation in the ED and stratifies patients' risk of major complications into 4 groups—high, moderate, low, and very low—according to electrocardiographic findings and presence or absence of 3 clinical predictors in the ED.

Main Outcome Measures Safety of physicians' triage decisions, defined as the proportion of patients with major cardiac complications who were admitted to inpatient cardiac care beds (coronary care unit or inpatient telemetry unit); efficiency of decisions, defined as the proportion of patients without major complications who were triaged to an ED observation unit or an unmonitored ward.

Results By intention-to-treat analysis, efficiency was higher in the intervention group (36%) than the preintervention group (21%) (difference, 15%; 95% confidence interval [CI], 8%-21%; $P<.001$). Safety was not significantly different (94% in the intervention group vs 89%; difference, 5%; 95% CI, –11% to 39%; $P=.57$). Subgroup analysis of intervention-group patients showed higher efficiency when physicians actually used the decision rule (38% vs 27%; difference, 11%; 95% CI, 3%-18%; $P=.01$). Improved efficiency was explained solely by different triage decisions for very low-risk patients. Most surveyed physicians (16/19 [84%]) believed that the decision rule improved patient care.

Conclusions Use of the clinical decision rule had a favorable impact on physicians' hospital triage decisions. Efficiency improved without compromising safety.

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AMONG PATIENTS ADMITTED from the emergency department (ED) with possible acute cardiac ischemia, only one quarter are diagnosed with unstable angina or acute myocardial infarction (MI), and less than 5% experience a life-threatening complication.[1,2] Many of these patients are admitted unnecessarily to cardiac care units. At the same time, 2% to 5% of patients with acute cardiac ischemia are improperly diagnosed in the ED and not triaged to cardiac care units.[3-8] Some of these patients experience life-threatening complications, raising concerns about the safety of physicians' decisions.

In response to these concerns, researchers have developed prediction rules to risk-stratify patients in the ED, and hospitals have established various levels of care: coronary care units, telemetry units, and, more recently, short-stay observation units.[1,2,9-17] However, no study has addressed whether accurate risk stratification can improve physicians' decisions in triaging patients to these different levels of care.

In 1996, Goldman and colleagues[1] published their prediction rule for complications in ED patients with suspected acute cardiac ischemia. Although these investigators derived and validated their prediction rule in more

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than 15000 ED patients, they did not measure its actual impact on physicians' decisions or patients' outcomes. In this study, we performed a prospective impact analysis of their prediction rule, as recommended by the Evidence-Based Medicine Working Group.[18] Using previous studies (TABLE 1[18-21]), we hypothesized that the rule's use would reduce unnecessary admissions to the coronary care or telemetry unit without increasing complications in patients triaged instead to observation units or unmonitored wards.

Table 1. Steps in the Evaluation of Goldman and Colleagues' Clinical Decision Rule

Date	Description	Level of Evidence[18]
1984-1986	Derivation of decision rule (n = 10 682)[1]	Level 4: identification of factors with predictive power
1990-1994	Validation of decision rule (n = 4676)[1]	Level 3: narrow validation; verification of predictive power in similar setting and population
1997-1999	Validation of decision rule at other sites by different investigators (n = 207; n = 1033)[19,20]	Level 2: broad validation; verification of predictive power in different settings and populations
1999-2002	Prospective impact analysis (present study; n = 1008), simulated impact analysis[21]	Level 1: impact; evidence that rule changes physician behavior and improves patient outcomes or resource use in a representative setting

METHODS

Study Design

Our prospective study compared physicians' triage decisions before and after the clinical decision rule was established as the standard of care in our ED. We studied 2 cohorts of patients admitted consecutively from the ED with suspected acute cardiac ischemia: one cohort before (preintervention group) and one cohort after introduction of the decision rule (intervention group). This study design is consistent with the Evidence-Based Medicine Working Group conclusion that "randomization of individual patients is unlikely to be appropriate" in the impact analysis of clinical decision rules.[18]

The primary impact of the decision rule was assessed by measuring the safety and efficiency of ED physicians' triage decisions. Safety was defined as the proportion of all patients who experienced major cardiac complications within 72 hours who were triaged to a coronary care or telemetry unit after evaluation in the ED. Efficiency was defined as the proportion of all patients who did not experience major cardiac complications who were triaged to an ED observation unit or unmonitored ward.

To test for possible temporal confounding, we used identical methods to study a third cohort (postintervention group) 1 year after the decision rule was discontinued as standard practice in the ED.

Setting

The study was performed at Cook County Hospital, a 700-bed urban teaching hospital whose ED cares for 120000 adults annually. The ED is staffed by full-time emergency medicine attending physicians and residents in the departments of emergency medicine or medicine. Usual options for hospital triage of patients with suspected acute cardiac ischemia include the coronary care unit, the inpatient telemetry unit, and the ED observation unit. When the observation unit is full, physicians might also admit patients to an unmonitored ward. Unlike the 12-bed inpatient telemetry unit, the 11-bed ED observation unit does not have telemetry monitoring, house staff coverage, or nurses with special training in cardiac care.[20,22] Patients triaged to the observation unit remain for fewer than 24 hours and receive serial electrocardiograms and cardiac enzyme measurements according to protocols administered by ED nurses and physician assistants, with backup from attending physicians. Patients triaged to the telemetry unit have an average hospital stay of 3 days.

Emergency medicine attending physicians make all admitting decisions, but cardiology consultation and approval is required for admitting patients to the coronary care unit. During the 4 years spent studying the decision rule, there were no significant changes in our hospital's ED patient volume, number of medical admissions, number of admissions to the ED observation unit, number of admissions for suspected acute cardiac ischemia, or number of beds in the coronary care unit, inpatient telemetry unit, or ED observation unit.

Patients

Patients were eligible for study if they were triaged from the ED to the hospital or the ED observation unit with suspected acute cardiac ischemia. Inclusion criteria included an admitting diagnosis of acute MI, rule out MI, unstable angina, acute cardiac ischemia, or coronary artery disease if cardiac enzyme tests were ordered in the ED. Patients in cardiac or respiratory arrest on initial presentation to the ED were ineligible for study, and we excluded patients who experienced cardiac or respiratory arrest after presentation to the ED but before triage could be performed.

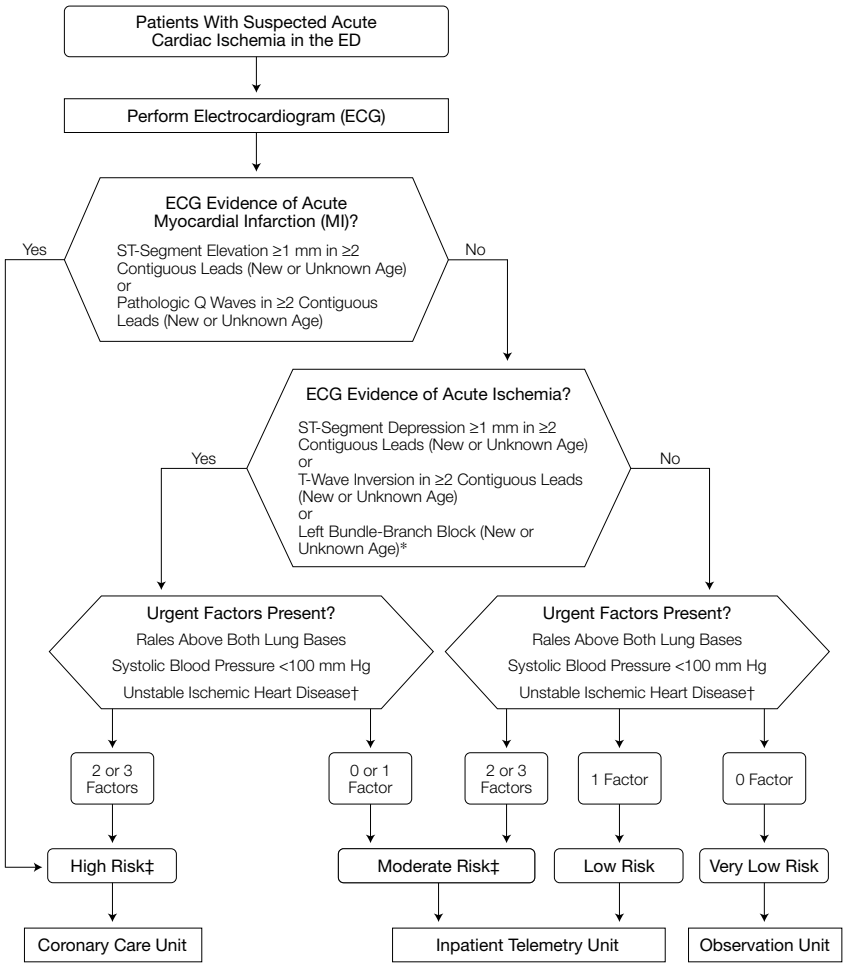
The preintervention group was studied prospectively during 4 consecutive weeks in March 1997.[19] After 3 months of pilot testing the decision rule in the ED, we enrolled the intervention group during 14 consecutive weeks from August 1999 through November 1999. We then discontinued use of the decision rule during the data analysis phase and 12 months later enrolled the postintervention group during 4 consecutive weeks in November 2000.

Our eligibility criteria differed from those in the study by Goldman and colleagues[1] in 2 ways: Goldman et al enrolled only patients presenting with chest pain and included patients discharged home directly from the ED. We enrolled patients with and without chest pain because a minority of patients presenting with acute coronary syndromes do not have chest pain,[23] and the decision rule appears to perform well for these patients.[20] We excluded

patients discharged home directly from the ED because in our ED, patients are discharged home only if the ED physician has excluded the possibility of acute cardiac ischemia and identified a convincing alternative diagnosis. Thus, our study eligibility criteria included all patients in whom the diagnosis of acute cardiac ischemia remained possible after evaluation by the ED physician.

However, to investigate whether use of the decision rule might have an unintended effect on decisions to discharge patients home, we studied a separate cohort of patients discharged home directly from the ED to monitor the safety of those decisions. During 5 consecutive weeks of the 14-week intervention period, we identified and followed up all patients discharged home from the ED after presenting with complaints of chest pain, epigastric pain, or dyspnea and in whom a 12-lead electrocardiogram was performed to evaluate possible acute cardiac ischemia. These patients were followed up for occurrence of major cardiac complications within 72 hours after discharge from the ED.

Figure 1. Clinical Decision Rule for Patients With Suspected Acute Cardiac Ischemia in the Emergency Department (ED)



* Modification to Goldman's prediction rule: Left bundle-branch block not known to be old was also considered evidence of ischemia on ECG.

†Unstable ischemic heart disease was 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 MI.

‡Cardiology consultation in the ED (for possible admission to the coronary care unit) was recommended for patients stratified as high risk, which included patients who had experienced a major complication in the ED (eg, cardiogenic shock). Modification to Goldman's prediction rule: Cardiology consultation for possible coronary care unit admission was also recommended for 2 subgroups of patients: (1) patients stratified as moderate risk by the original prediction rule because they had acute pulmonary edema or ongoing angina despite maximal medical therapy in the ED, and (2) patients presenting with unstable angina within 2 weeks of acute MI or within 6 months of coronary revascularization. Patients stratified as moderate risk who also had a high probability of significant coronary artery disease (using the Diamond and Forrester criteria[25]) were recommended for cardiology consultation.

Decision Rule

The rule of Goldman and colleagues[1] predicts major cardiac complications within 72 hours after evaluation in the ED. These complications include ventricular fibrillation, cardiac arrest, new complete heart block, insertion of a temporary pacemaker, emergency cardioversion, cardiogenic shock, use of an intra-aortic balloon pump, intubation, and recurrent ischemic chest pain requiring urgent coronary revascularization (coronary artery bypass grafting or percutaneous transluminal angioplasty before discharge from the hospital). The definition of complications in this study was identical to that used in the original study.[1]

The prediction rule stratifies patients' risk of major complications into 4 groups—high, moderate, low, and very low—according to electrocardiographic findings (Q waves or ST-segment elevations suggesting acute MI; ST-segment depressions or T-wave inversions suggesting acute ischemia) and the presence or absence of 3 clinical predictors in the ED: systolic blood pressure less than 100 mm Hg, rales heard above both lung bases, and known unstable ischemic heart disease. Risk is upgraded if complications (eg, cardiogenic shock) occur in the ED.[1]

We created a 1-page written decision rule (available on request) for physicians' use in the ED; it incorporates the prediction rule's risk-stratification algorithm and Goldman's subsequently published recommendations[24] about how to use the algorithm for triage decisions (FIGURE 1). Dur-

ing the process of creating the written decision rule, our ED physicians insisted on slight modifications to Goldman's triage recommendations because, unlike his risk-stratification algorithm, his triage recommendations had never been evaluated prospectively. However, only 1 of these modifications had the potential to affect our primary study outcomes: the written decision rule recommended triage to the telemetry unit, not the observation unit, for very low-risk patients with left bundle-branch blocks not known to be old.

Data Collection

On the 1-page depiction of the decision rule, there were prompts for ED physicians to provide the clinical data necessary to apply the rule accurately and space for an explanation when physicians made a triage decision different from the decision rule recommendation. Physicians' completion of the written decision rule form in the ED determined whether the physician had used the decision rule when making hospital triage decisions.

After approval by the institutional review board, trained research assistants enrolled all eligible patients who met inclusion criteria. The research assistants, blinded to the risk stratification process and not involved in subsequent data collection, identified patients' actual site of triage and personally interviewed patients to corroborate demographic data needed for posthospital follow-up (telephone numbers, addresses, next of kin, etc) after obtaining oral informed consent as specified by the hospital's institutional review board.

For patients discharged before 72 hours, we determined whether complications occurred outside the hospital within the 72-hour follow-up period by using telephone interviews. We visited the residence of patients we were unable to contact by telephone for face-to-face interviews. Interviews that identified patient contact with a clinician during the follow-up period prompted a review of all medical records. Any deaths within 72 hours were attributed to a major cardiac complication. For patients lost to follow-up, we reviewed clinic and hospital records and searched county, state, and national death records for 6 to 12 months following enrollment.

After patients were discharged from the hospital, their medical records were reviewed for possible cardiac complications by trained physician chart reviewers blinded to the risk stratification process and the clinical decision rule forms. At least 2 members of the outcomes adjudication panel then independently reviewed the charts of all patients with possible complications; if the 2 panel members disagreed about the occurrence, type, location, or timing of a complication, a third panel member reviewed the records and helped resolve the disagreement after further discussion.

At the conclusion of the study (after all patients were enrolled but before results were analyzed), we surveyed ED physicians about their perceptions of the usefulness of the clinical decision rule, its impact on their work in the ED, its impact on their triage decisions, and their opinions about continuing or discontinuing its use.

Data Analysis

We planned a sample size of 1000 intervention-group patients so that the width of the 95% confidence interval (CI) for each of our 2 primary outcome measures—safety and efficiency—would be no greater than 10 percentage points, assuming a 3% overall risk of major complications. This sample size provided more than 80% power to demonstrate a 10% difference in efficiency compared with that of the preintervention group, assuming a 2-sided α of .05.

To test for differences between groups, we used Wilcoxon rank-sum tests for ordinal data and Fisher exact or χ^2 tests for categorical data. For the primary study outcomes—triage decisions and their safety and efficiency—we constructed CIs for the differences between proportions in comparison groups by using the method of Miettinen and Nurminen.[26]

We assessed whether the effect of the clinical decision rule on triage decisions was homogeneous across the 4 risk strata by using stratified analysis and logistic regression (with design variables for the interaction between risk strata and comparison group). We chose to reject the conclusion of a homogeneous effect if the test for interaction was significant at the 10% level.

We stratified on baseline risk to control for differences between comparison groups. In subgroup analysis, we used logistic regression to examine whether ED physician differences confounded the relationship between use of the clinical decision rule and triage site (using an indicator variable for each attending ED physician). To assess for temporal trend in outcomes during the preintervention, intervention, and postintervention periods, we used χ^2 tests of linear trend. All P values are 2-sided, and because of multiple comparisons, we considered $P<.005$ as statistically significant. Data analysis was conducted with Stata, versions 6 and 7 (Stata Corp, College Station, Tex) and Arcus QuickStat Biomedical (Research Solutions, Cambridge, England).

RESULTS

Study Patients

Patients in the preintervention group have been described.[19] Among 1011 eligible patients in the intervention group, 3 were excluded because of respiratory arrest before triage. Of the remaining 1008 patients (TABLE 2), follow-up was complete in 994 (98.6%); no deaths were documented in the remaining 14. Overall, 35 patients (3.5%) experienced major cardiac complications during the initial 72 hours (TABLE 3). The clinical decision rule effectively stratified patients according to risk (TABLE 4).

Intention-to-Treat Analysis: Efficiency and Safety of Physicians' Triage Decisions

Intervention-group and preintervention-group patients were comparable in distribution across risk strata, overall risk of major complications, and stra-

tum-specific risk of major complications (Table 4).

Among 973 intervention-group patients who did not experience major complications, 350 were triaged to an observation unit or unmonitored ward. Thus, efficiency during the intervention period was 36% (350/973), significantly higher than that of the preintervention group (21% [42/198]; difference, 15%; 95% CI, 8%-21%; $P<.001$).

Among the 35 intervention-group patients who experienced major cardiac complications, 33 were triaged to the coronary care unit (n=18) or telemetry unit (n=15), and 2 were triaged to the observation unit. Thus, safety in the intervention group (94% [33/35]) was not significantly different from that of the preintervention group (89% [8/9]; difference, 5%; 95% CI: −11% to 39%; $P=.57$).

Overall, fewer intervention-group patients were triaged to inpatient monitored beds (coronary care or telemetry unit), reflecting a significant increase in triage to the observation unit, a decrease in triage to the telemetry unit, but no change in triage to the coronary care unit. These changes in triage decisions were explained by differences involving only very low-risk patients ($P<.001$); there were no significant differences in decisions involving high- ($P=.71$), moderate- ($P=.73$), or low-risk ($P=.43$) patients. As a result, patients in the intervention group who were triaged to the telemetry unit were more likely to be from risk strata higher than very low risk.

Table 2. Characteristics of the 1008 Intervention-Group Patients*

Characteristic	Admission Site: Coronary Care Unit (n = 110)	Admission Site: Inpatient Telemetry (n = 546)	Admission Site: Other (Emergency Department Observation Unit or Ward) (n = 352)	Total (n = 1008)
Length of hospital stay, median (10th, 90th percentile), d	4 (1, 12)	2 (1, 7)	1 (<1, 3)	2 (1, 6)
Age, mean (SD), y	57 (11.9)	58 (13.1)	55 (11.9)	57 (12.6)
Female, No. (%)	44 (40)	268 (49)	195 (55)	507 (50)
Race/ethnicity, No. (%)				
Black	68 (62)	379 (69)	225 (64)	672 (67)
Hispanic/Latino	15 (14)	64 (12)	61 (17)	140 (14)
White	14 (13)	46 (8)	25 (7)	85 (8)
Other	12 (11)	55 (10)	40 (11)	107 (11)
History, No. (%)				
Hypertension	78 (71)	400 (73)	201 (57)	679 (67)
Smoking, current	48 (44)	205 (38)	101 (29)	354 (35)
Diabetes mellitus	39 (35)	171 (31)	79 (22)	289 (29)
MI	27 (25)	111 (20)	25 (7)	163 (16)
Coronary angioplasty	19 (17)	43 (8)	6 (2)	68 (7)
Coronary artery bypass graft surgery	10 (9)	35 (6)	9 (3)	54 (5)
Presenting complaint of chest pain, No. (%)	82 (75)	407 (75)	288 (82)	777 (77)
Electrocardiogram in emergency department, No. (%)†				
Suspected acute MI	21 (19)	57 (10)	8 (2)	86 (9)
Suspected acute ischemia	44 (40)	187 (34)	54 (15)	285 (28)
LBBB (new or unknown age)	6 (5)	13 (2)	2 (0.6)	21 (2)
Old abnormalities (Q waves, ST, T, or LBBB)	19 (17)	69 (13)	35 (10)	123 (12)
Urgent factors in emergency department, No. (%)				
Unstable angina	54 (49)	127 (23)	26 (7)	207 (21)
Rales above both bases	12 (11)	58 (11)	8 (2)	78 (8)
Systolic blood pressure <100 mm Hg	6 (5)	9 (2)	4 (1)	19 (2)
Risk category, No. (%)‡				
High	25 (23)	61 (11)	9 (3)	95 (9)
Moderate	37 (34)	170 (31)	49 (14)	256 (25)
Low	33 (30)	114 (21)	29 (8)	176 (17)
Very low	15 (14)	201 (37)	265 (75)	481 (48)

*MI indicates myocardial infarction; LBBB, left bundle-branch block. Percentages within columns do not always sum to 100% because of rounding.
†Suspected acute MI denotes ST-segment elevation of 1 mm or more or pathologic Q waves in 2 or more contiguous leads, and these findings were not known to be old. Suspected acute ischemia denotes ST-segment depression of 1 mm or more or T-wave inversion in 2 or more contiguous leads, and these findings were not known to be old. Old Q, ST, T, or LBBB abnormalities denote a previous electrocardiogram that shows the same Q waves, ST-segment elevation or depression, T-wave inversion, or LBBB, and therefore the abnormalities were known to be old.
‡Risk categories are based on the clinical prediction rule of Goldman and colleagues.[1] In the original validation of the prediction rule, the risk of major cardiac complications within 72 hours was 0.6% for very low risk, 4% for low risk, 8% for moderate risk, and 16% for high risk.

Secondary Analyses: Subgroup Comparisons and Temporal Trends

Physicians used the decision rule in 832 (83%) of the 1008 intervention-group patients. When this subgroup was compared with the subgroup of 176 (17%) intervention-group patients in whom the decision rule was not used, all comparisons exactly paralleled the comparisons described above between the entire intervention group and the preintervention group. The 2 subgroups were comparable in the distribution across risk strata, stratum-specific risk, and overall risk of major complications. Efficiency was greater in the subgroup in which the decision rule was actually used (38% vs 27%; difference, 11%; 95% CI, 3%-18%; $P=.01$). In this subgroup, fewer very low-risk patients were triaged to inpatient monitored beds ($P<.001$), and a smaller proportion of admissions to the telemetry unit were patients at very low risk ($P=.02$). These subgroup differences persisted after patients' baseline risk and the identity of ED physicians were controlled for in the logistic regression model.

FIGURE 2 depicts temporal trends in physicians' triage decisions for the preintervention (1997), intervention (1999), and postintervention (2000) periods. Patient characteristics were comparable during these 3 periods, and tests for linear trend were not significant ($P>.14$ for all patients, $P=.22$ for very low-risk patients, and $P=.64$ for telemetry patients) for each of the 3 outcome measures. Thus, there was no evidence supporting temporal trend as an alternative explanation for the ob-

Table 3. Major Cardiac Complications Within 72 Hours of Triage for Intervention-Group Patients*

First Major Complication	No. Day 1	Day 2	Day 3	Total
Recurrent ischemia requiring coronary angiography and urgent revascularization recommended	4	10	4	**18**
Cardiogenic shock or intra-aortic balloon pump	3	3	0	**6**
Ventricular fibrillation, emergent cardioversion, or complete heart block	4	1	0	**5**
Intubation	2	2	0	**4**
Cardiac arrest	2	0	0	**2**
Total (first) complications	15	16	4	**35**

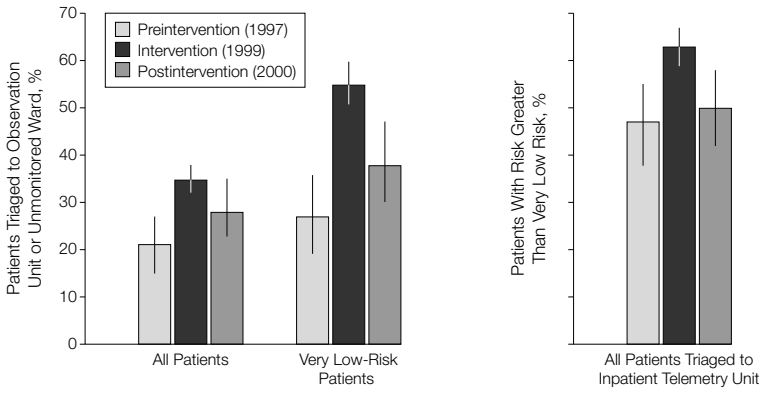
*Within 72 hours of hospital triage, 35 of 1008 patients experienced 47 major complications, which included 4 deaths. Among the 43 patients with myocardial infarction, 16 experienced a major complication within 72 hours.

Table 4. Distribution of Patients and Complications by Risk Category and Admission Site*

	Primary Analysis (Intention-to-Treat)			Subgroup Analysis		
	Preintervention Group (n = 207)	Intervention Group (n = 1008)	*P* Value	Intervention Group: Decision Rule Used (n = 832)	Intervention Group: Decision Rule Not Used (n = 176)	*P* Value
Risk category						
High	16 (8)	95 (9)	.60	79 (10)	16 (9)	.64
Moderate	52 (25)	256 (25)		209 (25)	47 (27)	
Low	31 (15)	176 (17)		151 (18)	25 (14)	
Very low	108 (52)	481 (48)		393 (47)	88 (50)	
Total	**207 (100)**	**1008 (100)**		**832 (100)**	**176 (100)**	
Complications by risk category (by risk group percentage)†						
High	4/16 (25)	10/95 (11)	.06	10/79 (13)	0/16 (0)	.23
Moderate	3/52 (6)	11/256 (4)		8/209 (4)	3/47 (6)	
Low	2/31 (6)	10/176 (6)		10/151 (7)	0/25 (0)	
Very low	0/108 (0)	4/481 (0.8)		3/393 (0.8)	1/88 (1.1)	
Overall risk of complications	**9/207 (4.3)**	**35/1008 (3.5)**	.42	**31/832 (3.7)**	**4/176 (2.3)**	.37
Admission site						
Coronary care unit	16 (8)	110 (11)	<.001	90 (11)	20 (11)	.06
Telemetry	148 (71)	546 (54)		438 (53)	108 (61)	
Other	43 (21)	352 (35)		304 (36)	48 (27)	
Total	**207 (100)**	**1008 (100)**		**832 (100)**	**176 (100)**	
Complications by admission site (risk by site percentage)†						
Coronary care unit	6/16 (37)	18/110 (16)	.41	16/90 (18)	2/20 (10)	.30
Telemetry	2/148 (1.4)	15/546 (2.7)		14/438 (3.2)	1/108 (0.9)	
Other	1/43 (2.3)	2/352 (0.6)		1/304 (0.3)	1/48 (2.1)	
Primary outcomes						
Efficiency‡	42/198 (21)	350/973 (36)	<.001	303/801 (38)	47/172 (27)	.01
Safety§	8/9 (89)	33/35 (94)	.57	30/31 (97)	3/4 (75)	.11

*All data are presented as No. (%).
†Complications indicate the number of patients who experienced at least 1 major cardiac complication within 72 hours of triage.
‡Efficiency indicates the proportion of patients without major cardiac complications within 3 days who were initially triaged to an emergency department observation unit or unmonitored ward.
§Safety indicates the proportion of patients with major cardiac complications within 3 days who were initially triaged to a coronary care or inpatient telemetry unit.

Figure 2. Triage Decisions: Preintervention, Intervention, and Postintervention



Total No. of Patients			
Preintervention	207	108	148
Intervention	1008	481	546
Postintervention	246	138	160

Error bars represent 95% CI.

served differences in triage decisions during the intervention period.

Physicians' Opinions About the Decision Rule

The physician survey was completed by 19 (73%) of the 26 attending ED physicians. Respondents evaluated the prediction rule favorably: 68% (13/19) reported that they thought it helped them make their triage decisions, and 84% (16/19) reported that they thought it improved patient care. Only 1 respondent favored discontinuing use of the prediction rule.

Patients Discharged Home Directly From the ED

During the intervention period, we followed up 326 consecutive patients in whom possible acute cardiac ischemia was initially suspected and who were discharged home directly from the ED (and therefore were not included in the intervention group) after the attending physician excluded the possibility of acute cardiac ischemia and made an alternative diagnosis. There were no complications or deaths among the 300 patients with complete follow-up. Among the 26 patients who were lost to follow-up, there were no recorded deaths (according to hospital, county, state, and national databases) during the 6 months following enrollment.

COMMENT

Use of the decision rule improved our physicians' decisions. It reduced unnecessary admissions to inpatient monitored beds without increasing complications in patients triaged instead to a short-stay observation unit. This improvement was achieved primarily by identifying very low-risk patients and not admitting them to inpatient telemetry beds. These results provide strong evidence that the decision rule can "inform physicians' judgments . . . with beneficial consequences."[18]

These findings are important for 3 reasons. First, no other decision rule or practice guideline applicable to all ED patients with suspected acute cardiac ischemia has achieved the same high level of evidentiary support. Goldman and colleagues' original study[1] met all methodologic standards of the Evidence-Based Medicine Working Group for the derivation and validation of a decision rule.[18] Subsequent studies in other settings[19,20] provided broader validation of the rule (Table 1). This study extends those findings and documents the beneficial impact of the decision rule when it is used prospectively in clinical practice (level 1 evidence).[18]

Second, our study expands the clinical scope of the decision rule. Goldman and colleagues[1] included in their study only patients presenting with a chief complaint of chest pain. In this study, we demonstrated benefit of the decision rule when it is applied to all ED patients with suspected acute cardiac ischemia, not just those with chest pain, which is important because one third of all patients with acute MI may present without chest pain.[23]

Third, our study's primary impact measures—safety and efficiency—link the decision physicians must make in the ED (triage to an inpatient monitored bed or not) with the most telling outcome of that decision (occurrence of a life-threatening complication within the next few days). Although these impact measures seem obvious, they have not been well described or studied before. It is important not to confuse safety and efficiency (as we define them) with the sensitivity and specificity of the decision rule itself. These 2 sets of measures may differ for a variety of reasons: physicians may apply the decision rule inaccurately or unreliably, they may overrule its recommendations in specific cases even when using it as a general rule, or they may be unable to implement its recommendations because of practical constraints (for example, bed availability). For these reasons, measures of the decision rule's impact (safety and efficiency) must be distinguished from measures of its predictive accuracy (sensitivity and specificity).

Although our study is not a randomized controlled trial, our analyses strongly support its internal validity. Baseline risk stratification and complication rates were similar in all patient groups studied. Improvement in physicians' efficiency could not be explained by temporal trends, and subgroup analysis during the intervention period suggested that actual use of the decision rule best explained the differences.

However, the external validity of our findings must be questioned. When used in other settings, the decision rule's impact may vary for several reasons.

First, not all hospitals have observation units.[27,28] Hospitals without observation units will need alternative low-intensity-care triage options for very low-risk patients to benefit from use of the decision rule. Second, we undertook this study only after extensive baseline data collection, pilot testing, and simulated impact analyses of the decision rule.[19-21] Similar painstaking groundwork—essential for physician "buy in" to quality improvement—may be needed in other hospitals, too. We cannot exclude the possibility of a Hawthorne effect in the intervention group, because the 1-page decision rule might have served as a daily reminder of ongoing investigation, whereas no such reminder occurred during the preintervention period. Finally, physicians' diagnosis of unstable angina and interpretation of electrocardiograms vary considerably.[19,21,29] Research designed to improve and standardize performance in these areas—critical to the accurate, reliable use of the decision rule—deserves wide attention.[2,14]

Precedent for caution about clinical impact can be found in studies of the Acute Cardiac Ischemia Time-Insensitive Predictive Instrument (ACI-TIPI),[2] which provides probability estimates of the diagnosis of unstable angina or acute MI. In the pretelemetry era (before 1983), Pozen and colleagues[9] found that use of this instrument modestly reduced admission to the coronary care unit for patients without acute cardiac ischemia (from 24% to 17%; $P=.003$). However, in a much larger study (N=10016) involving different hospitals in 1993,[2] the ACI-TIPI instrument had no significant impact on attending physicians' admitting decisions for patients with or without acute cardiac ischemia. Thus, we believe that broad verification of the decision rule's impact is no less important than broad validation of its accuracy.

Patients discharged home directly from the ED were not included in our measures of the decision rule's safety and efficiency. If they were, the calculated estimate of efficiency would rise markedly. The absence of life-threatening complications in such patients is reassuring; however, uncomplicated MIs may have been missed.[3,5-7] The constant distribution of risk strata across the 3 periods—before, during, and after use of the decision rule—suggests that the decision rule did not change physicians' threshold for hospital triage, another potential unintended consequence.

It is noteworthy that much larger sample sizes will be needed to achieve narrow confidence limits for the decision rule's safety. For example, given a 4% major complication rate,[1,19] 14 500 patients would be needed in each group to have 90% power to demonstrate a statistically significant increase in safety from 89% to 94%, the point estimates in our intention-to-treat analysis. Meta-analysis of more trials like this study, performed in varied settings, could provide the necessary statistical power, which is important from a medicolegal perspective because litigants may demand perfect safety (100%), an unrealistic goal. There have been no published reports documenting safety greater than that observed in this study when physicians actually used the decision rule (97%).

Future studies should also measure the impact of the decision rule on other outcomes: longer-term morbidity and mortality, resource use and cost-effectiveness, and physicians' timely use of complementary decision aids for treating subsets of triaged patients.[30-35] It is also important to learn whether information not used to derive and validate the original prediction rule—serum markers,[36-40] for example, or physicians' clinical judgment—can further improve the decision rule's accuracy or its safe efficient use. But, pending future research, we believe the decision rule provides the best available evidence-based foundation for physicians' decision making in this challenging clinical area.

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Drafting of the manuscript: Reilly, Evans.
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REFERENCES

1. Goldman L, Cook EF, Johnson PA, et al. Prediction of the need for intensive care in patients who come to emergency departments with acute chest pain. *N Engl J Med.* 1996;334:1498-1504.
2. Selker HP, Beshansky JR, Griffith JL, et al. Use of the acute cardiac ischemia 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;129:845-855.
3. Mehta RH, Eagle KA. Missed diagnoses of acute coronary syndromes in the emergency room—continuing challenges. *N Engl J Med.* 2000;342:1207-1210.
4. Schor S, Behar S, Modan B, Barell V, Drory J, Kariv I. Disposition of presumed coronary patients from an emergency room: a follow up study. *JAMA.* 1976; 236:941-943.
5. McCarthy BD, Beshansky JR, D'Agostino RB, Selker HP. Missed diagnoses of acute myocardial infarction in the emergency department: results from a multicenter study. *Ann Emerg Med.* 1993;22:579-582.
6. 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;60:219-224.
7. Pope JH, Aufderheide TP, Ruthazer R, et al. Missed diagnoses of acute cardiac ischemia in the emergency department. *N Engl J Med.* 2000;342:1163-1170.
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;18:1021-1034.
9. Pozen MW, D'Agostino RB, Selker HP, et al. 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; 310:1273-1278.
10. 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.
11. Selker HP, Griffith JL, Beshansky JR, et al. Patient-specific predictions of outcomes in myocardial infarction for real-time emergency use: a thrombolytic predictive instrument. *Ann Intern Med.* 1997;127:538-556.
12. 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;339:1882-1888.
13. Tatum JL, Jesse RL, Kantos MC, et al. Comprehensive strategy for the evaluation and triage of the chest pain patient. *Ann Emerg Med.* 1997;29:116-125.
14. Selker HP, Zalenski RJ, Antman EM, et al. An evaluation of technologies for identifying acute cardiac ischemia in the emergency department: executive summary of the National Heart Attack Alert Program Working Group Report. *Ann Emerg Med.* 1997;29: 1-12.
15. Zalenski RJ, McCarren M, Roberts R, et al. An evaluation of a chest pain diagnostic protocol to exclude acute cardiac ischemia in the emergency department. *Arch Intern Med.* 1997;157:1085-1091.

16. Goodacre SW. Should we establish chest pain observation units in the UK? a systematic review and critical appraisal of the literature. *J Accid Emerg Med.* 2000; 17:1-6.
17. 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 chest pain. *Ann Intern Med.* 1995;122:434-437.
18. McGinn TG, Guyatt GH, Wyer PC, et al. Users' guides to the medical literature, XXII: how to use articles about clinical decision rules. *JAMA.* 2000;284:79-84.
19. Reilly B, Durairaj L, Husain S, et al. Performance and potential impact of a chest pain prediction rule in a large public hospital. *Am J Med.* 1999;106:285-291.
20. Durairaj L, Reilly B, Das K, et al. Emergency department admissions to inpatient cardiac telemetry beds: a prospective cohort study of risk stratification and outcomes. *Am J Med.* 2001;110:7-11.
21. Reilly BM, Evans AT, Schaider JJ, Wang Y. Triage of patients with chest pain in the emergency department: a comparative study of physicians' decisions. *Am J Med.* 2002;112:95-103.
22. Martinez E, Reilly B, Evans A, Roberts RR. The observation unit: a new interface between inpatient and outpatient care. *Am J Med.* 2001;110:274-277.
23. Canto JG, Shlipak MG, Rogers WJ, et al. Prevalence, clinical characteristics, and mortality among patients with myocardial infarction presenting without chest pain. *JAMA.* 2000;283:3223-3229.
24. Goldman L. Telemetry or not telemetry: a great leap forward or a waste of resources? *Am J Med.* 2001; 110:67-68.
25. Diamond GA, Forrester JS. Analysis of probability as an aid in the clinical diagnosis of coronary artery disease. *N Engl J Med*. 1979;300:1350-1358.
26. Miettinen OS, Nurminen M. Comparative analysis of two rates. *Stat Med.* 1985;4:213-226.
27. Zalenski RJ, Rydman RJ, Ting S, Kampe L, Selker HP. A national survey of emergency department chest pain centers in the United States. *Am J Cardiol*. 1998; 81:1305-1309.
28. Mace SE, Shah J. Observation medicine in emergency medicine residency programs. *Acad Emerg Med*. 2002;9:169-171.
29. Panju AA, Hemmelgarn BR, Guyatt GH, Simel DL. Is this patient having a myocardial infarction? *JAMA.* 1998;280:1256-1263.
30. Antman EM, Cohen M, Bernink P, et al. The TIMI risk score for unstable angina/non-ST elevation MI: a method for prognostication and therapeutic decision-making. *JAMA.* 2000;284:835-842.
31. Braunwald E, Antman EM, Beasley JW, et al. ACA/AHA guidelines for the management of patients with unstable angina and non–ST-segment elevation myocardial infarction: executive summary and recommendations: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee on the management of patients with unstable angina). *Circulation.* 2000;102: 1193-1209.
32. Calvin JE, Klein LW, VandenBerg BJ, et al. Risk stratification in unstable angina: prospective validation of the Braunwald classification. *JAMA.* 1995;273: 136-141.
33. Ohman EM, Granger CB, Harrington RA, Lee KL. Risk stratification and therapeutic decision making in acute coronary syndromes. *JAMA.* 2000;284:876-878.
34. O'Rourke RA, Hochman JS, Cohen MC, Lucore CL, Popma JL, Cannon CP. New approaches to diagnosis and management of unstable angina and non-ST-segment elevation myocardial infarction. *Arch Intern Med.* 2001;161:674-682.
35. Nichol G, Walls R, Goldman L, et al. A critical pathway for management of patients with chest pain who are at low risk for myocardial ischemia: recommendations and potential impact. *Ann Intern Med.* 1997; 127:996-1005.
36. 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;337:1648-1653.
37. Antman EM, Tanasijevic MJ, Thompson B, et al. Cardiac-specific troponin I levels to predict the risk of mortality in patients with acute coronary syndrome. *N Engl J Med.* 1996;335:1342-1349.
38. Ohman EM, Armstrong PW, Christenson RH, et al. Cardiac troponin T levels for risk stratification in acute myocardial ischemia. *N Engl J Med.* 1996;335:1333-1341.
39. de Lemos JA, Morrow DA, Bentley JH, et al. The prognostic value of B-type natriuretic peptide in patients with acute coronary syndromes. *N Engl J Med.* 2001;345:1014-1021.
40. Bayes-Genis A, Conover CA, Overgaard MT, et al. Pregnancy-associated plasma protein A as a marker of acute coronary syndromes. *N Engl J Med.* 2001; 345:1022-1029.

Sound sense is the first principle and source of writing.
—Horace (65-8 BCE)