Evaluation of Two Acute Cardiac Ischemia Decision-Support Tools in a Rural Family Practice

Lee Green, MD, and Mindy Smith, MD, MS
Ann Arbor, Michigan

This study investigated the applicability in a primary care setting of two decision-support tools for evaluating the necessity of admitting patients with suspected acute cardiac ischemic disease to a cardiac intensive care unit. The heart disease predictive instrument (HDPI) of Pozen et al and the electrocardiogram scoring method of Brush et al were applied to records from all patients with cardiac-related diagnoses admitted to a family practice service.

A retrospective review of medical records of all patients admitted with suspected acute ischemic heart disease to a rural community hospital family practice service was conducted. Of 147 patients identified, 108 were admitted primarily for suspected ischemia. Twenty-four myocardial infarctions occurred among these 108 patients (22.2 percent). Patients with HDPI probabilities of less than 50 percent were very unlikely to sustain infarction and in no case required intensive intervention for any problem not apparent at admission. Only 15 instances of the four types of complications that the instrument of Brush et al is designed to predict occurred; this incidence was too low to allow statistical testing.

In summary, the heart disease predictive instrument reliably identified patients unlikely to require intensive care services in this population. Because of the low incidence of complications in this population, the instrument described by Brush et al was not found to be clinically useful.

The diagnosis and treatment of suspected acute ischemic cardiac disease is coming under increasing scrutiny in the United States.[1] Such patients account for 1.5 million admissions to coronary care units (CCUs) in US hospitals per year.[2,3] The high per-day cost of CCU care, especially when multiplied by this large number of admissions, makes CCU utilization an important concern of researchers and regulators alike. Fineberg et al[4] estimated that routine CCU care of suspected ischemia patients cost, in 1984, $2.04 million per life saved.

Coronary care units were introduced into medical practice and became routinely used in the United States with surprisingly little evaluation of their actual effectiveness. There is reason to question how often the CCU actually contributes to improved outcomes.[5] There is mounting evidence that these units are being used indiscriminately. The prevalence of actual myocardial infarction in patients admitted to CCUs for chest pain varies from 41.8 percent to 12.4 percent in various studies.[2–4,6,7] As many as 70 percent of patients admitted to some CCUs are not given an admitting diagnosis of myocardial infarction, but rather their admitting orders bear the ill-defined designation "rule out myocardial infarction."[4,8]

Numerous researchers have sought methods to predict which patients will benefit from CCU care and thus reduce the number of inappropriate admissions to CCUs. These efforts have commonly taken three forms: prediction of myocardial infarction, prediction of coronary ischemic disease (including but not limited to infarction), and prediction only of in-hospital complications. These three approaches are important to distinguish, as they have had differing degrees of success and of applicability to primary care populations.

Prediction of myocardial infarction using multiple-regression factor analyses[7] and computer-derived decision-tree protocols[8] have met with mixed results. Such analyses have been successfully applied to prediction of ischemic disease, however.[2,3,9,10] In addition, a normal or nonspecific admission electrocardiogram (ECG) has been found

Submitted, revised, December 21, 1987.

From the Department of Family Practice, The University of Michigan Medical School, Ann Arbor, Michigan. Requests for reprints should be addressed to Dr. Lee Green, The University of Michigan, Department of Family Practice, 1018 Fuller Rd, Ann Arbor, MI 48109.

to identify a subgroup of patients suspected of having myocardial infarction who are at a very low risk of complications.[6] It has also been noted in a series of 92 consecutive documented myocardial infarctions that potentially lethal dysrhythmias occurred only among those patients who had ST segment elevation upon admission or who had undergone cardiopulmonary resuscitation.[11]

The primary goal of this study was to investigate decision-support tools for possible improvement of CCU admitting practices in a rural family practice population. The second goal was to study the feasibility of admitting patients at low risk for adverse outcomes to non-intensive-care beds. Last, the use of health care resources, in terms of CCU days and dollar expenditures, was addressed.

The hypotheses tested were (1) myocardial infarction will occur almost exclusively among patients with high HDPI probability scores (over 50 percent), (2) complications (arrhythmias, conduction disturbances, pump failure, or recurrent angina pectoris) will occur almost exclusively among patients whose admission ECG scores "high risk" by the method of Brush et al, and (3) substantial cost savings can be realized without adverse outcomes by admitting selected patients with suspected ischemic heart disease to a non-CCU bed.

METHODS

Subjects

All patients with cardiac-related diagnoses admitted from January 1984 through September 1985 to one family practice service at a 100-bed community hospital in rural southern Michigan were retrospectively reviewed for possible inclusion in this study. All patients presenting to the service were admitted through the service, and specialists were consulted later if needed; there was no triage of patients directly to specialists. Patients were included only if they had both an admission electrocardiogram and serial determinations of creatine phosphokinase (CPK) levels with isoenzymes or lactate dehydrogenase (LDH) levels with isoenzymes.

The hospital is located in a town of 3,850 people with a median household income of $21,122. The hospital also serves the surrounding agricultural community of 18,000 people. Sixty-eight percent of workers are employed in blue-collar occupations. The population is 98 percent white. The hospital has an eight-bed CCU; ECG telemetry monitoring is available for patients on the nursing floors outside the CCU, and defibrillators are readily accessible. Regulated continuous intravenous infusions (including lidocaine) are available on the nursing floor as well. Family practice residents care for patients admitted to this service as members of a group practice model, which includes both residents and faculty from the University of Michigan Department of Family Practice.

Instruments

The heart disease predictive instrument (HDPI) developed by Pozen et al[3] was chosen as a clinically tested predictor of ischemia. The ECG-scoring method of Brush et al[6] was chosen as a predictor of complications. Both instruments have the advantage of being simple to use; they include relatively few variables, all of which are dichotomous, and can be easily programmed on a hand-held calculator[12] or reduced to a simple pocket chart.[13]

The seven factors composing the heart disease predictive instrument are (1) pain or pressure in chest or left arm, (2) whether chest pain is the patient's most important complaint, (3) history of myocardial infarction, (4) history of nitroglycerin use for chest pain, (5) ECG ST segment elevation or depression of 1 mm or more, (6) ECG ST segment "straightening" or "barring" with ≤0.5-mm elevation or depression, and (7) ECG T wave inversion or hyperacuity (≥50 percent of R wave amplitude). ECG changes must be present in at least two leads, excluding ${}_aV_R$. The formula is

$$P = [1 + \exp(b_0 + \sum_{i=1}^{7} b_i x_i)]^{-1}$$

The constant $b_0 = -7.5698$. The seven b_i, in order, are 0.9988, 0.7145, 0.4187, 0.5091, 0.7682, 0.8321, and 1.1278.

An ECG is scored as high risk by the Brush et al method if any of the following findings are present: ST segment elevation or depression or T wave inversion consistent with ischemia, infarction, or strain; or pathologic Q waves *and* these changes are not known to have been present on a previous ECG; or left ventricular hypertrophy, left bundle branch block, or paced rhythm is present regardless of old ECG findings. Complications were defined as arrhythmias, conduction disturbances, pump failure, or recurrent angina.

Procedure

The HDPI and ECG scoring factors, occurrences of arrhythmias, conduction disturbances, recurrent chest pain, congestive heart failure, route of admission (emergency department or family physicians' office), number of days in CCU, any medical or surgical treatments provided that were unavailable outside CCU, and primary admission diagnosis were recorded for each patient. Occurrence of myocardial infarction was designated if and only if CPK or LDH levels exceeded the laboratory-defined normal limits and CPK-MB fraction exceeded 5 percent, or if

LDH isoenzyme 1 exceeded LDH isoenzyme 2. Occurrence of myocardial infarction was determined using these enzyme criteria only after ECG interpretation had been carried out, and occurrence of infarction was then linked with the other data using computerized relational database software. HDPI probability scores and ECG risk group were calculated and entered by the computer database software, which was programmed with the methods of Pozen et al and Brush et al.

Analysis of Data

Occurrence of myocardial infarction was used as the outcome variable to assess the effectiveness of the HDPI. As noted above, the HDPI predicts ischemic disease, not infarction. Patients with low probabilities of ischemia should be very unlikely to suffer infarction, however. Consequently, though the HDPI does not predict infarction, it should identify a group of patients among whom myocardial infarction is rare.

The patient population was stratified into four groups. Group 1 comprised those patients whose HDPI score was less than 0.25, group 2 had scores of 0.25 or greater but less than 0.50, group 3 scored 0.50 or greater but less than 0.75, and group 4 scored greater than or equal to 0.75. Contingency tables of group vs myocardial infarction or no infarction were constructed for both all cardiac patients and only those patients admitted for suspected ischemia. Patients admitted for reasons other than suspected ischemia were then excluded from further analysis.

ECG findings were dichotomized into high and low risk by the method of Brush et al. Contingency tables of presence or absence of any complications and of life-threatening complications (ventricular fibrillation, sustained ventricular tachycardia, or third-degree block)[6] vs risk classification were constructed.

The data set was examined for confounding by age, sex, and source of admission, using chi-squared tests for categorical and regression for analytical variables.

Per-day bed charges were obtained from the hospital billing office and applied to length-of-stay data to analyze resource use.

RESULTS

Patients

One hundred forty-seven consecutive patients admitted from January 1985 through June 1986 were identified as meeting the stated criteria. While the design excluded charts missing any of the HDPI or ECG factors from analysis, in practice no charts had to be excluded. All patients were white. Thirty-nine patients (26.5 percent) were admitted for other problems including congestive heart failure (n = 17), syncope (n = 8), cardiac atrial dysrythmias (n = 4), respiratory failure (n = 2), and confusion, anxiety, pneumonia, hypertension, seizure, pulmonary embolism, hyponatremia, and viral pericarditis (n = 1 each), and had possible ischemia evaluated as part of their admissions. The 108 who were admitted with primary diagnoses of suspected ischemia form the population for all subsequent analyses. Secondary diagnoses among these patients included congestive heart failure (n = 10), diabetes mellitus (n = 9), hypertension (n = 2), and chronic obstructive pulmonary disease (n = 1). There were no patients in this group with diagnoses of electrolyte abnormalities, syncope, or substance abuse. The age and sex characteristics of the patient population are displayed in Table 1.

There were 24 observed myocardial infarctions among the 108 patients (22.2 percent) admitted for suspected ischemia. This rate is within the range defined in studies

TABLE 1. AGE AND SEX CHARACTERISTICS OF PATIENTS

Sex	No.	Age Range (years)	Mean Age (years)
All patients			
Male	84	30–88	65.5 ± 14.9
Female	63	37–94	73.1 ± 13.2
Total	147	30–94	69.0 ± 13.2
Patients admitted for suspected ischemia			
Male	65	30–88	63.8 ± 13.7
Female	43	37–94	72.4 ± 13.4
Total	108	30–94	67.2 ± 14.1

TABLE 2. NUMBER OF OCCURRENCES OF EACH HISTORICAL OR ELECTROCARDIOGRAPHIC FINDING AT ADMISSION AMONG PATIENTS ADMITTED FOR SUSPECTED ACUTE ISCHEMIC HEART DISEASE

Finding	Number of Occurrences
Chest pain present	91
Chest pain as chief complaint	78
History of myocardial infarction	34
History of nitroglycerin use	48
ST segment elevation or depression*	28
ST segment barring or straightening*	6
T wave inversion or hyperacuity*	51
Left ventricular strain	3
Left ventricular hypertrophy	0
Pathologic Q waves	4
Left bundle branch block	4
Paced rhythm (partial or total)	0

** See text under Instruments for descriptions of precise criteria for each finding*

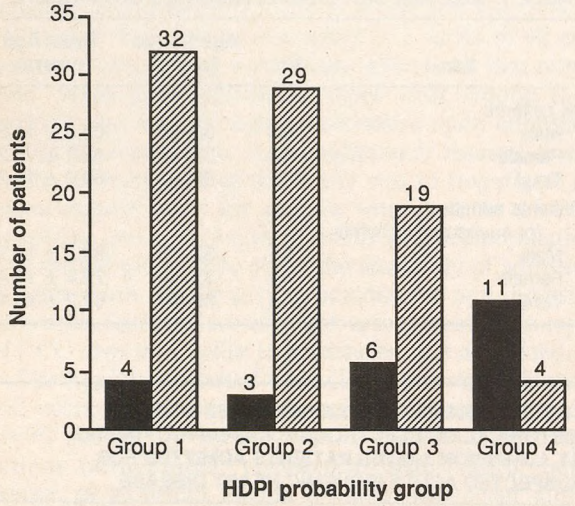

Figure 1. Number of suspected ischemia patients sustaining myocardial infarction or not in each group. Black bar—patients sustaining myocardial infarction; cross-hatched bar—patients not sustaining myocardial infarction. HDPI—heart disease predictive instrument

at larger centers.[2–4,6,7] The prevalences of each of the factors comprising the two instruments are summarized in Table 2.

Myocardial Infarction Probability Prediction Using the HDPI

The relationship of the HDPI group with myocardial infarction is demonstrated in Figure 1. Patients sustaining myocardial infarctions clustered in groups 3 and 4 at a very high level of statistical significance ($\chi^2(3) = 40.95$, $P < .0001$ for all admissions, $\chi^2(3) = 28.34$, $P < .0001$ for suspected-ischemia-only admissions).

Complication Prediction Using ECG

Sixty-two (57 percent) of the patients admitted for suspected ischemia scored at high risk by the Brush et al method. The outcome variables (the complications listed above), however, occurred too infrequently in this primary care population to allow statistical analysis. There were only 15 complications of any kind, 11 of them minor.

Source of Admission

The route of admission (family practice office vs emergency department) was not significantly related to patients' HDPI scores. Patients' personal physicians, however, were more likely to place patients in a non-CCU bed than emergency department physicians (Fisher's exact probability = .0090).

Individual Low-Risk Cases

No patient in the two low-probability groups required intensive intervention for any problem not apparent at admission. Four myocardial infarctions were observed in group 1, and three in group 2. These two low-probability groups accounted for 68 (63 percent) of total admissions. Only three of these patients actually used services available only in the CCU. Two developed cardiogenic shock. In both cases congestive heart failure was apparent at admission. Both patients subsequently died. One patient was kept in the CCU because of recurrent chest pain, but suffered no complications. Two of the seven myocardial infarctions in groups 1 and 2 were silent myocardial infarctions in patients with type II diabetes. One of these occurred in one of the patients who developed cardiogenic shock. One patient sustaining an uncomplicated myocardial infarction was managed outside the CCU without incident.

Use of Resources

This hospital's charges are typical of community hospitals in this area. Bed charges were $990/d for CCU (including ECG telemetry), $390/d for regular nursing beds, and $207/d for adding telemetry to a regular bed. A day charge is assessed for any part of the time from midnight to midnight. Patients admitted one day and discharged the next incurred a two-day charge.

A summary of hospital days and costs for group 1 and 2 patients is presented in Table 3. The most common scenario among group 1 and 2 patients was admission for chest pain, followed by an overnight stay in CCU and discharge home after myocardial infarction was ruled out, to return for outpatient follow-up. The average number of CCU days among group 1 and 2 patients not sustaining myocardial infarction was 1.95; the average calculated cost for the room alone among these patients was $1,931.

DISCUSSION

Evaluation of Instruments

The ability of the heart disease predictive instrument to identify patients unlikely to have acute ischemic heart disease in a rural family practice setting was demonstrated clearly in this study. The very high level of statistical sig-

TABLE 3. STAY AND ROOM COST BREAKDOWN FOR GROUP 1 AND GROUP 2 PATIENTS

Patient Characteristics	Coronary Care Unit			Cost of Regular Nursing Bed With Telemetry Added
	Number of Patients	Number of Days	Cost	
Sustaining myocardial infarction	7	26	$25,740	
Not sustaining myocardial infarction	61	119	$117,810	$71,043
Using intensive services	3	14	$13,860	
Using no services unique to CCU	65	133	$131,670	$79,401
Total	68	147	$145,530	

nificance reached on this small but unselected population is evidence of the strength of the predictive ability of the heart disease predictive instrument.

More important, this study provides evidence for the external validity of the HDPI. The population upon which the instrument was tested here is distinct from the urban large-hospital environment where the HDPI was developed. These findings suggest that the HDPI can be generalized to other populations.

The HDPI has several advantages that make it useful to the family physician. In addition to its applicability to a typical primary care population, the HDPI is a decision support tool, not a decision-making algorithm. This distinction is important theoretically because medical decision making is a very complex task and therefore probably impossible to reduce to a valid and generalizable algorithm. It is also important in terms of physician acceptance. Few physicians are likely to be comfortable using an algorithm to replace their experienced judgment. A simple tool that can significantly clarify the information available to them and that explicitly relies upon judgment and experience in handling exceptions is much more useful.

A third advantage is its "user-friendliness." The seven factors are already routinely obtained in the admission process. The instrument itself, as noted in the Methods section, can be programmed on a hand-held calculator or reduced to a simple chart that will fit into a notebook or pocket; it requires neither understanding formal decision theory nor following a branching tree diagram. With the HDPI attention is focused upon the important factors among the myriad data confronting the physician rather than adding another layer of unwelcome complexity.

The failure of this study to demonstrate identification of a subset of admissions at low risk for complications by ECG scoring reflects the infrequency of complications in this primary care population. This problem is likely to limit the clinical usefulness of the Brush et al method for family physicians to those dealing with certain patient populations having fairly high prevalences of complications.

It should be carefully noted that the value of the HDPI lies more in its ability to identify patients who will not require CCU treatment than in its ability to identify those who will. Only 42.5 percent of the patients with probabilities over 50 percent sustained myocardial infarction. Most of the patients currently being admitted have low probabilities of acute ischemia, however. Here, as in the original studies of Pozen et al,[2,3] the HDPI identifies a large group of patients who can safely avoid CCU admission.

Admission Practices

Among the patients described, non-CCU care of most patients with probabilities less than 50 percent would not have adversely affected outcomes. The few patients with low HPDI scores who needed services requiring the CCU were identifiable at admission. These findings are consistent with the results of the larger studies and theoretical analyses cited in the introduction.

Non-CCU alternatives to the care of low-probability "rule-out myocardial infarction" patients are not only feasible but are for several reasons desirable. The most obvious reason for using less intensive care in these times of cost-conscious medicine is the tremendous cost of CCU care. Under the traditional CCU system, the cost of ruling out a myocardial infarction for one low-probability patient easily exceeds $2,000 when even minimal laboratory, radiological, and other services are included. This cost is in the range of some of the surgical procedures that have come under close scrutiny by utilization reviewers and quality-assessment researchers. Application of the HDPI and non-CCU admission (with ECG monitoring) would have reduced this cost by over $800 per patient. Assuming that just 200,000 of the 1.5 million patients admitted per year for suspected myocardial infarction in the United States could be so managed, the potential cost saving would be $160 million.

Other reasons to prefer less intensive care are the alarm and disruption CCU admission may cause to patients and their families. Even if the patient and family are told that

"it's just to be safe," substantial anxiety is a natural reaction to admission to intensive care. Finally, the CCU environment is noisy, not conducive to sleep, tends to induce disorientation (and results in sedation or restraint), and lacks privacy.

CONCLUSIONS

In this study the heart disease predictive instrument successfully identified patients at low risk for myocardial infarction. Patients presenting with evidence of complications or diabetics at risk for silent myocardial infarction must be observed in the CCU; however, patients with probabilities of acute ischemic heart disease of less than 50 percent seldom require interventions not available in a less intensive setting. Those few who will require intervention are readily identifiable at admission. Used in conjunction with physicians' clinical judgment, the HDPI could reduce both costs and patient distress without compromising care for those needing the CCU.

References

1. Bogden PE, Schatz IJ: Cost-effective cardiology: The new challenge. JAMA 1985; 253:400
2. Pozen MW, D'Agostino RB, Mitchell JB, et al: The usefulness of a predictive instrument to reduce inappropriate admissions to the coronary care unit. Ann Intern Med 1980; 92:238–242
3. Pozen MW, D'Agostino RB, Selder 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
4. Fineberg HV, Scadden D, Goldman L: Care of patients with a low probability of acute myocardial infarction: Cost effectiveness of alternatives to coronary-care-unit admission. N Engl J Med 1984; 310:1301–1307
5. Bloom BS, Peterson OL: End results, cost and productivity of coronary-care units. N Engl J Med 1973; 288:72–78
6. Brush JE Jr, Brand DA, Acampora D, et al: Use of the initial electrocardiogram to predict in-hospital complications of acute myocardial infarction. N Engl J Med 1985; 312:1137–1141
7. Tierney WM, Roth BJ, Psaty B, et al: Predictors of myocardial infarction in emergency room patients. Crit Care Med 1985; 13: 526–531
8. Goldman L, Weinberg M, Weisberg M, et al: A computer-derived protocol to aid in the diagnosis of emergency room patients with acute chest pain. N Engl J Med 1982; 307:588–596
9. Lee TH, Cook EF, Weisberg M, et al: Acute chest pain in the emergency ward: Identification and evaluation of low risk patients. Arch Intern Med 1985; 145:65–69
10. 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
11. Gilbert GE: Use of the initial electrocardiogram to predict in-hospital complications of acute myocardial infarction, letter. N Engl J Med 1985; 313:693
12. Hagen MD: A pocket calculator program for using Pozen's formula. Comput Biol Med 1986; 16:155–157
13. Selker HP: Sorting out chest pain: Identifying acute cardiac ischemia in the emergency room setting: An approach based on the acute ischemic heart disease predictive instrument. Emerg Decis, June 1985, pp 8–17