Safety and Efficiency of a Chest Pain Diagnostic Algorithm With Selective Outpatient Stress Testing for Emergency Department Patients With Potential Ischemic Chest Pain

Frank Xavier Scheuermeyer, MD, MHSc, Grant Innes, MD, Eric Grafstein, MD, Marla Kiess, MD, Barb Boychuk, RN, Eugenia Yu, MSc, Daniel Kalla, MD, Jim Christenson, MD

From the Department of Emergency Medicine (Scheuermeyer, Grafstein, Boychuk, Yu, Kalla, Christenson) and the Division of Cardiology, Department of Medicine (Kiess), St Paul's Hospital and the University of British Columbia, Vancouver, British Columbia, Canada; and the Division of Emergency Medicine, Foothills Hospital and the University of Calgary, Calgary, Alberta, Canada (Innes).

Study objective: Chest pain units have been used to monitor and investigate emergency department (ED) patients with potential ischemic chest pain to reduce the possibility of missed acute coronary syndrome. We seek to optimize the use of hospital resources by implementing a chest pain diagnostic algorithm.

Methods: This was a prospective cohort study of ED patients with potential ischemic chest pain. High-risk patients were referred to cardiology, and patients without ECG or biomarker evidence of ischemia were discharged home after 2 to 6 hours of observation. Emergency physicians scheduled discharged patients for outpatient stress ECGs or radionuclide scans at the hospital within 48 hours. Patients with positive provocative test results were immediately referred back to the ED. The primary outcome was the rate of missed diagnosis of acute coronary syndrome at 30 days.

Results: We prospectively followed 1,116 consecutive patients who went through the chest pain diagnostic algorithm, of whom 197 (17.7%) were admitted at the index visit and 254 (22.8%) received outpatient testing on discharge. The 30-day acute coronary syndrome event rate was 10.8%, and the 30-day missed acute coronary syndrome rate was 0% (95% confidence interval 0% to 2.4%). Of the 120 acute coronary syndrome cases, 99 (82.5%) were diagnosed at the index ED visit, and 21 patients (17.5%) received the diagnosis during outpatient stress testing.

Conclusion: In ED patients with chest pain, a structured diagnostic approach with time-focused ED decision points, brief observation, and selective application of early outpatient provocative testing appears both safe and diagnostically efficient, even though some patients with acute coronary syndrome may be discharged for outpatient stress testing on the index ED visit. [Ann Emerg Med. 2012;59:256-264.]

Please see page 257 for the Editor's Capsule Summary of this article.

Provide **feedback** on this article at the journal's Web site, www.annemergmed.com.
A **podcast** for this article is available at www.annemergmed.com.

0196-0644/$-see front matter

doi:10.1016/j.annemergmed.2011.10.016

INTRODUCTION

Background

Approximately 15% to 25% of patients presenting to an emergency department (ED) with chest pain receive a diagnosis of acute coronary syndrome within 30 days, and between 2% and 5% of these patients are discharged inappropriately after receiving an incorrect minimizing diagnosis.[1,2] To improve early diagnostic accuracy, the 2007 American College of Cardiology/American Heart Association non-ST-elevation myocardial infarction guidelines recommend observation and serial investigations for up to 12 hours, followed by provocative cardiac testing, preferably with inpatients, but with outpatients if testing results can be obtained within 72 hours.[3] Although the medical and legal consequences of missed acute coronary syndrome are high, hospital resources may not be sufficient to admit, observe, monitor, and investigate all at-risk patients. Keeping such patients in EDs may worsen crowding, which has been associated with a lower standard of care and increased incidence of adverse events in cardiac patients.[4-6]

To address these concerns, many hospitals have implemented chest pain observation units.[7-15] Diagnostic algorithms vary by institution, but most units observe and monitor patients with potential cardiac ischemia, obtain serial cardiac biomarker and ECG results, and conduct provocative cardiac testing. Patients with negative chest pain unit investigation results are discharged, whereas those with worrisome results are

Editor's Capsule Summary

What is already known on this topic

Guidelines recommend that patients with symptoms concerning for acute coronary syndrome undergo testing for myocardial ischemia within 72 hours.

What question this study addressed

Can low-risk chest pain patients be managed as outpatients after 2 to 6 hours of emergency department (ED) evaluation, receiving outpatient provocative testing at the emergency physician's discretion?

What this study adds to our knowledge

There were no deaths and no acute myocardial infarctions at 30 days in the 845 patients who were managed as outpatients. Twenty-one of the 254 outpatients who had provocative testing showed signs of reversible ischemia and were readmitted without incident.

How this is relevant to clinical practice

This single-site study suggests that low-risk patients can be safely managed as outpatients after ED evaluation.

hospitalized, and lengths of stay vary from 9 to 50 hours.[7-11] Meyer et al discharged ED patients at low risk for cardiac ischemia and arranged for 72-hour outpatient provocative stress testing; 18 of 903 (2%) patients who were discharged with outpatient testing required cardiac revascularization within 6 months.[11]

In a previous study at our institution, in which emergency physicians used an individualized approach to patients with potential ischemia, we found that 35% of patients were admitted, median ED length of stay was 6.5 hours, and our 30-day acute coronary syndrome "miss" rate was 5.3%.[4] To improve diagnostic accuracy, safety, and resource use at our hospital, collaborators from the Departments of Emergency Medicine, Cardiology, and Nuclear Medicine developed an algorithm to provide a streamlined approach to patients with potential cardiac chest pain. This intervention combined brief ED observation with expedited outpatient provocative testing when indicated. We hypothesized that this diagnostic strategy would provide a low (<2%) acute coronary syndrome miss rate while maintaining a median ED length of stay at approximately 6 hours.

MATERIALS AND METHODS

Setting

St Paul's Hospital in Vancouver, British Columbia, is an inner-city teaching hospital and provincial referral center affiliated with the University of British Columbia. The ED has an annual census of 60,000, and the hospital is a cardiac center with a 24-hour catheterization laboratory; cardiac surgery, including transplants; and 12-bed coronary care unit. This prospective cohort study was conducted between February and September 2006.

Triage nurses identified patients with potential ischemic chest pain, ordered immediate ECGs, and advised emergency physicians of the patients' presence and location through an overhead announcement. Patients were assessed by an emergency physician, and those with high-risk features on history (ie, change in angina pattern or new rest angina) or physical examination (ie, new murmur or clinical heart failure) or with objective findings of ischemia on initial ECG (Figure 1) were immediately referred to a cardiologist. Patients also had cardiac biomarker test results (troponin T; Roche Elecsys; Hoffman LaRoche, Laval, Quebec, Canada) obtained, and those with a value above the upper limit of normal at our institution (>0.04 ng/mL) were referred to the cardiology service.

Patients without these high-risk features on initial assessment received a structured protocol with continuous cardiopulmonary monitoring and ECGs and troponin level tests at 2 and 6 hours. Patients could be referred at any time if their clinical condition deteriorated; for example, new hemodynamic instability, new ECG changes consistent with ischemia, or new biomarker-level increases. At the physicians' discretion, patients having clear alternate cause of chest discomfort could be discharged at any time.

At 6 hours, patients who had no objective ischemia or ongoing pain were discharged. Patients who the attending physician deemed were very low risk (for example, younger, minimal cardiac risk factors) were requested to follow up with their primary care providers. Patients believed to be at risk received an appointment time to follow up with a stress test within 48 hours at our institution. They were also requested to take a daily aspirin and to return to the ED if they had increasing chest pain, dyspnea, or weakness.

Outpatient provocative stress testing (Bruce protocol) was supervised and interpreted in real time by a staff cardiologist, and only patients with a minimum of 6 hours of ED observation and serial negative investigation results were permitted to have such testing. Patients with negative stress test results were discharged by the cardiologist, with primary care follow-up. Patients with abnormal baseline ECG results, equivocal stress testing, or inability to complete the Bruce protocol underwent nuclear medicine myocardial perfusion imaging scanning. Any patient with a positive provocative test result was referred directly to the ED for cardiology consultation.

Selection of Participants

Individuals with chest pain and no clear noncardiac cause were eligible for the study. Patients typically received a Canadian Emergency Department Information Systems (a standardized, validated form of triage code[12]) designation of "chest pain, cardiac features" when they presented at the triage desk.

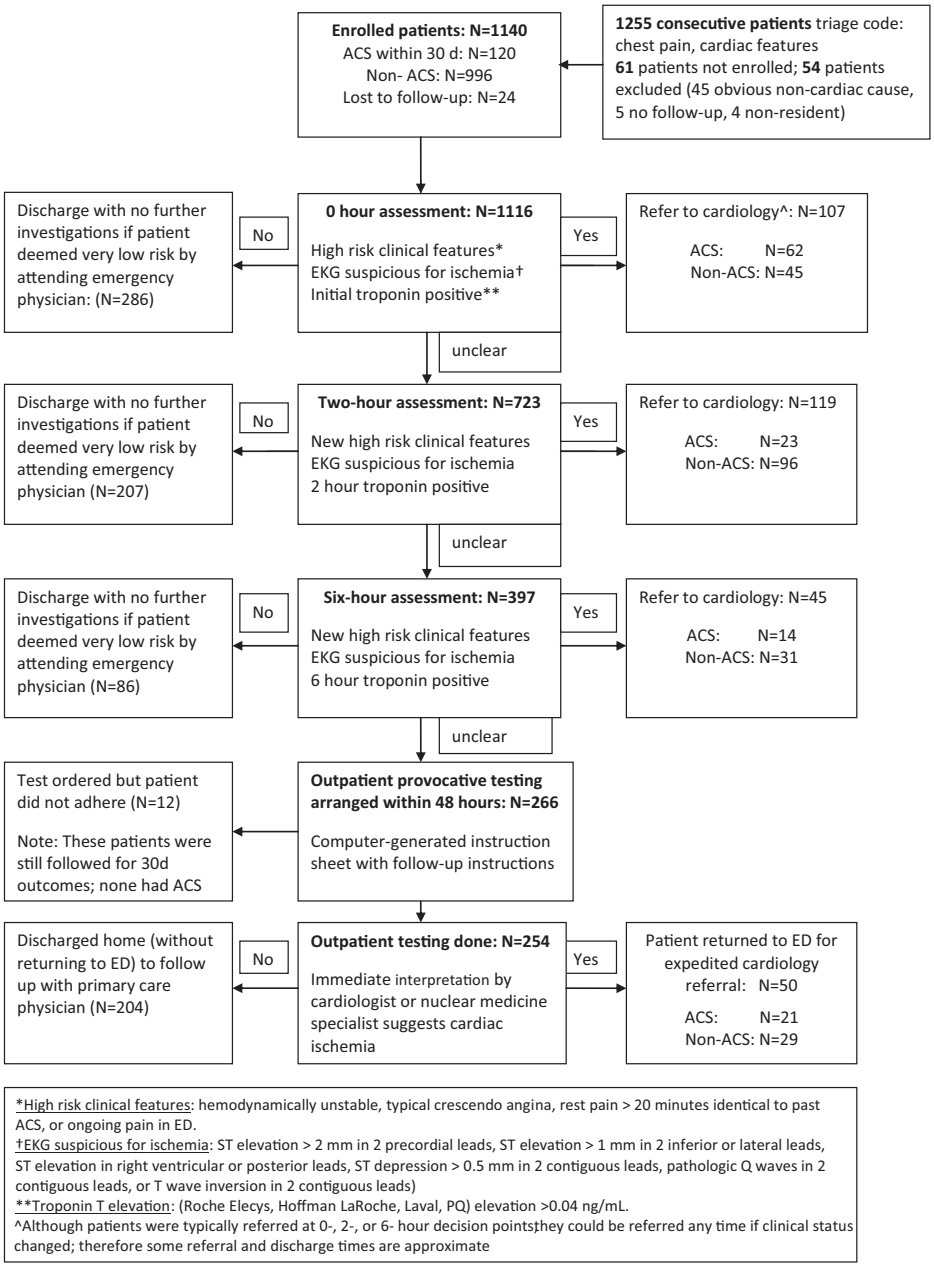

Figure 1. Patient flow through chest pain diagnostic algorithm, stratified by timed decision points. *ACS*, Acute coronary syndrome.

Research assistants obtained consent for follow-up and enrolled consecutive patients daily from 7 AM until 11 PM. Patients arriving outside of these hours and discharged before 7 AM were enrolled the next day by telephone. Patients were excluded if they were younger than 25 years, had a clear noncardiac cause of chest pain on initial assessment, were enrolled in the previous 30 days, had no fixed address in the province of British Columbia, had severe communication problems, or had a terminal noncardiac illness. This investigation was a substudy of a validation cohort to develop a clinical prediction rule for the early discharge of ED patients with low-risk ischemic chest pain; both the University of British Columbia and the Providence Health Care Research Ethics Boards approved the main study.

Data Collection and Processing

After enrolling patients, research assistants blinded to patient outcomes and the research hypothesis recorded admission and departure times, along with cardiac medications administered, consultations, inpatient and planned outpatient testing,

Acute Myocardial Infarction
Troponin level >1.0
Troponin level between 0.05 and 1.0 and one of the following:
- Dynamic ECG changes consistent with ischemia
- Positive coronary angiogram result (>70% lesion)
- Positive provocative stress test result (nuclide scan or stress ECG)

ECG changes consistent with acute MI, including
- New pathologic Q waves
- New LBBB
- ST-segment elevation (measured 60 ms after J point) (with no LBBB, paced or ventricular rhythm, benign early repolarization, pericarditis, or left-sided ventricular hypertrophy with strain)
  - >2 mm in 2 contiguous precordial leads
  - >1 mm in 2 contiguous interior or lateral leads
  - >1 mm in V8, V9 (posterior MI)
  - >1 mm in V4R (right ventricular MI)
- Tall R wave in V1 with precordial ST depression (posterior MI)

Thrombolysis with no other cause evident
Death with no other cause evident

Definite Unstable Angina
Rest pain >20 min and at least 1 of the following:
- Troponin level between 0.05 and 1.0, with no other criteria for AMI
- ECGs with no persistent ST-segment elevation but with other reversible changes consistent with ischemia
  - Transient ST-segment elevation >1.0 mm in 2 contiguous leads
  - Dynamic ST-segment depression >0.5 mm in 2 contiguous leads
  - Dynamic T-wave inversion in 2 contiguous leads
- Hospital admission and treatment for acute coronary syndrome with at least 1 of
  - Positive coronary angiogram result
  - Positive provocative stress test result

No acute coronary syndrome will be assigned if none of the above applies or in the following situations:
- Troponin level between 0.05 and 1.0 but stress test or angiogram result negative
- If other criteria are unclear but stress test or angiogram result negative

MI, Myocardial infarction; *LBBB*, left bundle-branch block.

Figure 2. Definitions. *AMI*, Acute myocardial infarction.

Death
Tachycardia requiring medical intervention or cardioversion
Bradycardia requiring medical intervention or pacing
Respiratory failure requiring assisted ventilations through
- Bag-valve-mask
- Noninvasive positive-pressure ventilation
- Tracheal intubation

Proven pulmonary embolism
Proven symptomatic aortic dissection or aortic aneurysm
New congestive heart failure requiring intravenous medications
Hypotension requiring colloids, vasoactive agents, or intra-aortic balloon pump
Chest compression
Percutaneous coronary intervention (*not* angiogram only)
Coronary artery bypass grafting

Figure 3. Adverse events.

provisional ED diagnosis, and adverse events. To calculate clinical risk, the Thrombolysis in Myocardial Infarction (TIMI) score was obtained for each patient.[13] After 30 days, research assistants telephoned patients to identify any intervening events, including physician or hospital visits in the first 30 days. Primary care physicians were contacted to obtain results of any outpatient tests or for confirmation of any new diagnoses. If patient contact was lost, records from all other regional hospitals were reviewed to identify any possible acute coronary syndrome–related visits. Finally, the British Columbia Vital Statistics registry was cross-referenced to locate patients who died outside of the hospital system. All data were collected on specific study forms and entered into an Oracle database (Oracle Corp, Redwood City, CA).

Outcome Measures and Primary Data Analysis

The primary clinical outcome was the number of missed cases of acute coronary syndrome, which was defined as acute myocardial infarction or definite unstable angina. Investigators blinded to ED discharge diagnoses assigned 30-day diagnoses according to predetermined mutually exclusive explicit criteria (Figure 2). Predetermined adverse events are described in Figure 3. If the diagnosis or adverse event was unclear, 2 cardiologists blinded to both patient outcomes and the research hypothesis independently reviewed the case and assigned a diagnosis; in case of disagreement, adjudication was performed by the principal investigator (J.C.). A missed case of acute coronary syndrome was defined as a patient who was discharged from the ED with a non–acute coronary syndrome diagnosis, without specific follow-up (outpatient cardiology consultation or provocative testing), who subsequently proved to have an acute coronary syndrome diagnosis or an adverse event within 30 days.

Research assistants blinded to 30-day acute coronary syndrome outcomes and the study hypothesis reviewed hospital records to obtain secondary outcomes. These included the number of patients who were discharged from the ED but had acute coronary syndrome identified on subsequent outpatient testing, the number of patients who were discharged from the ED and had a subsequent myocardial infarction or adverse event, the adherence rate with outpatient testing, and the ED length of stay. In addition, other information was collected: the number of cardiology consultations, the admission rate, hospital length of stay, and the number of ECGs, troponin levels, and provocative tests obtained. Because our ED relies on a computer order-entry system, these data—all of which were physician ordered—are automatically entered into the ED database, and missing or conflicting data were not a concern. A random sample of 5% of charts was reviewed by an investigator (F.S.), and κ values were obtained for 2 dichotomous outcomes: admission rate and cardiology consultations.

Results are presented as proportions, or means with SDs, wherever applicable (SPSS version 16.0.2; SPSS, Inc., Chicago, IL).

RESULTS

During the study period, 1,255 consecutive patients presented with a triage code of "chest pain, cardiac features." We analyzed 1,194 (95.1%) patients in the chest pain diagnostic algorithm protocol, with 54 exclusions (Figure 1). Of 1,140 eligible patients, 24 (2.1%) were lost to follow-up, but none of these patients had a regional ED visit or died within 30 days. Table 1 summarizes baseline characteristics and Table 2

Table 1. Baseline demographics.

Baseline Characteristics	Chest Pain Diagnostic Algorithm Cohort (N=1,116)
Mean age, y (SD)	54.7 (15.4)
Sex, No. (%) men	668 (60.0)
Arrival by emergency medical services, No. (%)	321 (28.8)
Median time to physician assessment, min (IQR)	27 (18,45)
Initial vital signs, mean (SD)	
Pulse rate, beats/min	80.3 (18.8)
Systolic BP, mm Hg	142.2 (26.1)
Diastolic BP, mm Hg	79.9 (14.1)
Respiratory rate, breaths/min	18.5 (3.1)
Initial abnormal ECG result, No. (%)*	268 (25.1)
Cardiac risk factors, No. (%)	
Previous ACS	267 (23.9)
Smoker	351 (31.5)
Hypertension	423 (38.2)
Diabetes	155 (14.0)
Hyperlipidemia	303 (27.3)
TIMI score, No. (%)	
0	494 (44.3)
1	307 (27.5)
2	137 (12.2)
3	110 (9.9)
4	40 (3.6)
5	21 (1.9)
6	6 (0.5)
7	1 (0.1)

*An abnormal ECG result was defined as having a left bundle-branch block, a paced rhythm with left ventricular hypertrophy, ST-segment elevation greater than 2 mm in 2 precordial leads, ST-segment elevation greater than 1 mm in 2 inferior or lateral leads, ST-segment elevation in right ventricular or posterior leads, ST-segment depression greater than 0.5 mm in 2 contiguous leads, pathologic Q waves in 2 contiguous leads, or T-wave inversion in 2 contiguous leads. T-wave flattening was not considered abnormal.

Table 2. Clinical outcomes.

30-Day Results	Chest Pain Diagnostic Algorithm Cohort (n=1,116)
No. (%)	
AMI	39 (3.5)
Definite unstable angina	81 (7.3)
No ACS but adverse event*	45 (4.0)
No ACS, no adverse event	951 (83.1)
Number of ACS cases	120 (10.8)
Missed ACS, No. (%; 95% confidence interval)	0 (0; 0–2.4)

*There were 48 adverse events (3 patients had 2 adverse events each).

describes clinical outcomes for the study cohort, showing that the acute coronary syndrome rate was 120 of 1,116 (10.8%). Five cases required adjudication to determine diagnosis. Our primary outcome, the missed acute coronary syndrome rate at 30-day follow-up, was 0% (95% confidence interval 0% to 2.4%).

Figure 1 illustrates the diagnostic decisions and dispositions made by emergency physicians. Of the 1,116 patients, 286 (25.6%) were discharged after the initial physician assessment, 207 (18.5%) after the 2-hour assessment, and a further 86 (7.7%) after the 6-hour assessment. In total, 271 patients (24.3%) were referred for cardiology evaluation during their ED visit, 254 (22.8%) underwent outpatient provocative testing after their ED visit, and 591 (52.9%) had neither.

Table 3. Outcomes of outpatient provocative testing.

Results	Outpatient Testing Arranged (n=266)
No. (%)	
Outpatient testing	254 (95.5)
Negative testing result	204 (76.7)
Positive testing result	50 (18.8)
ACS diagnosed after positive test result	21 (7.9)
No ACS or adverse event after positive test result	29 (10.9)
Did not follow up	12 (4.5)

Sixty-two (52%) of 120 acute coronary syndrome patients were identified at the initial physician assessment, 37 (31%) were identified during the 6-hour observation period, and 21 (17%) were identified by outpatient provocative testing. All patients in the final group had unstable angina and none experienced a delay-related adverse event or myocardial infarction. Of 266 patients referred for outpatient provocative tests, 254 (95%) were adherent; results are described in Table 3. No patients returned to the ED before provocative testing with a diagnosis of acute coronary syndrome, and no patients who failed to comply with outpatient testing proved to have acute coronary syndrome.

All 39 AMI patients were recognized and admitted at the index ED visit, along with 60 of 81 unstable angina patients. The remaining 21 were discharged from the ED, with no objective evidence of acute coronary syndrome, but were readmitted within 48 hours with positive provocative cardiac test results. Two of the 21 discharged patients with acute coronary syndrome had mildly elevated but stable troponin levels during their ED stay, but these were attributed to coexistent end-stage renal disease. None of the other patients with acute coronary syndrome had elevated biomarkers or ECG changes when they returned to the hospital, and none of the 21 discharged patients with acute coronary syndrome had a 30-day diagnosis of acute myocardial infarction. Of the 120 patients with acute coronary syndrome, 11 (9.2%)—all with unstable angina—had a TIMI score of zero.

Table 4 illustrates the risk factors (age and TIMI score [expressed in several measures of central tendency]) among patients, stratified by 0-, 2-, and 6-hour decisions. Patients who received a cardiology consultation at zero or 2 hours were older and had the highest TIMI scores; patients who were discharged at zero or 2 hours were younger and had the lowest TIMI scores.

Considering only patients who had a physician decision at 6 hours, patients who were discharged home without provocative testing had the lower TIMI scores, those discharged home with

Table 4. Physician decisions and patient risk (n=1,116).

Decision and Time*	Number	Sex (% Men)	Age, Mean (SD)	TIMI Score, Mean (SD)	TIMI Score, Median (IQR)	ACS, No. (%)
0 h	393					
Consultation	107	62 (57.9)	63.9 (11.4)	3.43 (1.71)	3.0 (3.0, 4.0)	62 (57.9)
Discharge	286	140 (49.0)	43.7 (15.6)	0.21 (0.37)	0 (0, 0)	0
2 h	326					
Consultation	119	92 (77.3)	62.9 (13.4)	2.58 (1.38)	3.0 (2.0, 4.0)	23 (19.3)
Discharge	207	132 (63.8)	49.5 (14.6)	0.45 (0.40)	0 (0, 0)	0
6 h	397					
Consultation	45	26 (57.8)	57.6 (13.2)	1.57 (1.16)	1.0 (1.0, 2.0)	14 (31.1)
Discharge, test	266	171 (64.2)	59.5 (12.3)	1.27 (0.93)	1.0 (0, 1.0)	21 (7.9)
Discharge, no test	86	45 (52.3)	57.2 (14.9)	0.88 (1.03)	0 (0, 1.0)	0
Stress results	254					
Did not adhere	12	9 (75.0)	55.7 (15.8)	1.10 (1.05)	1.0 (0, 1.0)	0
Stress passed	204	133 (65.2)	58.3 (12.2)	1.15 (0.93)	1.0 (0, 1.0)	0
Stress failed	50	29 (0.58)	65.5 (12.3)	1.85 (0.99)	2.0 (1.0, 3.0)	21 (42.0)
Stress failure analysis	50					
ACS	21	14 (66.7)	67.7 (11.3)	1.94 (0.95)	2.0 (1.0, 3.0)	21 (100.0)
No ACS	29	15 (51.7)	61.1 (13.5)	1.78 (0.90)	2.0 (1.0, 3.0)	0 (0.0)

*See Figure 1.

provocative testing had intermediate scores, and those referred to cardiology had higher scores. However, there was little difference in age or TIMI scores between patients who had normal outpatient testing results and those whose test result was positive. Furthermore, patients with positive stress test results who received a 30-day acute coronary syndrome diagnosis had ages and TIMI scores similar to those of patients who had a positive stress test result but received no acute coronary syndrome diagnosis.

Structured chart abstractions demonstrated excellent reviewer agreement. The κ value was 1.0 for admission and 0.90 for consultation. Additional outcomes are illustrated in Table E1 (available online at http://www.annemergmed.com). The median ED length of stay was 6.2 hours, with 225 patients (20.2%) physically discharged within 3 hours. (Although 493 patients were "discharged" from the chest pain diagnostic algorithm at zero and 2 hours, they did not leave the department within 3 hours owing to factors such as follow-up arrangements or social work consultations.) Forty-five patients had 48 adverse events, chiefly electrical cardioversion for acute atrial fibrillation. Seven patients died within the follow-up period, 4 who were admitted at the index visit and 3 who were discharged home; 6 had severe underlying noncardiac disease, whereas the seventh was offered admission at the index visit but declined (Appendix E1, available online at http://www.annemergmed.com).

Table E2 (available online at http://www.annemergmed.com) illustrates the 30-day diagnoses for patients who were discharged from the ED, stratified by time of discharge. Patients who were discharged at zero and 2 hours had a greater proportion of obvious noncardiac diagnoses, whereas those discharged at 6 hours without a stress test had a higher proportion of "nonspecific chest pain." Of 928 patients (83.1%) who had no acute coronary syndrome and no adverse event, only 77 (8.3%) were admitted to the hospital. Table E1 (available online at http://www.annemergmed.com) shows the 30-day diagnoses for patients who were admitted to the hospital to rule out acute coronary syndrome but did not receive an acute coronary syndrome diagnosis, showing that two thirds had nonspecific chest pain with no ominous diagnoses.

LIMITATIONS

This was a single-center cohort study performed in an inner-city Canadian ED with comprehensive cardiology services, and these results may be difficult to reproduce in other settings. The observational design is not ideal, but a randomized trial in our institution was not possible. Once the intervention was in place, subjecting patients to previous care without rapid outpatient testing was not considered ethical. Although an ideal comparison would have been similar structured care with inpatient provocative testing, our hospital resources precluded this approach.

None of the 21 patients with acute coronary syndrome who received a diagnosis with outpatient provocative tests after ED discharge experienced a myocardial infarction or adverse event; however, if larger numbers of patients with acute coronary syndrome had been discharged for such testing, it is possible that adverse events would have occurred. Nonconsecutive patient sampling is a concern, but the intensive nature of the data collection limited us to periods when research nurses were available. There was not a significant systematic exclusion of patients except the patients who were rapidly transported for cardiac intervention. We enrolled patients with chest pain; therefore, our findings cannot be generalized to patients with atypical ischemia presentations such as dyspnea, nausea, or weakness. Because we did not subject all patients to provocative testing or angiography, it is possible that clinically occult acute coronary syndrome events were missed, as were events that occurred more than 30 days after ED discharge. Finally, TIMI

scoring, although valuable for patients who have acute coronary syndrome and are admitted to cardiology wards, may not provide appropriate risk stratification of ED patients.[14-17]

We did not analyze physician decisions to consult or discharge patients. No measure of care provider expectations or comfort with this intervention was documented, nor was patient satisfaction documented, and there was cost evaluation.

DISCUSSION

In this intensive 30-day follow-up study of 1,116 ED patients with potential ischemic chest pain, 120 patients had definite acute coronary syndrome and 0% were missed (95% confidence interval 0% to 2.4%) with the diagnostic algorithm described. These results compare favorably to the 5% miss rate observed in an earlier chest pain cohort at the same setting before the implementation of the accelerated diagnostic protocol,[4] whereas the median ED length of stay was similar.

Enhanced diagnostic sensitivity and the low admission rate are probably attributable to the availability of expedited outpatient provocative testing, rather than prolonged ED observation or mandatory admission with extensive inpatient testing. Without rapid outpatient investigations, it is likely that emergency physicians would have admitted more patients for investigation. Only 22.8% of patients underwent provocative testing—as opposed to much higher rates observed in other studies[7-10,18-22]—and this may indicate that our emergency physicians were able to accurately risk-stratify patients during their index ED visit. Patients with an early disposition (zero or 2 hours) fell into 2 categories: either high-risk patients (older, higher TIMI score) who were referred to cardiology or very low-risk patients (young, TIMI scores typically zero, with a clear alternative noncardiac diagnosis) who were discharged. Patients with a 6-hour disposition were older, typically had some cardiac risk factors but no evidence of ischemic, and were frequently discharged with a diagnosis of nonspecific chest pain as opposed to a noncardiac diagnosis.

This suggests that some combination of objective risk scoring, as well as clinical judgment, could be used in the application of these tests rather than making them a mandatory component of chest pain unit investigation. Our finding that nearly 10% of acute coronary syndrome patients had a TIMI score of zero echoes that of previous reports[14-17] illustrating the difficulty in using a low score to safely rule out acute coronary syndrome in ED patients.

In our chest pain diagnostic algorithm cohort, 21 of 81 unstable angina patients had occult disease in the ED, which was identified only with early provocative testing; this underscores the value of this rapid testing as a vital component of the chest pain diagnostic process. Although the numbers are small, that none of our discharged acute coronary syndrome patients had an adverse event suggests that not all chest pain unit patients require immediate diagnostic testing during the index visit. Our findings support the American College of Cardiology/American Heart Association recommendations that discharge of chest pain unit patients is acceptable, provided provocative testing can be arranged within 72 hours. Unfortunately, the wait for this testing often exceeds this benchmark,[21] but keeping patients in a chest pain unit until all testing is completed may be unrealistic, given health system constraints.

Other authors have concluded that inpatient stress testing is important,[23] especially in an urban environment such as ours, where many patients have no access to primary care and follow-up rates for outpatient stress testing may be as low as 17%.[24] Despite our inner-city environment, the high adherence rate with outpatient stress testing was probably critical to our low rate of missed acute coronary syndrome. None of our nonadherent patients subsequently proved to have acute coronary syndrome. Furthermore, the success of our outpatient program possibly allowed physicians confidently to discharge patients at 6 hours, knowing that nonadherence was unlikely. This may have kept our median ED length of stay at 6.5 hours, which compares favorably with that of other chest pain units, where length of stay ranges from 9 to 50 hours.[7-11]

Meyer et al[11] evaluated 7,178 patients with chest pain but excluded all those believed by the emergency physician to have acute coronary syndrome. Of the included patients, 979 were discharged with an outpatient stress test, and 18 of those (2%) required cardiac intervention (percutaneous coronary intervention or coronary artery bypass graft) within 6 months. To compare, 1,875 patients—none of whom were deemed to be at risk for acute coronary syndrome—were admitted to the cardiology service and 1,057 patients were held for ED-based provocative testing. The admission rates in our chest pain diagnostic algorithm cohort were substantially lower, and we had no access to ED-based provocative testing. According to our experience and the work of Meyer et al,[11] it may be safe to discharge some patients who ultimately receive a diagnosis of unstable angina from the ED, provided rapid outpatient diagnostics are available.

Rates of acute myocardial infarction have been decreasing.[25] Furthermore, out-of-hospital ST-segment elevation myocardial infarction recognition programs and "direct to cardiac catheterization laboratory" diversion protocols are reducing the number of ST-elevation myocardial infarction patients who arrive in EDs.[26] This means that emergency physicians will treat higher proportions of low-risk patients who have vague clinical presentations, in which acute coronary syndrome is difficult to immediately rule out during a brief ED visit. The potentially greater difficulty in identifying subtle presentations, especially during a brief ED visit, means that many patients will require a structured approach similar to that described here. The challenge is to increase efficiency and diagnostic sensitivity without increasing ED, chest pain unit, or hospital crowding.

Although the majority of our patients did not have acute coronary syndrome, only 7.8% of these non–acute coronary syndrome patients were admitted, suggesting that our chest pain diagnostic algorithm model appears to provide diagnostic accuracy without prolonged observation and without admitting

large numbers of patients who ultimately prove not to have cardiac disease. Approximately two thirds of patients received a disposition (consultation versus discharge) within 2 hours owing to their age and physician risk scoring. However, for the remaining patients who received a 6-hour disposition, there was less difference in age and TIMI scores; almost all patients had scores of zero, 1, or 2. Few of these patients had ongoing pain, and none had objective markers of ischemia such as ECG or biomarker changes. The challenge may lie in accurately risk-stratifying this subset of patients, who still had a 12% acute coronary syndrome rate.

Strengths of the study include detailed prospective data capture, the use of explicit a priori outcome definitions, and a high follow-up rate. Our intensive 30-day follow-up procedures provide a high level of confidence that all significant adverse events were captured and that our safety and sensitivity conclusions are robust.

In ED patients with chest pain of potential cardiac origin, a structured diagnostic approach with time-focused ED decision points, brief observation, and selective application of early outpatient provocative testing appears both safe and diagnostically efficient, even though some patients with acute coronary syndrome may be discharged for outpatient stress testing on the index ED visit.

Supervising editor: Deborah B. Diercks, MD

Author contributions: GI, EG, MK, DK, and JC developed the chest pain diagnostic algorithm. FS and JC conceived the study. BB supervised the conduct of the trial and data collection. BB and EY managed the database. FS provided statistical analysis. FS drafted the article, and all authors contributed to its revision, notably GI and JC. FS takes responsibility for the paper as a whole.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication April 9, 2011. Revisions received August 10, 2011, and September 2, 2011. Accepted for publication October 7, 2011. Available online January 4, 2012.

Address for correspondence: Frank Scheuermeyer, MD, MHSc, E-mail frank.scheuermeyer@gmail.com.

REFERENCES

1. 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.
2. Christenson J, Innes G, McKnight D, et al. Safety and efficiency of emergency department assessment of chest discomfort. *CMAJ*. 2004;170:1803-1807.
3. Anderson JL, Adams CD, Antman EM, et al. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non–ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non–ST-Elevation Myocardial Infarction). *J Am Coll Cardiol*. 2007;50:e1-e157.
4. Greene J. The perils of low-risk chest pain: emergency physicians struggle to balance risk with overtesting. *Ann Emerg Med*. 2010; 56:25A-28A.
5. Pines JM, Pollack CV, Diercks DB, et al. The association between emergency department crowding and adverse cardiovascular outcomes in patients with chest pain. *Acad Emerg Med*. 2009;16: 617-625.
6. Diercks DB, Roe MT, Chen AY, et al. Prolonged emergency department stays of non–ST-segment elevation myocardial infarction patients are associated with worse adherence to the American College of Cardiology/American Heart Association guidelines for management and increased adverse events. *Ann Emerg Med*. 2007;50:489-496.
7. 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.
8. Roberts RR, Zalenski RJ, Mensah EK, et al. Costs of an emergency department–based accelerated diagnostic protocol vs hospitalization in patients with chest pain. A randomized controlled trial. *JAMA*. 1997;278:1670-1676.
9. Goodacre S, Nicholl J, Dixon S, et al. Randomized controlled trial and economic evaluation of a chest pain observation unit compared with routine care. *BMJ*. 2004;328:254-260.
10. Gomez MA, Anderson JL, Karagounis LA, et al. An emergency department–based protocol for rapidly ruling out myocardial ischemia reduces hospital time and expense: results of a randomized study (ROMIO). *J Am Coll Cardiol*. 1996;23:25-33.
11. Meyer MC, Mooney RP, Sekara AK, et al. A critical pathway for patients with acute chest pain and low risk for short term adverse cardiac events: role of outpatient stress testing. *Ann Emerg Med*. 2006;47:427-437.
12. Innes G, Murray M, Grafstein E; for the Canadian Emergency Department Information System (CEDIS) Working Group. A consensus-based process to define standard national data elements for a Canadian emergency information system. *CJEM*. 2001;4:277-284.
13. Antman EM, Cohen M, Bernink PJ, et al. The TIMI risk score for unstable angina/non-ST elevation MI: a method for prognostication and therapeutic decision making. *JAMA*. 2004; 284:835-842.
14. Hess EP, Perry JJ, Calder LA, et al. Prospective validation of a modified thrombolysis in myocardial infarction risk score in emergency department patients with chest pain and possible acute coronary syndrome. *Acad Emerg Med*. 2010;4:368-375.
15. Chase M, Robey JL, Zogby KE. Prospective validation of the Thrombolysis in Myocardial Infarction risk score in the emergency department chest pain population. *Ann Emerg Med*. 2006;48: 252-259.
16. Conway Morris A, Caesar D, Gray S, et al. TIMI risk score accurately risk stratifies patients with undifferentiated chest pain presenting to an emergency department. *Heart*. 2006;92:1333-1334.
17. Pollack CV Jr, Sites FD, Shofer FS, et al. Application of the TIMI risk score for unstable angina and non-ST elevation acute coronary syndrome to an unselected emergency department chest pain population. *Acad Emerg Med*. 2006;13:13-18.
18. Fesmire FM, Hughes AD, Fody EP, et al. The Erlanger chest pain evaluation protocol: a one-year experience with serial 12-lead ECG monitoring, two-hour delta serum marker measurements,

and selective nuclear stress testing to identify and exclude acute coronary syndromes. *Ann Emerg Med*. 2002;40:584-594.
19. Gibler WV, Runyon JP, Levy RC, et al. A rapid diagnostic and treatment center for patients with chest pain in the emergency department. *Ann Emerg Med*. 1995;21:1-8.
20. Nichol G, Walls R, Goldman L, et al. A critical pathway for management of patients with acute chest pain who are at low risk for myocardial ischemia: recommendations and potential impact. *Ann Intern Med*. 1997;127:996-1005.
21. Storrow AB, Gibler WB. Chest pain centers: diagnosis of acute coronary syndromes. *Ann Emerg Med*. 2000;35:449-461.
22. Newby LK, Mark DB. The chest pain unit—ready for prime time? *N Engl J Med*. 1998;339:1930-1932.
23. Zalensky 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.
24. Field DL, Hedges JR, Arnold KJ. Limitations of chest pain follow-up from an urban teaching hospital emergency department. *J Emerg Med*. 1987;6:363-368.
25. Yeh RW, Sidney S, Chandra M, et al. Population trends in the incidence and outcomes of acute myocardial infarction. *N Engl J Med*. 2010;362:2155-2165.
26. Lee CH, Van Gelder CM, Cone DC. Early cardiac catheterization laboratory activation by paramedics for patients with ST-segment elevation myocardial infarction on prehospital 12-lead electrocardiograms. *Prehosp Emerg Care*. 2010;14:153-158.

IMAGES IN EMERGENCY MEDICINE

(continued from p. 255)

DIAGNOSIS:

Methanol toxicity. Methanol toxicity is primarily due to its toxic metabolite formic acid, formed in the liver, which causes systemic metabolic acidosis. Patients present with symptoms of dizziness, headache, nausea, vomiting, abdominal pain, and blurring of vision usually 12 to 24 hours after ingestion. If not treated promptly, the patient experiences respiratory and renal failure, which eventually leads to coma and death. Because of selective toxicity to the retrolaminar optic nerve myelin sheath, there is acute irreversible blindness.[1] Methanol commonly affects the bilateral basal ganglion, causing hemorrhagic and nonhemorrhagic damage of the putamen, which is evident on MRI. Acute conditions that can involve the deep gray matter nuclei bilaterally and symmetrically and are more commonly observed are carbon monoxide poisoning, acute hypoxia, and ingestion of toxic materials (methanol, ethylene glycol, or cyanide) that have selective affinity in the basal ganglion.[2,3]

Management is to be instituted as early as possible: (1) gastric lavage with sodium bicarbonate within 2 hours of ingestion; (2) correction of acidosis with sodium bicarbonate infusion; (3) intravenous methyl prednisolone and osmotic diuresis for decreasing edema and preventing the worsening of optic neuropathy[4]; (4) inhibition of metabolism of methanol by intravenous fomepizole (not available in India); and (5) elimination of toxins by hemodialysis, as well as clearance of blood formate by calcium leucovorin.[5] Hence, unconsciousness in patients with anion gap metabolic acidosis with sluggish pupillary response (bilateral optic atrophy) and bilateral basal ganglion lesion predominantly of the putamen and globus pallidus is suggestive of methanol intoxication.

The authors acknowledge the Department of Radiology and Ophthalmology, CSM Medical University, Lucknow, for their expert opinion in this particular case.

REFERENCES

1. Younger DS. Pollutants and industrial hazards. In: Rowland LP, ed. *Merritt's Textbook of Neurology*.9th ed. Baltimore, MD: Williams & Wilkins; 1995:992-993.
2. Hantson P, Duprez T, Mahieu P. Neurotoxicity to the basal ganglia shown by magnetic resonance imaging following poisoning by methanol and other substances. *Clin Toxicol*. 1997;35:151-161.
3. Gaul HP, Wallace CJ, Auer RN, et al. MR findings in methanol intoxication. *AJNR Am J Neuroradiol*. 1995;16:1783-1786.
4. Sodhi PK, Goyal JL, Mehta DK. Methanol-induced optic neuropathy: treatment with intravenous high dose steroids. *Int J Clin Pract*. 2001;55:599-602.
5. Tripathi KD. Ethyl and methyl alcohols. In: Tripathi M, ed. *Essentials of Medical Pharmacology*.6th ed. New Delhi, India: Jaypee; 2008:386-387.

APPENDIX E1.

Deaths.

1. Deaths at index visit (all patients were admitted to the hospital at the index visit).

A 78-year-old woman with mesenteric ischemia died on postadmission day 6.

A 68-year-old man with palliative multiple myeloma died on postadmission day 16 after multiple cardiac arrests.

A 78-year-old man died of heart failure on postadmission day 2 after his family refused aggressive resuscitation.

A 75-year-old woman with severe restrictive lung disease died on postadmission day 6 after her family requested that no heroic measures be undertaken.

2. Deaths during 30 days

A 76-year-old man with palliative coronary artery disease declined admission or cardiology intervention despite being informed of the risk, was returned to his care facility, and died 2 days after the index ED visit.

A 76-year-old woman was readmitted to the hospital with a spontaneous intracranial hemorrhage 30 days after the index ED visits and died rapidly after her family refused critical care intervention.

A 55-year-old woman was admitted to the internal medicine ward with congestive heart failure at the index visit and discharged home. She re-presented 29 days after the index ED visit, was admitted to internal medicine with congestive heart failure, refused aggressive resuscitation, and died soon after.

Table E1. Thirty-day diagnoses of patient admitted to the hospital (with presumed acute coronary syndrome) from the ED at the index visit.

Diagnosis	No. (%), N=77
Nonspecific chest pain	50 (64.9)*
Neuropathic chest pain	2 (2.6)
Stable angina	3 (3.9)
Heart failure	3 (3.9)
Aortic aneurysm (stable)	1 (1.3)
Hypertension	1 (1.3)
Pericarditis	1 (1.3)
Arrhythmia	1 (1.3)
Cardiomyopathy	1 (1.3)
Coronary artery dissection	1 (1.3)
Nonspecific syncope	3 (3.9)
Sepsis	2 (2.6)
Pneumonia	1 (1.3)
Chronic obstructive pulmonary disease	3 (3.9)
Esophageal spasm	1 (1.3)
Nonspecific gastrointestinal	3 (3.9)

*May not add to 100% because of rounding.

Table E2. Diagnoses of patients discharged from the ED, stratified by discharge time.

Diagnosis, No. (%)	(n=579)
Discharge at 0 h (n=286)	
Alternate cardiac diagnoses	27*
Aortic dissection†	1
Atrial fibrillation	10
Atrial flutter	1
Atrial septal defect	1
Heart failure	3
Hypertension	2
Mitral valve prolapse (chronic)	1
Palpitations	3
Pericarditis	2
Supraventricular tachycardia	3
Gastrointestinal	15
Biliary colic	2
Crohn's disease exacerbation	1
Esophagitis	1
Gastroenteritis	2
Gastrointestinal bleeding	1
Gastrointestinal reflux	7
Hernia	1
Pulmonary	12
Asthma	4
Exacerbation of chronic obstructive lung disease	1
Pneumonia	7
Neurologic	8
Headache (nonspecific)	2
Presyncope	2
Transient ischemic attack	1
Vertigo (nonspecific)	2
Weakness (nonspecific)	1
Infectious	8
Cellulitis	2
Viral illness	5
Zoster	1
Musculoskeletal	126
Chest wall pain	126
Other	90
Adverse drug event	1
Anxiety	22
Alcohol intoxication	2
Nonspecific chest pain	65
Discharge at 2 h (n=207)	
Alternate cardiac diagnoses	18 (8.7)
Atrial fibrillation	8 (3.9)
Heart failure	3 (1.4)
Hypertension	2 (1.0)
Myocarditis	2 (1.0)
Pericarditis	3 (1.4)
Gastrointestinal	9
Biliary colic	2 (1.0)
Gastrointestinal reflux	2 (1.0)
Nonspecific abdominal pain	5 (2.4)
Pulmonary	4 (1.9)
Asthma	2 (1.0)
Exacerbation of chronic obstructive lung disease	2 (1.0)
Neurologic	3 (1.4)
Headache (nonspecific)	2 (1.0)
Vertigo (nonspecific)	1 (0.5)
Musculoskeletal	52 (25.1)
Chest wall pain	52 (25.1)

Table E2. Continued.

Diagnosis, No. (%) (n=579)	
Other	121 (58.5)
Allergic reaction	1 (0.5)
Anemia	1 (0.5)
Anxiety	3 (1.4)
Nonspecific chest pain	116 (53.1)
Discharge at 6 h (n=86)	
Alternate cardiac diagnoses	7 (8.1)
Atrial fibrillation	4 (4.7)
Bradycardia	1 (1.2)
Endocarditis	1 (1.2)
Heart failure	1 (1.2)
Gastrointestinal	2 (2.3)
Gastrointestinal reflux	2 (2.3)
Pulmonary	2 (2.3)
Pneumonia	2 (2.3)
Other	75 (87.2)
Anxiety	1 (1.2)
Nonspecific chest pain	74 (86.0)

*May not add to 100% because of rounding.
†Although patients were "discharged" from the chest pain diagnostic algorithm pathway, they may have been admitted to other noncardiology services (for example, the one patient with an aortic dissection immediately received a cardiovascular surgery consultation but was considered "discharged" from the chest pain diagnostic algorithm protocol). At our institution, for example, patients with heart failure or atrial fibrillation who have not received a diagnosis of acute coronary syndrome are admitted to the internal medicine service.