

ORIGINAL ARTICLE

A prospective, observational study of a chest pain observation unit in a British hospital

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Objectives: To establish a chest pain observation unit, monitor its performance in terms of appropriate discharge after assessment, and estimate the cost per patient.

Methods: Prospective, observational, cohort study of patients attending a large, city, teaching hospital accident and emergency department between 1 March 1999 and 29 February 2000 with acute undifferentiated chest pain. Patients were managed on a chest pain observation unit, entailing two to six hours of observation, serial electrocardiograph recording, cardiac enzyme measurement, and, where appropriate, exercise stress test. Patients were discharged home if all tests were negative and admitted to hospital if tests were positive or equivocal. The following outcomes were measured—proportion of participants discharged after assessment; clinical status three days after discharge; cardiac events and procedures during the following six months; and cost of assessment and admission.

Results: Twenty three participants (4.3%) had a final diagnosis of myocardial infarction. All were detected and admitted to hospital. A total of 461 patients (86.3%) were discharged after assessment, 357 (66.9%) avoided hospital admission entirely. At review three days later these patients had no new ECG changes and only one raised troponin T measurement. In the six months after assessment, three cardiac deaths, two myocardial infarctions, and two revascularisation procedures were recorded among those discharged. The mean cost of assessment and hospital admission was £221 per patient, or £323 if subsequent interventional cardiology costs were included.

Conclusions: The chest pain observation unit is a practical alternative to routine care for acute chest pain in the United Kingdom. Negative assessment effectively rules out immediate, serious morbidity, but not longer term morbidity and mortality. Costs seem to be similar to routine care.

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Chest pain is a frequent cause for medical admission and attendance at the accident and emergency (A&E) department.¹ Assessment aims to rapidly and accurately differentiate potentially serious causes, such as acute myocardial infarction or unstable angina, from benign conditions. The sparse data available relating to this problem in the United Kingdom (UK) suggest that management is suboptimal. It has recently been estimated that 6% of patients discharged from the A&E department after presenting with chest pain have significant myocardial damage.² Meanwhile, a substantial proportion of those admitted have a benign cause.^{1,3}

The chest pain observation unit (CPOU) offers a potential alternative.⁴ Patients undergo intensive electrocardiographic (ECG) monitoring and cardiac enzyme testing, followed by provocative cardiac testing (usually exercise stress test). This approach was developed in the United States (US) and is now used in many American emergency departments.⁵ CPOU protocols are safe, with very low rates of missed pathology among those discharged.⁴ Demonstrating improved outcome is difficult, because of the low incidence of adverse events in the selected, low risk population. However, evidence from randomised controlled trials shows that CPOUs are cost saving in the US.⁶⁻⁸

Substantial differences exist between the US and the UK in both clinical practice, and the organisation of health services. A previous study,³ done before the development of CPOU care at our hospital, estimated the mean cost of inpatient assessment for low risk, CPOU eligible patients to be approximately £356 per patient (or £458 if interventional cardiology costs were included). Comparable costs in the US are much higher,^{3,4} so we cannot assume that CPOU care will be a practical or cost saving alternative to routine care in the UK.

We aimed to establish a CPOU in a typical British hospital, evaluate its performance in terms of appropriate discharge home of those with benign chest pain, and to estimate the cost of CPOU assessment and related hospital admission.

METHODS

The Northern General Hospital Accident and Emergency Department is the only adult A&E department in Sheffield. Approximately 75 000 new patients attend per year, 4% of whom attend with chest pain. Before the introduction of a CPOU, 65% of these patients were admitted after assessment in the A&E department.³

The CPOU is a two bedded unit based in the A&E department, staffed by two coronary care trained, chest pain nurses (CP nurses). Equipment consists of two ST segment monitors, exercise treadmill, and full resuscitative equipment. Medical cover is provided by middle grade emergency medical staff. The unit functions from 9 00 am to 9 00 pm, Monday to Friday. Patients attending outside these hours are admitted to the medical admissions ward and referred to the CPOU the following day.

Patients are not assessed on the CPOU if any of the criteria listed in appendix 1 are met. These criteria use validated clinical predictors⁹⁻¹¹ to identify two groups of patients. Firstly, those who are at minimal risk of an acute coronary event and simply risk false positive tests if they undergo further assessment (item 5), and secondly, those who are at high risk of an

Abbreviations: CPOU, chest pain observation unit; CP nurse, chest pain nurse; CHD, coronary heart disease

acute coronary event who are either unlikely to test negative on CPOU assessment or would not be considered safe for discharge even if all tests were negative (item 4).

The protocol for CPOU assessment is outlined in appendix 2. It typically takes two to six hours to complete. All elements have been researched and shown to be effective in detecting acute myocardial ischaemia.¹²⁻¹⁹ ST segment monitoring, serial ECG, and cardiac enzyme testing identify those with myocardial damage.¹²⁻¹⁷ A trade off has to be made between maximising enzyme sensitivity with prolonged observation and best use of limited resources. This is done by the combination of measurement of both CK-MB (mass) and troponin T at least six hours after the onset of pain, (sensitivity for myocardial infarction at least 90% and 85% respectively)¹² and measurement of the gradient of rise of CK-MB (mass) over two hours (sensitivity 95%).¹⁴

The role of exercise testing in acute chest pain is well established.^{18, 19} It is used to stratify patients to high risk (early positive test, requiring admission), intermediate risk (late positive test, admission if prolonged or recurrent pain) or low risk (negative test, discharge) groups. Patients with known coronary heart disease (CHD), confirmed by recent diagnostic testing, or those who are unable to undergo exercise testing or achieve 85% of their predicted heart rate are discharged unless they have had recurrent or prolonged cardiac type pain.

Most CPOU management, including exercise stress test supervision, is provided by the CP nurses. They are also responsible for supervising and auditing thrombolysis, education and training of nursing staff, and care of patients with acute coronary syndromes in the A&E department. Medical staff review each patient to confirm eligibility before CPOU assessment, review test results to determine disposal from the CPOU, and occasionally assist with supervision of the exercise stress test.

The following data are routinely collected on a standard proforma from all CPOU patients—history and examination details, investigations, CPOU protocol results, details of any adverse events on the CPOU, and disposal (admission or discharge) from the CPOU. Patients discharged after CPOU assessment are routinely invited to attend 72 hours after discharge for clinical assessment by a CP nurse, ECG, and troponin T measurement.

Data collected from patients attending between 1 March 1999 and 29 February 2000 form the basis of this study. Case notes of all patients admitted after CPOU assessment were reviewed. The final diagnosis and length of hospital stay was recorded. The hospital computer database was searched for all patients, for any related A&E department attendance or hospital admission up to six months after attendance. Case notes retrieved where relevant, from which the following details were recorded—status at six months (dead or alive), related A&E department attendance or hospital admissions, further diagnostic test results, and any cardiac events or procedures. If the patients' status at six months was not evident from the notes, their general practitioner (GP) was contacted by post.

The final diagnosis was defined as the most senior available medical opinion, taking into account the results of all relevant diagnostic tests. Acute myocardial infarction was defined by World Health Organisation criteria.²⁰ Patients diagnosed as having myocardial ischaemia but without these criteria were all classified as having angina. No differentiation was made between stable and unstable angina, as it was found that such distinctions were often highly subjective or based entirely on the results of CPOU assessment.

Ethical approval was given by the North Sheffield Research Ethics Committee. As the new service involved no intervention or follow up procedure that was not already well established, and data collection and analysis did not go beyond that required for thorough audit of a new service, it was decided that routine Northern General Hospital information and consent procedures should be used.

Economic analysis

The mean cost per patient of CPOU assessment, including overnight admission before assessment and medical admission after assessment, was estimated using Northern General Hospital financial data. The daily cost of medical admission, including all overheads and staffing costs, is £150.

The following assumptions were made—CP nurses spent half of their time managing CPOU patients (averaging four hours per patient =£60); and all CPOU patients received 45 minutes of medical time (£15), blood tests as per protocol (£15), a chest radiograph (£6), four hours of hospital overheads (£15) and use of CPOU equipment (£16). For patients admitted overnight before CPOU assessment, a mean length of stay of 12 hours was assumed and £75 added per patient. For patients admitted after CPOU assessment the cost of hospital stay was calculated by multiplying the length of stay (in days) by £150. The total cost was divided by the total number of patients to give the mean cost per patient, excluding interventional cardiology costs. The cost of the follow up visit was not included in analysis as this visit was undertaken principally to audit the introduction of the service and was not intended to be part of routine patient assessment.

The cost of interventional cardiology has previously been shown to be an important, if controversial, determinant of cost effectiveness.³ To calculate the mean cost per patient with these costs included, we used the following estimates of cost per procedure—angiography (£537), angioplasty (£3311), and CABG (£6489). These costs were added to the total for all patients receiving these procedures over the six months after attendance.

Mean cost per patient, using the CPOU, could be compared with the cost of inpatient assessment before development of the CPOU.³ However, this comparison assumes that all CPOU patients would be admitted if the CPOU were not available. A more meaningful comparison would assume that, with no CPOU available, a proportion of CPOU patients would be discharged home from the A&E department without further testing. Unfortunately, only an appropriately designed, controlled trial can provide an accurate estimate of this proportion. Therefore, we performed a simple decision analysis to determine how the relative costs of CPOU and routine inpatient assessment compare when the proportion of CPOU patients who it is assumed would have been discharged is varied over a credible range.

RESULTS

Over the year the CPOU opened from 9 00 am to 9 00 pm on 154 days and from 9 00 am to 5 00 pm on 98 days (total 252 days). During this time 534 patients underwent protocol evaluation, an average of 2.1 patients per day. Mean age was 52.2 years, 329 (61.6%) were male, and 101 (18.9%) had known CHD. 417 (78.1%) came directly from the A&E department, while 117 (21.9%) required overnight admission before assessment.

All patients received serial ECG, CK-MB(mass) and troponin T measurement. A total of 366 (68.5%) subsequently

Table 1 Final diagnoses of all patients (n=534)

Diagnosis	Number (%) admitted	Number (%) discharged	Number (%) of total
Myocardial infarction	23 (100)	0 (0)	23 (4.3)
Angina	36 (36.4)	63 (63.6)	99 (18.5)
Non-specific chest pain	5 (5.4)	88 (94.6)	93 (17.4)
Musculoskeletal pain	4 (2.4)	165 (97.6)	169 (31.6)
Gastro-oesophageal pain	3 (3.6)	80 (96.4)	83 (15.3)
Anxiety	0 (0)	41 (100)	41 (7.7)
Other	2 (7.7)	24 (92.3)	26 (4.9)

Table 2 Admitted patients (n=73)—final diagnoses and reasons for admission

Final diagnosis	Number (%)	Reason for admission
Myocardial infarction	23 (31.5)	All had raised enzymes, 6 also had serial ECG changes
Angina	36 (49.3)	15 raised enzymes, 11 positive EST, 4 inconclusive EST, 4 serial ECG changes, 2 clinical criteria
Non-specific chest pain	5 (6.8)	2 positive EST, 1 inconclusive EST, 2 serial ECG changes
Musculoskeletal	4 (5.5)	2 serial ECG changes, 1 raised enzymes, 1 inconclusive EST
Gastro-oesophageal	3 (4.1)	2 inconclusive EST, 1 raised enzymes
Other	2 (2.7)	Both serial ECG changes

ECG, electrocardiograph; EST, exercise stress test.

underwent an exercise stress test; 168 patients did not undergo exercise stress testing for the following reasons—52 were admitted with positive blood tests or serial ECG changes, 75 had recent diagnostic testing for CHD, and 41 had physical limitations.

After CPOU assessment 73 patients (13.7%) were admitted and 461 (86.3%) discharged. Their final diagnoses are outlined in table 1. Of those discharged, 357 (66.9% of total) were referred to the CPOU directly from the A&E department and therefore avoided hospital admission completely. Most patients received no further diagnostic testing after CPOU assessment. The final diagnosis therefore represents the diagnostic impression of the most senior clinician rather than a definitive diagnosis based on rigorous testing.

Admitted patients

Table 2 outlines the positive tests that resulted in admission. All cases of myocardial infarction were identified by increased cardiac enzyme activities, with or without serial ECG changes. Length of stay for all those admitted ranged from one to fifteen days (mean 91 hours, median 72 hours).

Six months after attendance, 15 (20.6%) patients had reattended the A&E department with related complaints and 17 (23.3%) had been readmitted to hospital. Six patients underwent angiography, five underwent coronary stenting or angioplasty, and three received coronary artery bypass grafting. Three patients had died, two from cardiac causes, and one non-cardiac.

Discharged patients

Of the 461 patients discharged, 407 (89.4%) attended follow up three days later. At follow up six patients had recurrent chest pain requiring admission (three with known CHD, two with positive or inconclusive exercise stress test, and one with gastro-oesophageal pain). No patient had any significant new ECG changes at follow up. One patient, who had been discharged after a late positive exercise stress test, had a troponin T level greater than 0.1 ng/ml.

Six month follow up data were available for 429 patients (93.1%)—28 from the A&E department or hospital notes, 376 from GP letter, and 25 from direct patient contact. Seven patients had died—three from cardiac causes and four from causes unrelated to their chest pain. Two of the cardiac deaths occurred in patients with known CHD, who died from progressive cardiac disease after CPOU assessment ruled out an acute event. The other cardiac death occurred three months after an entirely negative CPOU assessment, including exercise stress testing.

Two patients suffered myocardial infarction during the six months—one had known CHD, the other had a full negative assessment including exercise stress test. Two other patients, both with known CHD, had revascularisation procedures—one angioplasty and one coronary artery bypass graft.

Ten patients underwent angiography. This was negative in three cases, confirming negative CPOU assessment, and positive in seven cases—five with known CHD, one with a late positive exercise test on CPOU, and one unable to perform an exercise stress test because of physical limitations.

Sixty (13.0%) discharged patients attended the A&E department with related complaints during the six months after assessment and 46 (10.0%) were admitted to hospital.

Economic analysis

The mean cost per patient was £221 without inclusion of interventional cardiology costs and £323 with these costs included. If it is assumed that, without a CPOU, all CPOU eligible patients would be admitted, the comparable costs for routine care are £356 and £458 respectively.³ If 65% of CPOU eligible patients would be admitted, and 35% discharged, costs of CPOU and routine care would be identical. If the proportion of patients admitted is less than 65%, routine care is cheaper. If the proportion of patients admitted is more than 65%, CPOU care is cheaper.

DISCUSSION

The CPOU is a practical option for managing patients presenting to hospital with acute chest pain in the UK. Some 86.3% of patients were discharged after assessment and 66.9% avoided admission entirely. All cases of myocardial infarction were successfully detected. Three day follow up revealed a very low rate of missed pathology that compares well with previously reported routine practice.²

Adverse events among discharged patients were uncommon over the following six months but did occur even after a comprehensively negative assessment. This is unsurprising as, although cardiac markers and exercise stress test may predict subsequent outcome, they have imperfect sensitivity,^{12, 21} particularly for longer term outcomes.²² Patients with a negative CPOU assessment may be safely discharged home but appropriate follow up must be arranged.

Caveats regarding the longer term predictive value of CPOU assessment are particularly true of patients with known CHD in whom the assessment only rules out an acute coronary event. Such patients have a substantial risk of recurrent pain, reattendance, readmission, and adverse events. Close follow up is therefore essential.

Some 18.7% of the cohort was diagnosed as having angina without myocardial infarction. Approximately one third of these were admitted to hospital after assessment. The diagnosis of angina was usually based upon either previous diagnostic testing for CHD or the results of CPOU tests (positive exercise stress test or raised enzyme activity without a significant rise in creatinine kinase). We made no distinction between stable and unstable angina in these patients. It became apparent that, where the clinicians had made such a distinction, it was often based upon the results of CPOU assessment. This created a somewhat spurious impression that CPOU assessment effectively discriminated between stable and unstable angina. Determining whether admission or discharge of patients with angina is “appropriate” or not is therefore difficult. However, the low rate of pathology detected at three day review, suggests that discharging the majority of these patients was appropriate.

Although acute chest pain is a common cause for attendance at the A&E department, only a minority are

suitable for CPOU assessment. Our previous study³ estimated that only 37% of admitted patients would be suitable for CPOU assessment (24% of all patients attending with chest pain, approximately 58 patients per month). Common causes for exclusion are—new ECG changes, comorbidity, and patients with known CHD presenting with prolonged or recurrent anginal pain. This prospective study confirms that these estimates were reasonably accurate.

Mean cost per patient of CPOU assessment was £221, or £323 if interventional cardiology costs are included. These figures are less than our previous estimate³ of the cost of inpatient care for similar, low risk patients (£356 and £458 respectively). However, if 35% of CPOU patients would have been discharged from the A&E department without further investigation, mean cost per patient would have been identical to routine care. The relative costs of CPOU and routine care therefore may be very similar and highly dependent upon the proportion of CPOU eligible patients who would be discharged if no CPOU were available.

The estimates of CPOU cost are also subject to great uncertainty, from both random variation (particularly the estimates of the frequency of high cost, low incidence procedures such as coronary angiography) and assumptions made in developing cost estimates, such as the amount of time CP nurses spend caring for CPOU patients. It is therefore difficult to draw any conclusion regarding cost effectiveness. The true difference in cost could be substantial and could favour either option.

The low rate of missed pathology observed in our cohort is encouraging and suggests that CPOU care may be superior to routine care in the UK. Collinson *et al*³ found that 6% of patients discharged from the A&E after routine assessment had increased troponin T measurements. Compared with this the CPOU performs well, but it is possible that differences in selection of the two cohorts could explain these difference in outcome. We therefore need a randomised controlled trial, and a rigorous economic evaluation to provide an unbiased assessment of the comparative effectiveness and cost effectiveness of CPOU and routine care.

Acute chest pain is an important health care problem that has received insufficient attention in the UK. This study has shown that the CPOU is a practical alternative for managing acute chest pain in the UK. Most patients can be appropriately discharged after negative assessment, although subsequent follow up is required. Economic analysis suggests that costs of CPOU and routine care are similar, but this estimate is subject to substantial uncertainty. A randomised controlled trial is now required to determine if it is more effective and more cost effective than routine care.

Contributors

Steve Goodacre formed the study hypothesis, designed the study, analysed the data and wrote the paper. Francis Morris initiated the research and assisted in study design, data analysis and writing the paper. Stephen Campbell assisted in the study design, data analysis and writing the paper. Jane Arnold and Karen Angelini collected the data and assisted in study design and writing the paper.

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Conflicts of interest: none.

APPENDIX 1 EXCLUSION CRITERIA FOR CPOU ASSESSMENT

1 Any of the following ECG changes, unless known to be old— >1 mm ST elevation or depression, or >3 mm T wave inversion in two contiguous leads; atrial fibrillation; tachyarrhythmia (>120 beats per minute); bradycardia (<40 beats per minute); 2nd or 3rd degree heart block; or left bundle branch block.

2 Comorbidity requiring hospital admission, for example, heart failure, poor social support.

3 Suspected or proven alternative cause requiring hospital admission, for example, pulmonary embolus, dissecting aortic aneurism.

4 Known CHD with anginal pain that consists of recurrent episodes or an episode lasting more than one hour.

5 Minimal risk of myocardial ischaemia—that is, pain that is stabbing, pleuritic, positional or reproduced by palpation in a patient with no history of, and few risk factors for, CHD.

APPENDIX 2 OUTLINE OF THE CPOU PROTOCOL

1 Serial ECG and continuous ST monitoring

Serial ECGs are recorded hourly. Most patients receive continuous ST segment monitoring. The patient is admitted if the following are recorded— >1 mm ST elevation or depression in any two contiguous leads; T wave changes unrelated to posture or hyperventilation; arrhythmia; 2nd or 3rd degree heart block; or left bundle branch block.

2 Cardiac enzyme measurement

This depends upon the time from the most significant episode of pain to presentation at hospital—

If more than 12 hours, one blood sample for troponin T and CK-MB(mass) is taken

If less than 12 hours, two blood samples are taken. 1st—immediately for CK-MB (mass). 2nd—at least 2 hours later and 6 hours after the onset of pain for CK-MB(mass) and troponin T.

The patient is admitted if troponin T is >0.1 ng/ml; either CK-MB(mass) is >5 ng/ml; or the CK-MB(mass) gradient is >1.6 ng/ml.

3 Exercise stress testing

Uses the Bruce protocol and is interpreted as follows—

Early positive—arrhythmia; >1 mm ST elevation; or >1 mm horizontal or down-sloping ST depression at stage 1 or 2 of the Bruce protocol.

Late positive—any of the above changes occurring at stage 3 or beyond.

Negative—at least stage 3 and 85% of predicted maximal heart rate achieved without the above ECG changes.

Inconclusive—no ECG changes but unable to achieve stage 3 or 85% of predicted maximal heart rate.

Patients with early positive tests are admitted and those with negative tests discharged. Patients with late positive, equivocal or inconclusive tests; who are unable to perform exercise stress test or are known to have CHD are discharged with appropriate follow up unless they have ongoing anginal pain.

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REFERENCES

- 1 Capewell S, McMurray JJV. "Chest pain - please admit", is there an alternative? *BMJ* 2000;**320**:951-2.
- 2 Collinson PO, Premachandram S, Hashemi K. Prospective audit of incidence of prognostically important myocardial damage in patients discharged from emergency department. *BMJ* 2000;**320**:1702-5.
- 3 Goodacre SW, Morris FM, Angelini K, *et al*. Is a chest pain observation unit likely to be cost-saving in a typical UK hospital? *Emerg Med J* 2001;**18**:11-14.
- 4 Goodacre SW. Should we establish chest pain observation units in the United Kingdom? A systematic review and critical appraisal of the literature. *J Accid Emerg Med* 2000;**17**:1-6.
- 5 Zalenski RJ, Rydman RJ, Ting S, *et al*. A national survey of emergency department chest pain centres in the United States. *Am J Cardiol* 1998;**81**:1305-9.
- 6 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**:1882-8.

- 7 **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**:1670–6.
- 8 **Gomez MA**, Anderson JL, Karagounis LA, *et al.* An emergency department-based protocol for rapidly ruling out myocardial ischaemia reduces hospital time and expense: results of a randomized study (ROMIO). *J Am Coll Cardiol* 1996;**28**:25–33.
- 9 **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.
- 10 **Pozen MW**, D'Agostino RB, Selker HP, *et al.* A predictive instrument to improve coronary-care-unit admission practices in acute ischaemic heart disease. A prospective multicenter study. *N Engl J Med* 1984;**310**:1273–8.
- 11 **Panju AA**, Hemmelgarn BR, Guyatt GH, *et al.* The rational clinical examination. Is this patient having a myocardial infarction? *JAMA* 1998;**280**:1256–63.
- 12 **American College of Emergency Physicians.** Clinical policy: Critical issues in the evaluation and management of adult patients presenting with suspected acute myocardial infarction or unstable angina. *Ann Emerg Med* 2000;**35**:521–44.
- 13 **Fesmire FM**, Percy RF, Bardoner JB, *et al.* Usefulness of automated serial 12-lead ECG monitoring during the initial emergency department evaluation of patients with chest pain. *Ann Emerg Med* 1998;**31**:3–11.
- 14 **Fesmire FM**, Percy RF, Bardoner JB, *et al.* Serial creatinine kinase (CK) MB testing during the emergency department evaluation of chest pain: utility of a 2-hour deltaCK-MB of +1.6ng/ml. *Am Heart J* 1998;**136**:237–44.
- 15 **de Winter RJ**, Koster RW, Sturk A, *et al.* Value of myoglobin, troponin T and CK-MB(mass) in ruling out acute myocardial infarction in the emergency room. *Circulation* 1995;**92**:3401–7.
- 16 **Gibler WB**, Young GP, Hedges JR, *et al.* Acute myocardial infarction in chest pain patients with nondiagnostic ECGs: serial CK-MB sampling in the emergency department. *Ann Emerg Med* 1992;**21**:504–12.
- 17 **Hamm CW**, Goldman BW, Heeschen C, *et al.* 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**:1648–53.
- 18 **Kerns JR**, Shaub TF, Fontanarosa PB. Emergency cardiac stress testing in the evaluation of emergency department patients with atypical chest pain. *Ann Emerg Med* 1993;**22**:794–8.
- 19 **Kirk JD**, Turnipseed S, Lewis RL, *et al.* Evaluation of chest pain in low-risk patients presenting to the emergency department: the role of immediate exercise testing. *Ann Emerg Med* 1998;**32**:1–7.
- 20 **Gillum RF**, Fortman SP, Prineas RJ. International diagnostic criteria for acute myocardial infarction and stroke. *Am Heart J* 1984;**108**:150–8.
- 21 **Gibbons RJ**, Balady GJ, Beasley JW, *et al.* ACC/AHA guidelines for exercise testing: a report of the American College of Cardiologists/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). *J Am Coll Cardiol* 1997;**30**:260–315.
- 22 **Peacock WF**, Emerman CL, McEneaney ES, *et al.* Prediction of short- and long-term outcomes by troponin T levels in low-risk patients evaluated for acute coronary syndromes. *Ann Emerg Med* 2000;**35**:213–20.