Cost effectiveness of diagnostic strategies for patients with acute, undifferentiated chest pain

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Objective: Patients presenting to hospital with acute, undifferentiated chest pain have a low, but important, risk of significant myocardial ischaemia. Potential diagnostic strategies for patients with acute, undifferentiated chest pain vary from low cost, poor effectiveness (discharging all home) to high cost, high effectiveness (admission and intensive investigation). This paper aimed to estimate the relative cost effectiveness of these strategies.

Methods: Decision analysis modelling was used to measure the incremental cost per quality adjusted year of life (QALY) gained for five potential strategies to diagnose acute undifferentiated chest pain, compared with the next most effective strategy, or a baseline strategy of discharging all patients home without further testing.

Results: Cardiac enzyme testing alone costs £17,432/QALY compared with discharge without testing. Adding two to six hours of observation and repeat enzyme testing costs an additional £18,567/QALY. Adding exercise testing to this strategy costs £28,553/QALY. A strategy of overnight admission, enzyme, and exercise testing has an incremental cost of £120,369/QALY, while a strategy consisting of overnight admission without exercise testing is subject to extended dominance. Sensitivity analysis revealed that the results are sensitive to variations in the direct costs of running each strategy and to variation in assumptions regarding the effect of diagnostic testing upon quality of life of those with non-cardiac disease.

Conclusion: Observation based strategies incur similar costs per QALY to presently funded interventions for coronary heart disease, while strategies requiring hospital admission may be prohibitively poor value for money. Validation of the true costs and effects of observation based strategies is essential before widespread implementation.

Abbreviations: QALY, quality adjusted year of life; AMI, acute myocardial infarction; UA, unstable angina; CHD, coronary heart disease; CPOU, chest pain observation unit; EST, exercise stress test; NCP, non-cardiac pain
Strategies were eliminated if they were dominated—that is, if another strategy saved more QALYs for the same or lower cost. They were also eliminated if subject to extended dominance by a combination of two other strategies, that is, if their incremental cost effectiveness compared with the cheaper strategy exceeded the incremental cost effectiveness of the more expensive strategy.

**Study population**

The population was defined as 1000 patients presenting to hospital with acute chest pain unexplained by trauma or chest radiological findings, and;

1. No ECG changes diagnostic of AMI or UA;
2. Either risk factors for CHD or clinical features suggesting CHD (that is, patients at negligible risk of CHD are excluded);
3. No evidence of other serious abnormality requiring hospital admission.
4. No clinically obvious UA, defined as known CHD with prolonged or recurrent episodes of cardiac type chest pain.

These criteria were used to define the population for a prospective study of patients with acute, undifferentiated chest pain managed in the Northern General Hospital (NGH) CPOU. Similar definitions have been used elsewhere.”

Data from this study population were used for the model. The mean age was 54 years, 61% were male, and median time to presentation to hospital was three hours from onset of pain.

**Potential strategies**

The following strategies were considered:

0. Discharge all patients without additional testing
1. Cardiac enzyme testing at presentation
2. Observation until at least six hours after onset of pain then cardiac enzymes
3. As (2) above, but then followed by exercise stress test (EST) if blood tests are negative
4. Admit to hospital for 24 hours then cardiac enzymes. No EST before discharge
5. As (4) above, but then followed by EST if blood tests are negative

For each strategy, any patient with a positive test is admitted. If all tests are negative the patient is discharged.

**Data sources**

The following descriptions of the data sources and the estimates used in the model are by necessity brief. Further details and an outline of the decision tree are available from the authors.

The prevalence of AMI and UA were estimated to be 4% and 8% respectively, using empirical data from the NGH CPOU study, and review of CPOU literature. Studies identified by a recent literature review were searched for estimates of the sensitivity for AMI, specificity for UA and specificity of cardiac enzyme tests at presentation (strategy 1), after four hours of observation (strategies 2 to 3), and at 24 hours after the onset of pain (strategies 4 and 5). Diagnostic performance of EST was derived from a meta-analysis of studies. The calculated sensitivities and specificities of each strategy are outlined in table 1.

The immediate benefit of identifying patients with AMI/UA lies in providing hospital treatment to reduce short-term (30 day) mortality or progression to Q-wave infarction. Mortality was estimated to be 8% for treated NQW AMI and 6% for treated UA, while the infarction rate for UA was estimated to be 10%. We estimated that treatment would reduce mortality and progression to Q-wave infarction by 50% using data from studies of missed AMI, overviews of the treatment effects of aspirin, heparin, and β blocking drugs, and comparison of the prognosis for AMI/UA before and after the introduction of modern treatment. Estimates of untreated mortality and infarction rates were therefore double the corresponding treated rate. It was assumed that short-term mortality was zero for non-cardiac pain (NCP) regardless of any treatment given.

Effectiveness was expressed as discounted QALYs saved. This was assumed to be zero for those who died within 30 days. Patients with NCP were assumed to have the same annual mortality rate as the age adjusted, normal UK population. For patients with UA and AMI, survival over the first three years was estimated using data from the multicentre chest pain study. Following this the annual mortality was assumed to be 3.5 times the age and sex adjusted rate. Values of 23.24 years for NCP, 12.68 years for AMI, and 12.96 years for UA were obtained. After discounting at a rate of 6% per annum life expectancies were 13.08 years for NCP, 9.20 years for AMI and 9.33 years for UA. These values were quality adjusted, using health utility data from a study of patients attending the NGH CPOU, to give estimates of discounted quality adjusted life expectancy of 9.28 for NCP, 5.98 for AMI, and 6.06 for UA.

Unit costs for medical admission were obtained from published estimates, while unit costs for medical treatment were obtained from the British National Formulary (aspirin, β blocker, and subcutaneous heparin). Costs for cardiac enzyme tests (CK-MB (mass) or troponin) were estimated to be £5 per test, using data from the NGH pathology department. Costs for treating AMI and UA were estimated using data from patients admitted after assessment on the NGH CPOU. The costs of investigating false positive tests were estimated from data for patients admitted after CPOU evaluation. The cost of terminal care was estimated from published unit costs of death in A&E.

The direct costs of running each strategy were estimated by summing its constituent elements. The costs of initial A&E and assessment were assumed to be the same in all cases, regardless of strategy, so were not included in analysis. The direct cost of running strategy 0 was therefore assumed to be zero.

Any strategy that, by detecting cases of AMI or UA, increases the number of patients surviving will incur the cost of treating these survivors. The annual cost of managing CHD in Newcastle was estimated to be £1358 per patient (uprated for inflation). Over 13 years, discounted at a rate of 6% per annum, this produces a lifetime cost of £12 743 per patient.

One way sensitivity analyses were undertaken for costs, utilities, treatment effects, mortality rates, infarction rates, and prevalences. Each parameter was varied through a credible range of values to determine how much this changed the findings of the analysis. Finally, it is possible that false positive diagnosis may cause anxiety and reduce quality of life. Therefore the assumption that patient utility with NCP is unaffected by diagnosis was tested in sensitivity analysis.

Baseline estimates and the ranges for all sensitivity analyses are outlined in the appendix.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Sensitivity for AMI</th>
<th>Sensitivity for UA</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.45 (0.3–0.6)</td>
<td>0.10 (0.05–0.15)</td>
<td>0.95 (0.85–0.98)</td>
</tr>
<tr>
<td>1</td>
<td>0.85 (0.6–0.95)</td>
<td>0.20 (0.1–0.4)</td>
<td>0.95 (0.85–0.98)</td>
</tr>
<tr>
<td>2</td>
<td>0.85 (0.6–0.95)</td>
<td>0.75 (0.6–0.9)</td>
<td>0.75 (0.65–0.85)</td>
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<tr>
<td>3</td>
<td>0.98 (0.9–1.0)</td>
<td>0.50 (0.3–0.7)</td>
<td>0.95 (0.85–0.98)</td>
</tr>
<tr>
<td>4</td>
<td>0.98 (0.9–1.0)</td>
<td>0.75 (0.6–0.9)</td>
<td>0.75 (0.65–0.85)</td>
</tr>
</tbody>
</table>
RESULTS
Table 2 shows the results of the baseline analysis. The expected costs of strategy 0 reflect the costs of subsequent care of this population even if there is no diagnostic intervention. As the strategies increase in complexity, the expected costs increase. The QALYs gained by strategy 0 reflect the quality adjusted life expectancy of the population without diagnostic intervention. As the diagnostic sensitivity of the strategies increase, so do the QALYs gained. No strategy clearly dominated any other, although strategy 4 was subject to extended dominance. The incremental cost effectiveness of strategy 3, relative to strategy 2, is lower than the incremental cost effectiveness of strategy 4, relative to strategy 2. So, if one were prepared to pay the incremental cost per QALY required by strategy 4, it would make more sense to go one step further and pay for strategy 3, which gives you more additional QALYs at a lower incremental cost per QALY. Table 3 shows the results with strategy 4 excluded. There is now a stepwise progression of increasing incremental cost effectiveness relative to the preceding strategy. The estimates of incremental cost effectiveness for each strategy were comparatively insensitive to variation of — prevalence of AMI or UA; utilities of AMI or UA; mortality estimates; treatment effect estimates; costs of treatment of AMI and UA; cost of terminal care; and cost of long term treatment of survivors. Results were sensitive, however, to variations in the cost of each strategy, the cost of ruling out cardiac disease and, in particular, the effect of diagnostic testing upon the utility of NCP. If, for example, it is assumed receiving a false positive diagnosis leads to reduced quality of life for the following three months, then strategy 3 is dominated. Conversely, assuming that true negative diagnosis has a beneficial effect (perhaps through “reassurance”), has a positive influence in favour of strategy 3. Variation in the cost of ruling out cardiac disease in those with false positive tests also principally affected the cost effectiveness of strategy 3.

DISCUSSION
The cost effectiveness of diagnostic strategies requires evaluation with the same rigour as therapeutic interventions. This is particularly true of acute chest pain, a common complaint with many potential diagnostic strategies to detect life threatening conditions that are amenable to treatment. Inefficient resource use in this situation will therefore have an important effect upon health service resource use.

This analysis has shown that strategies based on short periods of observation are likely to represent a more efficient use of resources than those requiring overnight admission. Strategies involving immediate cardiac enzyme testing alone (strategy 1); observation for two to six hours and repeat enzyme testing (strategy 2); and observation, repeat enzyme testing and exercise stress testing (strategy 3) have incremental cost effectiveness ratios similar to estimates for currently funded cardiovascular interventions. Whereas strategies requiring overnight hospital admission were either subject to extended dominance (strategy 4) or prohibitively expensive (strategy 5).

The combination of two to six hours of observation and exercise stress testing seems to be effective and reasonable cost effective. Yet this finding is sensitive to variation in the cost of providing the strategy, the cost of ruling out false positives, and the effect of false positive diagnosis upon quality of life. We have few empirical data to determine how accurate our baseline estimates and assumptions are. Therefore this strategy should be carefully evaluated in practice before widespread implementation is considered. In particular, we need to know more about the effect of test results upon individuals with NCP. Most patients with acute, undifferentiated chest pain have a non-cardiac cause. We need to know whether extensive diagnostic testing leads to greater reassurance through true negative tests or greater uncertainty through false positive tests.

We assumed that all patients in the population would undergo the strategy provided. However, in practice patients may be selected on the basis of their clinical features (and often the clinicians “gut feeling”) to one or other strategy or immediate discharge. No data exist to allow us to estimate the sensitivity and specificity of this approach. The sensitivity and specificity of clinical features are known to be suboptimal, but selection need not be perfect for this to be a cost effective alternative. Again, empirical data are needed to evaluate the role of clinician acumen in selecting patients for testing regimens.

We did not include estimates of the costs of litigation to the health service if patients with AMI are misdiagnosed and are sent home. Inclusion of such costs would be controversial. Firstly, they are uncommon and unpredictable and therefore

<table>
<thead>
<tr>
<th>Table 2 Results of baseline analysis</th>
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<tbody>
<tr>
<td>Strategy</td>
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</tr>
<tr>
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<td>1</td>
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<table>
<thead>
<tr>
<th>Table 3 Results of baseline analysis with strategy 4 excluded</th>
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</thead>
<tbody>
<tr>
<td>Strategy</td>
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<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>5</td>
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</table>
The study was undertaken as a dissertation for a Masters degree in health economics with an interest in cost-effectiveness analysis. The main purpose of the study was to assess the cost of various strategies for the diagnosis and treatment of chest pain, with particular emphasis on the effect of diagnostic testing, with or without exercise stress testing, on the cost-effectiveness of different interventions. The study was based on published data and included a review of the literature on the subject. The results showed that diagnostic strategies for acute, undifferentiated chest pain entailing observation and cardiac enzyme testing, with or without exercise stress testing, have similar cost-effectiveness ratios to currently funded cardiovascular interventions. Strategies requiring overnight admission for all patients seem to be poor value for money. Observational studies now require empirical validation and comparison with "real life" alternatives. The effect of diagnostic testing upon the health of those without cardiac disease and the direct costs of running the service are important determinants of cost effectiveness.

Contributors

The study was undertaken as a dissertation for a Masters degree in Health Services Research by SG and was supervised by NC.

References


Appendix

<table>
<thead>
<tr>
<th>Variable description</th>
<th>Baseline value</th>
<th>Range for sensitivity analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of AMI</td>
<td>4%</td>
<td>1–10%</td>
</tr>
<tr>
<td>Prevalence of UA</td>
<td>8%</td>
<td>5–20%</td>
</tr>
<tr>
<td>30 day mortality of untreated AMI</td>
<td>8%</td>
<td>2–14%</td>
</tr>
<tr>
<td>30 day mortality of untreated UA</td>
<td>6%</td>
<td>3–10%</td>
</tr>
<tr>
<td>30 day mortality of untreated NCP</td>
<td>Zero</td>
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<tr>
<td>Infarction rate of untreated AMI</td>
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<td>Treatment effect upon short term mortality of untreated AMI</td>
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<td>0.3–0.8</td>
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<tr>
<td>Treatment effect upon short term mortality of untreated UA</td>
<td>0.5</td>
<td>0.3–0.8</td>
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<tr>
<td>Treatment effect upon short term mortality of untreated NCP</td>
<td>0.5</td>
<td>0.3–0.8</td>
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<tr>
<td>Treatment effect upon infarction rate of UA</td>
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<td>0.3–0.8</td>
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<td>Quality adjusted life expectancy of death</td>
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<tr>
<td>Discounted, quality adjusted life expectancy after AMI</td>
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<tr>
<td>Discounted, quality adjusted life expectancy after UA</td>
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<td>Cost of running strategy 0</td>
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<td>Direct cost of running strategy 1</td>
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<td>Cost of treating AMI</td>
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<td>Cost of treating UA</td>
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<td>Cost of terminal care</td>
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<td>Cost of ruling out AMI/UA after false positive tests</td>
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<td>Long term cost of treating survivors with UA</td>
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