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Stress echocardiography in the district hospital setting: a cost-saving analysis

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Aims Accurate and cost-effective techniques are required for investigating patients experiencing chest pain, given the significant workload this patient cohort represents. We determined the cost impact of stress echocardiography compared with myocardial perfusion scintigraphy and coronary angiography in the investigation of patients with chest pain deemed unsuitable for exercise treadmill testing.

Methods and results A total of 200 patients with chest pain—with a low–intermediate probability of coronary artery disease—consecutively referred for stress echocardiography were recruited. Referring clinicians were asked which management strategy they would have chosen were the stress echocardiography service unavailable. The cost saving of stress echocardiography, an accuracy analysis, and adverse outcomes at 6 and 24 months follow-up were determined. The total cost attributable to the stress echocardiography service was £58 368. If unavailable, 78 (39%) patients would have been referred for angiography and 122 (61%) for perfusion scintigraphy at a cost of £56 316 and £42 090, respectively, with a total cost of £98 406. This represents a cost saving of £40 038.

Conclusion Stress echocardiography is a cost saving method for the investigation of chest pain in patients with low–intermediate risk of flow limiting coronary artery disease in the district hospital setting.

Keywords Stress echocardiography • Cost saving • Myocardial perfusion scintigraphy • Coronary angiography

Introduction

In spite of significant advances in medical care infrastructure, pharmacological therapy, and invasive management options, coronary artery disease remains the leading cause of mortality worldwide. One in five men and one in seven women die annually in the UK from coronary disease, a total of ~94 000 deaths.[1] There are almost 150 000 patients who suffer a myocardial infarction and 100 000 new cases of angina annually in the UK.[2] The economic impact of this disease burden is staggering. Coronary artery disease cost the National Health Service £3.2 billion in 2006, rising to a total figure of £9 billion for the UK economy when production losses due to mortality and morbidity are included.[3]

Against this financial backdrop, there is therefore considerable incentive to diagnose coronary artery disease before it leads to either significant morbidity or mortality. The information derived from first line tests should, therefore, allow efficient patient screening and thus risk stratification. A high degree of specificity and sensitivity are required in order to discriminate cardiac from non-cardiac chest pain. Stress echocardiography is a proven accurate, non-invasive, and relatively inexpensive technique for the detection and exclusion of coronary artery disease when performed by experienced operators. A normal stress echocardiogram portends an excellent prognosis[4–9] with an all-cause mortality rate of <1% per year. However, despite stress echocardiography being available for two decades, it is still highly under-utilized, with only 50% of hospitals in the UK able to perform stress echocardiograms and of those <20% perform more than 200 studies per year. A recent report from the British Cardiovascular Society Working Group[10] recognized the under-utilization of stress echocardiography in the evaluation of patients presenting with chest pain. Our study investigated the cost saving provided by the introduction of a stress echocardiography service into our hospital.

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Methods

Patient selection

The study was performed in the Poole District General Hospital (Dorset, UK) between December 2004 and December 2005, during which 200 patients consecutively referred for investigation of chest pain using stress echocardiography were recruited. Referrals for stress echocardiography were accepted from cardiologists or physicians at consultant level only. The patient group had a low to intermediate probability of coronary artery disease and had either undergone an inconclusive exercise treadmill test or were unsuitable for one. Reasons for treadmill testing being unsuitable included resting ECG abnormalities such as left bundle branch block or T-wave/ST-segment changes, inability to walk on a treadmill (e.g. arthritis, previous loss of lower limb) and 'inconclusive' tests, in which patients may have achieved target heart rate but at low workload (e.g. after just 3 min). One experienced operator, who allocated patients either to the exercise or dobutamine methods of stress, performed the stress echocardiogram studies. Full informed consent was obtained from all participants.

Stress echocardiography: practical protocol

Stress echocardiographic imaging acquisition protocols have been reported previously.[11–12] In summary, resting and stress images were obtained with patients placed in the left lateral decubitus position utilizing a Philips Sonos 7500 machine with digital loop stress echocardiography software. Routine apical four-, two-, and three-chamber views, as well as parasternal long- and short-axis views, were recorded.

In the case of exercise stress echocardiography, BRUCE protocol symptom-limited treadmill exercise testing was performed with images acquired immediately (within 90 s) after peak exercise. Early post-exercise images with the best endocardial definition were displayed alongside the corresponding baseline images. In patients in whom exercise testing was deemed not possible, dobutamine was infused peripherally in 3 min dose increments, starting from 10 μg/kg/min and increased to 20, 30, and 40 μg/kg/min. If no endpoint was reached, atropine was added to the continuing 40 μg/kg/min dobutamine infusion in six divided doses of 0.2 mg up to a maximum of 1.2 mg.

Endpoints were the achievement of 85% of age-predicted maximum heart rate; development of ischaemia (i.e. wall motion abnormality); achievement of peak dose (40 μg/kg/min of dobutamine + 1.2 mg atropine); or the occurrence of intolerable side effects. The stress images were then acquired and assessed in the same way as in the exercise stress protocol. In patients with poor echocardiographic images, a continuous intravenous infusion of a contrast agent was used (Sonovue®, Bracco Diagnostics, Italy) using a specific oscillating syringe pump (Bracco Diagnostics).

Resting left ventricular function was assessed categorically as normal or abnormal. Markers for previous infarction included detection of akinesis or dyskinesis on the resting images. Normal wall motion, or identical wall motion abnormalities to resting images, was used to denote the absence of reversible ischaemia, whereas new or worsening wall motion abnormalities in the immediate post-stress images were used to signify myocardial ischaemia.[13–14] For the purposes of our study, a positive SE was defined as evidence of any reversible wall ischaemia, irrespective of the extent of ischaemia and number of territories involved, and a negative study was defined by the absence of reversible ischaemia.

Cost analysis

The cost of stress echocardiography was calculated by incorporating the doctor's fee in performing study and interpretation, nurse and technician fees, consumables including contrast agent (one vial per test) and depreciation of the echocardiography machine. Identical methods were used to calculate the cost of a perfusion scintigraphy study and coronary angiogram. Additionally, we calculated the cost of subsequent coronary angiography required for patients with abnormal stress echocardiograms, if it was appropriate to investigate these patients further.

At the time of referral for stress echocardiography, the referring consultant (cardiologist or physician) was asked that if stress echocardiography were unavailable, which (if any) investigation would have otherwise been requested. These included:

(1) Coronary angiogram (£722.00)
(2) Myocardial perfusion scintigraphy (£345.00)
(3) None (£0.00)

We did not use national tariff costings for each test, as there is no tariff for stress echocardiography. We therefore calculated the local cost for each test. Our values correlate well with both previously published data[15] and, for those available, the national tariffs.[16] We were able to calculate the cost of investigating patients with chest pain using stress echocardiography as the first-line investigation and the subsequent requirement of coronary angiography if appropriate per annum. We then calculated the annual cost of investigating patients with chest pain using coronary angiography or myocardial perfusion scintigraphy. The difference between these two values allowed us to assess if the use of stress echocardiography in investigating patients with chest pain, compared with conventional methods, provides cost saving.

Adverse events follow-up

In patients reported as having a normal stress echocardiogram, the occurrence of major adverse cardiac events (defined as cardiac death, non-fatal myocardial infarction, and need for coronary revascularization) was assessed. This was obtained by reviewing medical records and contact with the patient's primary care physician via telephone to establish each patient's outcome. This was performed 6 months post stress echocardiography and was then repeated at 2 years. In patients reported as having evidence of an abnormal study (reversible ischaemia), subsequent coronary angiography and out-patient follow-up was reviewed and significant coronary disease was defined as presence of a stenosis of >50% severity, as judged by the performing cardiologist by visual assessment. In both groups, no patients were lost to follow-up.

Statistical analysis

Sensitivity was defined as the ability of the screening test (i.e. stress echocardiography) to correctly identify the presence of disease (i.e. coronary artery with an obstructive lesion of >50%). Specificity was defined as the ability of the screening test to identify correctly the absence of disease. The positive predictive value (PPV) was defined as the probability that the patient has disease if the test is positive. Negative predictive value (NPV) was defined as the probability that a patient will be disease-free if the test is negative.

Results

Patient demographics

Ninety-two patients were men (46%) and 108 were women. The mean age was 62 years (age range 33–86 years).

Cost analysis

Stress echocardiography available

The cost of 200 patients undergoing stress echocardiography at our unit was

$$200 \times £133.00 = £26\,600.$$

Of these, 44 (29.5%) patients subsequently required coronary angiography at a cost of

$$44 \times £722.00 = £31\,768.$$

In total, therefore, the annual cost of investigating 200 patients with chest pain using stress echocardiography and subsequent coronary angiography was

$$£26\,600 + £31\,768 = £58\,368$$

Stress echocardiography unavailable

From the questionnaire it was possible to calculate the cost if stress echocardiography had been unavailable. We found that 78 patients (39%) would have undergone coronary angiography at a cost of

$$78 \times £722.00 = £56\,316$$

One hundred and twenty-two patients (61%) would have undergone perfusion scintigraphy at a cost of

$$122 \times £345.00 = £42\,090$$

Therefore, the total annual cost of investigating 200 patients with chest pain if stress echocardiography is unavailable is

$$£56\,316 + £42\,090 = £98\,406.$$

The annual cost saving per 200 patients using stress echocardiography for investigation of chest pain is

$$£98\,406 - £58\,368 = £40\,038.$$

These cost savings are summarized in *Table 1*.

Table 1 Cost saving using stress echocardiography during the investigation of 200 patients with chest pain

Stress echocardiography available	
Stress echo cost for 200 patients	£26 600
44 subsequent coronary angiograms	£31 768
Total cost attributable to stress echo	£58 368
Stress echocardiography unavailable	
Coronary angiography	£56 316
Myocardial perfusion scintigraphy	£42 090
Total	£98 406
Total cost saving per 200 patients	£40 038

Accuracy analysis

Images suitable for interpretation were obtained in all 200 patients. One hundred and forty-one patients were reported as having a normal stress echocardiogram and there was a 100% follow up success rate. At 6 months, there was one death unrelated to cardiovascular disease (bronchopneumonia). At 2 year follow-up, four patients who had been event-free at 6 months had been diagnosed with coronary disease. There had been one death due to carcinoma of the colon. Therefore, in total, 137 of 141 patients with a normal stress echocardiogram had no adverse cardiovascular events during a 2-year follow-up.

A total of 59 patients had an abnormal stress echocardiogram and, of these, 15 patients were considered unsuitable for subsequent coronary angiography due to age, co-morbidities, or patient wishes for medical treatment only. These patients were excluded from the accuracy assessment of stress echocardiography. This meant that 44 of 59 patients who had abnormal stress test underwent coronary angiography and all 44 had coronary disease confirmed at angiography. Sensitivity, specificity, PPV, and NPV were 98, 100, 100, and 99%, respectively.

Discussion

Over the past two decades there has been an explosion in the use of stress tests, and in particular stress imaging tests, for the evaluation of patients with chest pain. The current socioeconomic factors require that this expenditure improves patient outcomes as efficiently as possible.

We calculated the annual cost saving provided by introduction of this service into our dept was £40 038 per 200 patients studied. The increased use of stress imaging tests is unlikely to have lead to an increase in costs due to inappropriate tests as all requestors of tests had to stipulate what test they would otherwise have done. There were no responses in the 'no test' group, suggesting that a test would always have been requested.

Our study findings are in keeping with previously published work on the cost-effectiveness of stress echocardiography, especially when compared with exercise treadmill testing.[15,17–18] The prognostic use of stress echocardiography has also been previously established in several different patient populations, including hypertension,[19–20] left bundle branch block,[21] left ventricular dysfunction,[22] and atrial fibrillation.[23] In spite of this, the exercise ECG continues to be used ubiquitously and this is probably due to a combination of the huge clinical experience with the test,[24] its relative very low cost and also widespread availability.

MPS has similar indications and accuracy to SE and a recent meta-analysis[25] demonstrated comparable prognostic use. A study in over 9000 patients suggested that the most cost-effective strategy would support use of SE in low-risk patients with chest pain with suspected coronary disease, whereas high-risk patients would benefit from referral for MPS imaging.[26] Despite these findings and a wealth of other published data, current guidelines from the National Institute for Health and Clinical Excellence (NICE) recommend nuclear imaging as the first-line non-invasive investigation in such patients and make no mention of SE.[27] Furthermore, SE has several advantages over MPS. Nuclear imaging involves significant doses of radiation.[28] As radiation damage is cumulative,

a strategy involving non-ionizing imaging is highly desirable in patients who may subsequently undergo, or already have undergone, coronary angiography.[29] SE also has several advantages over MPS like shorter imaging time, portability, lower cost, and availability of ancillary information about cardiac structures (e.g. valves, pericardium).[30]

A workforce document published by the British Cardiovascular Society in 2005[31] suggested that a 24-fold increase in non-invasive imaging cardiologists was required nationally and that this could result in an estimated 50% reduction in referrals for coronary angiography. One of the challenges to realizing the aim of stress echocardiography expansion across the UK remains the dearth of adequately trained cardiologists. National workforce planning suggests the need for 11–15 echocardiography consultants per million population, but it remains rare for a hospital to employ a specialist in echocardiography.[32] MPS thus seems more widespread compared with stress echocardiography due to both long-standing experience with nuclear imaging and a relative lack of physicians capable of performing stress echocardiography, leading to fewer patients being investigated by stress echocardiography.

Limitations

All stress echocardiogram studies were performed and interpreted by a sole operator. Inter-observer variability in stress echocardiography has previously been reported[33] and thus independent image analysis by more than one expert would be preferable. We did not include the initial setup costs of the stress echocardiography service, the required training, testing, and certifying physicians in stress echocardiography, but rather examined running costs. Although initial setup costs would impact on cost-effectiveness, overall these were considered minimal in comparison with the working lifetime cost saving. The extremely high sensitivity and specificity we found is likely to be related to the fact that a sole experienced operator performed all of the studies and also the small numbers involved. It is to be expected that as numbers increase and registrars/sonographers are trained in stress echocardiography, the accuracy of the test would be affected.

Of the 59, 15 (25.4%) patients who had an abnormal stress echocardiogram were excluded from the analysis as they did not proceed to coronary angiography. Although this is a limitation of the analysis, it actually reflects real practice as many patients are not referred for further testing due co-morbidities. However, it is reassuring that the 44 of 59 (74.6%) patients who were analysed showed a sensitivity of 98% for stress echocardiography. Cost-effectiveness analyses in themselves have difficulties that should be acknowledged[34] (and are outside the scope of this article). Nonetheless, several studies, as referenced above, have confirmed the accuracy, safety, and cost-effectiveness of stress echocardiography, especially in comparison with exercise ECG testing. The cost and accuracy of myocardial perfusion scintigraphy, including onward referrals for coronary angiography, was not calculated as this was beyond the focus of the study. However, any additional coronary angiography accrued by perfusion studies would only increase further the relative cost saving of stress echocardiography.

Finally, the authors recognize that they did not address whether the use of stress echocardiography in the investigation of chest pain was able to reduce mortality when compared with other tests. However, while this is an important question, it would have required a much larger sample size and is beyond the remit of this study.

In conclusion, our study indicates that the use of stress echocardiography in the district general hospital setting, to investigate patients with low–intermediate probability of flow limiting coronary artery disease, saves cost when compared with myocardial perfusion scintigraphy and coronary angiography. This has led to an increase in non-invasive investigation of chest pain in our hospital, an approach in accord with national aims to expand the utilization of stress echocardiography.

Conflict of interest: none declared.

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