Cost-effectiveness of myocardial perfusion imaging in the evaluation of patients with known or suspected coronary artery disease

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Substantial evidence supports the clinical application of myocardial perfusion imaging (MPI) in patients with suspected or chronic coronary artery disease (CAD). Current recommendations encourage the use of MPI for prognostication and as a ‘gatekeeper’ to cardiac catheterization. Moreover, recent economic evidence indicates that MPI, as a result of improved diagnosis and risk estimation, provides substantial cost savings when compared with other competitive modalities for suspected and known CAD. Thus, on the basis of both clinical and cost considerations, MPI is increasingly viewed as a cost-effective, non-invasive test that can be used to optimize management in patients with CAD.

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Introduction

The availability of new treatments and technologies has led to dramatic improvements in the diagnosis and risk stratification of patients with known or suspected coronary artery disease (CAD), in turn resulting in reductions of 35–50% in mortality from atherosclerotic disease. However, these advances in new technology coupled with increased use of medical services and an ageing population have also led to an extraordinary increase in the costs of care in Western Europe and the U.S.A.

Given the current climate of rationalization and containment of healthcare costs, clinical and economic analyses are advocated to assess the quality of healthcare and identify optimal methods for assessment of alternative diagnostic strategies for allocation of scarce resources. Cost-effectiveness analysis uses a societal perspective to identify the cost of alternative healthcare testing choices and compare the economic and clinical incremental value of each test. This mirrors the clinical decision-making process, in which clinicians must weigh test choices by considering whether the incremental value of a referral justifies the use of the test.

Types of cost analysis

Three types of cost analysis are commonly used: cost minimization analysis, cost-effectiveness analysis and cost-benefit analysis. Cost minimization of savings is defined as the lowest cost strategy given similar outcomes between comparative tests. Using incremental cost-effectiveness analysis, a test is judged cost-effective compared with another if costs are lower with equivalent outcome or if outcome is markedly improved. A dominant strategy results when a test is both lower in cost and improves outcome. In a cost-benefit analysis, two tests are compared on the basis of total costs, including the costs of resources used and outcomes, with an incremental value less than zero indicative of a favoured strategy.

Defining the clinical effectiveness of myocardial perfusion SPECT imaging

Two critical factors help to establish the quality of single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI): (1) the incremental value of myocardial perfusion and function data, and (2) the ability of the test to provide prognostic value for risk stratification. Numerous studies have shown that the incremental value of MPI is between 10% and 50%, with greater increments in subsets of patients where testing is most effective, such as in patients at intermediate risk, pre-operative in evaluation in vascular
surgery patients, stable chest pain patients, women and the elderly[12,13]. Risk stratification is increasingly seen as the mainstay for assessing test accuracy. For non-invasive testing populations, a normal or low-risk MPI result is associated with <1% risk of major cardiac events (including death or myocardial infarction [MI]) for up to 2 years post-testing, which in turn implies low cost of care (Fig. 1). All patients with normal scans are considered at low-risk and rarely require referral for cardiac catheterization. In a recent review, between <3% and 5% of patients with normal scans required cardiac catheterization.[16]

The frequency of false-positive and false-negative studies also requires consideration. A false-negative test result is an untoward event in patients with a low-risk scan including, for example, admission for an acute coronary syndrome. A false-positive test result includes subsequent referral to coronary angiography following abnormal perfusion results. The rate of false-negative test results for myocardial perfusion SPECT is exceedingly low. The false-positive test rate for dual isotope myocardial perfusion SPECT is about 20–25%, similar to that reported for echocardiographic wall motion abnormalities.[17] A further reduction in the false-positive rate is possible with the inclusion of regional wall motion and thickness as well as left ventricular ejection fraction.[16] Both false-positive and false-negative test results are considered cost waste. A recent review of the cost implications of cost waste showed that the 5-year cost of care was US$1804 less for stress MPI than for echocardiography.[17]

The costs of care also increase in association with the level of risk based on the MPI scan and the underlying risk of CAD in the population. Further differentiation of risk is affected by the extent and severity of perfusion abnormalities. The annual risk of cardiac death or MI increases from 3.5% in patients with mild perfusion abnormalities to 6.9% in patients with severe perfusion abnormalities.[14]. Therefore, in order to contain healthcare costs using risk-based management strategies, intensive care (including optimal medical therapy and consideration of cardiac catheterization) is focused on high-risk patient subsets (e.g. multivessel perfusion abnormalities, ejection fraction <45%). From this analysis, high-risk patients require considerable resources for optimal care (i.e. high cost) (Fig. 1). However, the high cost of care is justified due to the greater frequency of coronary disease and the ability to provide life-saving treatment. Thus, the expenditure is worth the added cost due to the benefit of improved life expectancy. Similar findings are noted with measures of left ventricular ejection fraction.[16].

Cost effectiveness analysis

The recently published ACC/AHA/ASIM/ACP guideline[12] for stable chest pain patients encourages the use of nuclear imaging as a ‘gatekeeper’ to the cardiac catheterization laboratory. Evidence of provocative ischaemia with stable chest pain symptoms helps to identify patients with a greater likelihood of obstructive disease.

Two recent multicentre registries have examined the economic value of the conservative non-invasive testing strategy compared with direct catheterization for stable patients[18,19]. In the U.S.A. and many other Western countries, these patients are commonly referred directly for coronary angiography, although such practice is often unsubstantiated by national guidelines for cardiac catheterization[12]. Whilst a direct catheterization approach is acceptable for patients with unstable symptoms, this invasive diagnostic procedure is not without risk in lower risk, stable patients. The ACC catheterization database of 700 hospitals has indicated a 1% risk of procedural complications (including death, haemorrhagic complications or acute infarction) in such patients.

The Economics of Myocardial Perfusion Imaging in Europe (EMPIRE) study[18] evaluated the economic implications of four diagnostic testing strategies in 396 patients from eight hospitals in the U.K., France, Italy and Germany (Table 1). Substantially lower diagnostic and 2-year costs of care were reported when a more

![Figure 1 Optimal risk stratification in the inpatient and outpatient setting.](https://springer.com/)

<table>
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<th>Table 1 Diagnostic testing strategies evaluated in the Economics of Myocardial Perfusion Imaging in Europe (EMPIRE) study[18]</th>
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<td>Strategy</td>
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conservative, non-invasive approach was adopted compared with direct referral to coronary angiography (Fig. 2). Two-year costs ranged from 4022 to 4626 Euros for the non-invasive strategies resulting in cost savings of 23–34% compared with direct catheterization testing. Similarly, cost savings of 22–55% were reported when catheterization was limited to patients with evidence of moderate-to-severe perfusion abnormalities on the stress MPI scan (CSMC Study)\(^1\) (Table 2).

The Economics of Noninvasive Diagnosis (END) multicentre study\(^1\) compared the clinical and economic outcomes of a direct catheterization approach with initial stress MPI followed by coronary angiography in the setting of provocative ischaemia in 11249 stable chest pain patients followed for 3 years. Consistent with current ACC/AHA guidelines for percutaneous coronary interventions, patients with Canadian Cardiovascular Society Class I or II angina (i.e. mild-to-moderate chest pain) were required to have evidence of moderate-to-large areas of ischaemia subtending a significant coronary stenosis for a class I indication for an interventional procedure. Both cohorts were matched for pre-test likelihood of cardiac survival to ensure comparability. Thus, if outcomes were similar between the two cohorts, any cost differences could be attributable to excessive variation in treatment practices and opportunities for cost savings.

![Graph](https://example.com/graph.png)

**Figure 2** 2-Year costs of care for varying diagnostic testing strategies — results from the EMPIRE\(^1\) and END\(^1\) studies. END stable chest pain patients include intermediate risk patient costs only.

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<th>Study</th>
<th>Range of cost savings (%)</th>
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<tr>
<td>CSMC(^1)</td>
<td>22–55</td>
</tr>
<tr>
<td>EMPIRE(^1)</td>
<td>23–34</td>
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<tr>
<td>END(^1)</td>
<td>30–41</td>
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*Selective catheterization, if evidence of demonstrable ischaemia.\)

The two cohorts had similar 3-year event rates (cardiac death or MI); however, using a cost minimization approach, the lowest cost strategy for diagnosis and 3-year costs of care was for using initial stress MPI followed by selective catheterization, with cost savings of 30–41% over the 3-year follow-up period (Fig. 2, Table 2). The significantly greater costs of care for the direct angiography cohort were driven by greater utilization of percutaneous coronary interventions (particularly in patients with intermediate coronary stenosis). In comparison, patients with normal or low-risk MPI results rarely proceeded to angiography. A similar pattern of clinical and economic results was noted for subset analysis of women\(^2\).

**Conclusion**

The results of the EMPIRE\(^1\) and END\(^1\) studies are consistent with an ever-increasing body of evidence\(^2,23\) suggesting conservative medical management to be a viable alternative to invasive treatment strategies. Non-invasive testing has increasingly been at the core of these more conservative management strategies. There is substantial evidence to support clinical application of MPI in patients with both suspected and chronic CAD so as to provide prognostic information to assist in the clinical decision-making process. Moreover, recent economic evidence indicates that MPI is also a very competitive modality for routine testing in suspected and known CAD. It is anticipated that ongoing trials in patients with stable chest pain (COURAGE), heart failure (IMAGING-HF), diabetes (DIAD) and post-myocardial infarction (INSPIRE) will provide additional evidence to support the use of MPI.

**References**


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