Cardiac risk assessment before non-cardiac surgery

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Received 28 August 2012; accepted after revision 13 November 2012; online publish-ahead-of-print 2 January 2013

Cardiovascular events account for half of the deaths related to non-cardiac surgery. Identification of a patient’s risk and perioperative management appropriate to that risk is important to optimize the clinical outcome of surgery. Key concepts of preoperative cardiac risk assessment are contained within American and European guidelines. Risk indices stratify patients according to clinical and surgery-specific predictors. The most widely used is the Lee index; however, all have limitations. Patients at intermediate and high risk following risk index stratification and assessment of functional capacity require further non-invasive assessment to detect myocardial ischaemia using, for instance, exercise electrocardiography, myocardial perfusion scintigraphy, or stress echocardiography. It can be difficult, however, to decide which technique and predictor is most effective and local practice differs. Invasive coronary angiography is not recommended unless it would be performed in the absence of surgery. Appropriate pain management should be considered in all patients and beta-blockade may improve the outcome in intermediate- and high-risk patients. Identifying patients with risk factors or previously undiagnosed coronary artery disease enables the preoperative cardiac risk assessment to guide long-term treatment.

Keywords
Risk assessment • non-cardiac surgery

Introduction

Perioperative morbidity and mortality due to coronary artery disease (CAD) is an important complication of non-cardiac surgery. In the USA ~27 million patients undergo non-cardiac surgery annually,1 with 50 000 suffering a post-operative myocardial infarction (MI).2 Cardiovascular events account for approximately half of all deaths related to non-cardiac surgery.3,4 The Preoperative Ischaemic Evaluation (POISE) trial reported perioperative mortality for non-cardiac surgery to be 2.7% (226/8351) with 1.6% (133/8351) having a cardiovascular cause.5 In addition to underlying cardiac pathology, systemic factors, such as pain, increased catecholamines, and hypercoagulability, contribute to perioperative risk since they can influence oxygen supply and demand resulting in myocardial ischaemia.6 Appropriate perioperative management reduces cardiac events such as non-fatal MI, heart failure, and cardiac death and so it is important to identify risk before surgery.

Mukherjee and Eagle7 identified eight steps for preoperative cardiac risk stratification reflected by American College of Cardiology/American Heart Association (ACC/AHA)8 and European Society of Cardiology (ESC)9 guidelines. The steps are: clinical evaluation, surgery-specific risk, functional capacity, non-invasive and invasive testing as required, medical therapy, perioperative care and surveillance, and long-term therapy.

Clinical evaluation and surgery-specific risk

Many predictors of perioperative cardiac events have been identified although none can be used in isolation because cardiac events can have a number of underlying causes. Consequently, a risk index should include important predictors that identify risk such as demographics, clinical, electrocardiographic (ECG), biochemical, and surgery-specific factors. Well-known indices include those of Goldman et al.,9 Detsky et al.,10 (which includes cardiac symptoms), and Lee11 (the revised cardiac risk index, Table 1).

The Lee index is the most widely used of the three8,12 but all have their limitations. Although the Goldman index has a negative predictive value (NPV) of 96.8% its positive predictive value is only 21.6%.12 The data for the Lee index accrued from non-emergency surgery are not generalizable to higher risk emergency surgery and it is not representative of the general surgical population as selection bias meant that the study population was predominantly orthopaedic (35%), vascular (21%), and thoracic (12%). The
index also stratifies all surgical procedures as either high risk or not high risk. Although a simple index is desirable, dichotomizing variables achieves simplicity at the expense of accuracy. It also does not consider other well-evidenced risk factors of CAD such as age, cholesterol, hypertension, smoking, and gender, which may identify patients who have unidentified CAD. Age, which is excluded from the Lee index, is an important risk factor because of the ageing population in which CAD, surgical procedures, and surgical complications occur.13 Surgery-specific risk is an important indicator, yet all three indices only include high-risk procedures. Boersma et al.14 analysed the Lee index’s ability to predict cardiovascular death in a retrospective cohort of patients who had undergone non-cardiac surgery. When additional surgical information was added to stratify patients, prognostic accuracy measured as the C statistic rose from 0.63 to 0.79 (where 0.5 indicates no predictive value and 1.0 perfect predictive value), and further to 0.85 when age was included. This model depicted in the ESC guidelines (Erasmus model) is clearly a better risk discriminator.3,15 Surgery-specific risk is an important indicator, yet all three indices only include high-risk procedures.

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Functional capacity
Functional capacity is an important perioperative and a long-term prognostic indicator of cardiac events.27,8 Exercise testing is an objective assessment of functional capacity, but it can also be assessed by a self-administered questionnaire. The Duke Activity Status Index correlates well with peak oxygen uptake and functional capacity17 and it is an effective alternative to treadmill testing.2 Less than four metabolic equivalent of tasks (METs) is poor functional capacity and hence high risk, 4–10 METs are moderate risk, and ≈10 METs are good functional capacity with low risk. However, although functional capacity is an effective prognostic indicator in thoracic surgery, it may be weaker for other surgery. It is also important to distinguish between cardiovascular functional capacity and other limitation, for example, in a patient awaiting orthopaedic surgery. This highlights the importance of not using a single prognostic indicator for risk assessment.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Revised cardiac risk index, adapted from Lee11</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lee index</strong></td>
<td></td>
</tr>
<tr>
<td>1. High-risk surgical procedures</td>
<td>Intraperitoneal</td>
</tr>
<tr>
<td>2. History of ischaemic heart disease</td>
<td>Intrathoracic</td>
</tr>
<tr>
<td>3. History of congestive heart failure</td>
<td>Suprainguinal vascular</td>
</tr>
<tr>
<td>4. History of cerebrovascular disease</td>
<td>History of myocardial infarction</td>
</tr>
<tr>
<td>5. Preoperative treatment with insulin</td>
<td>History of abnormal exercise ECG</td>
</tr>
<tr>
<td>6. Preoperative serum creatinine &gt;2.0 mg/dL</td>
<td>Current complaint of chest pain considered secondary to myocardial ischaemia</td>
</tr>
<tr>
<td>Risk of major cardiac event (each risk factor is assigned one point)</td>
<td>Use of nitrate therapy</td>
</tr>
<tr>
<td>Points</td>
<td>ECG with pathological Q-waves</td>
</tr>
<tr>
<td>0</td>
<td>History of congestive heart failure</td>
</tr>
<tr>
<td>1</td>
<td>Pulmonary oedema</td>
</tr>
<tr>
<td>2</td>
<td>Paroxysmal nocturnal dyspnoea</td>
</tr>
<tr>
<td>3 or more</td>
<td>Bilateral rales or S3 gallop</td>
</tr>
<tr>
<td></td>
<td>Chest radiograph showing pulmonary vascular redistribution</td>
</tr>
<tr>
<td></td>
<td>History of transient ischaemic attack or stroke</td>
</tr>
<tr>
<td>Class</td>
<td>Risk (%)</td>
</tr>
<tr>
<td>I</td>
<td>0.4</td>
</tr>
<tr>
<td>II</td>
<td>0.9</td>
</tr>
<tr>
<td>III</td>
<td>6.6</td>
</tr>
<tr>
<td>IV</td>
<td>11</td>
</tr>
</tbody>
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Definition of major cardiac event includes: myocardial infarction, pulmonary oedema, ventricular fibrillation, primary cardiac arrest, and complete heart block.
Imaging and other tests

Clinical assessment can rule out the need for further testing in low-risk patients, but those at intermediate and high risk may need further testing (Figure 1). The aim of non-invasive testing is to assess three prognostic indicators of left ventricular (LV) dysfunction, myocardial ischaemia and valve dysfunction.3

Radionuclide ventriculography

LV dysfunction can be assessed by echocardiography, radionuclide ventriculography (RNV), myocardial perfusion scintigraphy (MPS), magnetic resonance imaging (MRI), and X-ray computed tomography (CT).3 RNV can measure the left ventricular ejection fraction (LVEF) accurately and reproducibly, although all of the other techniques have been used in this setting.

Pasternak et al.18 used RNV in 50 patients with and without clinical evidence of CAD undergoing elective aortic aneurysm repair to assess the predictive value of the EF for perioperative MI and death. The patients were stratified by the EF into three groups: Group 1 (56–85%), Group 2 (36–55%), and Group 3 (27–35%). No patients in Group 1 had a perioperative MI, compared with 20% in Group 2 but with no deaths, and 80% with one cardiac arrest and one cardiac death in Group 3. However, the numbers were small, particularly in Group 3 with only five patients.

Kertai19 compared the predictive power of ECG, RNV, MPS, and stress echocardiography in patients undergoing major vascular surgery (Figure 1). Eight studies using RNV carried out between 1983 and 1989 found a sensitivity of 50% and specificity of 91% for perioperative non-fatal MI and cardiac death in patients with the LVEF <35%.

Baron et al.20 found that the LVEF was only useful for predicting subsequent heart failure and, although several early studies verified these data, others did not.7 In earlier studies small sample sizes and retrospective study designs decreased their validity. There is therefore conflicting evidence on the value of the LVEF for predicting perioperative events.

Exercise ECG

Kertai19 found a low sensitivity, specificity, and positive predictive value of the exercise ECG in vascular patients (74, 69, 10% respectively) but a high negative predictive value of 98%.

McPhail et al.21 and Cutler et al.22 reported that if a patient was able to reach 85 or >75%, respectively, of their predicted maximum heart rate they were at low risk of complication.

The exercise ECG may therefore be useful for detecting low-risk patients. However, many patients are unable to complete an exercise stress test for non-cardiovascular reasons, such as those awaiting orthopaedic and neurological surgery, patients with peripheral vascular disease and the elderly.2,7 In these cases pharmacological stress MPS can be useful.

Myocardial perfusion scintigraphy

MPS is a well-validated method of detecting and quantifying myocardial function, scarring, and ischaemia (Figure 2). Boucher et al.23 used MPS to assess patients with suspected CAD undergoing non-emergency vascular surgery. Clinical factors were not useful indicators but patients with inducible ischaemia had an increased risk of cardiac events compared with those without.

Leppo et al.24 found that 33% (14/42) of patients with inducible ischaemia suffered a non-fatal MI or perioperative cardiac death, compared with 2% (1/47) of patients without (P < 0.001).

Vanzetto et al.25 found that the presence and amount of inducible ischaemia correlated with the risk of cardiac events and that MPS was superior to clinical variables alone, although ECG abnormalities and a history of MI were also good indicators.

Eagle et al.26 also found the combination of clinical factors and MPS to be accurate indicators of outcome and these results have been confirmed in numerous studies and meta-analyses.3,27 Thus a strategy of initial clinical assessment with selective MPS may lead to a reliable assessment of risk while minimizing the need for further tests and radiation exposure.4

The high sensitivity and very high NPV of normal MPS (97–100%)2,8,13 mean that the probability of an event in a person with a normal scan is very low.16 However, most studies have been in patients undergoing peripheral vascular surgery and the accuracy of MPS in other forms of surgery is less clear.

Stratmann et al.28 studied the prognostic accuracy of MPS in patients undergoing non-vascular surgery and found that patients with a normal MPS had low risk of events and the finding has been confirmed by Wong et al.29 in patients undergoing kidney transplantation. ECG-gated MPS, which provides information on ventricular function as well as myocardial ischaemia, has also been found to be a useful prognostic indicator.30

In assessing the risk of future coronary events in patients with stable CAD, the ischaemic burden assessed by MPS is related to risk, with extensive ischaemia associated with a higher risk than limited ischaemia.31 Patients with >10% ischaemic burden
have lower event rates with revascularization than with medical therapy, and patients in whom the ischaemic burden can be reduced, either by medical therapy or by intervention, are at reduced risk. There is no evidence whether the same concepts are relevant to perioperative risk although it is reasonable to assume that they do.

**Stress echocardiography**

Dobutamine stress echocardiography (DSE) is able to assess LV function at rest, heart valve abnormalities, and myocardial ischaemia (Figure 3). Several studies and meta-analyses have found it to be a good prognostic indicator in vascular and non-vascular
surgery with a high NPV (90–100%), comparable with MPS. Poldermans et al. found the presence of new wall motion abnormality to be a powerful prognostic indicator and subsequent studies have also shown the extent of this abnormality to be important. Pasquet et al. found the sensitivity of DSE to be comparable with MPS but specificity to be superior. Kertai found DSE to have the highest sensitivity of the six modalities analysed (85%) and significantly superior to MPS although Shaw et al. in a meta-analysis of 15 studies related to vascular surgery found them to be comparable.

Other imaging techniques

MRI can detect inducible perfusion abnormalities and is a strong predictor of perioperative events with a sensitivity of 91% (95% CI: 88–94%) and specificity 81% (95% CI: 77–85%). CT coronary calcium scoring and CT coronary angiography may also be good indicators, but the literature assessing these techniques is small and their true value is unclear. A recent study has shown that the assessment of coronary calcium adds additional prognostic value to MPS for predicting cardiac events after non-cardiac surgery, although the majority of events were post-operative rather than perioperative.

Invasive procedures

Coronary angiography and revascularization with percutaneous coronary intervention (PCI) or coronary artery bypass grafting is not recommended for risk reduction before non-cardiac surgery as it causes unnecessary delay and exposes the patient to the risk of the additional procedure. Randomized control trials have shown PCI before elective vascular surgery does not reduce perioperative complications. This may be because any potential benefit of intervention is counterbalanced by its drawbacks such as delay to planned surgery and anti-platelet therapy required for PCI. Revascularization is, therefore, normally reserved for patients with urgent or unstable conditions such as unstable angina, high-risk disease or angina unresponsive to medical therapy.

Medical therapy and perioperative surveillance

It is now known that prophylactic glyceryl trinitrate does not improve the outcome in non-cardiac surgery, but other treatments may be helpful. Beta-blockers reduce oxygen consumption during the perioperative catecholamine surge and have other cardio-protective effects. Their benefits have been shown in several meta-analyses. The Dutch Echographic Cardiac Risk Evaluating Applying Stress Echo (DECREASE) trial showed fewer cardiac events with betablockade in intermediate-risk patients undergoing vascular surgery. Mangano et al. compared atenolol with placebo in a study of 200 patients with or at risk of CAD undergoing non-cardiac surgery (vascular and non-vascular) and found fewer events and reduced mortality with atenolol, with the benefit persisting for 2 years. However, other trials including the PeriOperative Beta-BlockadE (POBBLE) trial and Diabetes Postoperative Mortality and Morbidity (DIPOM) trial do not support these findings. The POISE trial showed more hypotension and stroke with beta-blockade in low-risk patients suggesting that beta-blockade should be reserved for high- and intermediate-risk patients and those already receiving treatment. Lindenaier et al. also found the benefit of beta-blockade to be greater with higher risk and recommended that harm outweighed benefit in low-risk patients. However, most data on beta-blockers are observational and randomized control trials are required for more clear evidence.

Statins (because of their lipid-lowering and pleiotropic effects) and the α2 agonist clonidine decrease cardiac events and improve survival during non-cardiac surgery. Statins may involve hypercoagulability, catecholamine surges, and other stresses. Anticoagulants and effective pain management, such as epidural or spinal opiates, decrease these responses and improve the outcome, although randomized control trials are lacking. Surveillance for perioperative MI includes regular ECGs that should be performed in all patients and serum biomarkers such as creatine kinase and troponin in patients with ECG changes or chest pain, but it is not known whether this is beneficial in stable patients who have undergone intermediate or high-risk procedures.
Conclusions

Perioperative cardiac morbidity and mortality is an important factor in patients undergoing non-cardiac surgery. The European and USA guidelines for cardiac risk assessment provide a framework for determining a patient’s risk and prognosis. Clinical and surgical risk and functional capacity are assessed to determine which patients will benefit from further testing and modification of perioperative management. If the surgery is not an emergency, there is the opportunity to consider postponing or cancelling surgery in high-risk patients or converting to lower risk procedures such as laparoscopic or less extensive surgery. In contrast, emergency surgery should not be delayed but should be undertaken with appropriate perioperative surveillance and management. Cardiac risk assessment can also identify patients who require long-term cardiovascular risk management.

We are left with some unknowns, however, and randomized control trials are needed to produce firmer evidence in some areas including whether either medical therapy or revascularization can significantly reverse high perioperative risk once identified, and the cost-effectiveness of perioperative risk assessment.

Funding

This work was supported by the NIHR Cardiovascular Biomedical Research Unit of Royal Brompton and Harefield NHS Foundation Trust and Imperial College London.

Conflict of interest: none declared.

References

Multimodality imaging in a rare case of tuberculous pericarditis

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A 26-year-old female presented with a 1-month history of chest pain, low-grade fever, and dyspnoea. The pericardial friction rub was audible. Electrocardiogram and chest X-ray were normal; mild mononcytosis, and slightly elevated C-reactive protein were observed. The separation of pericardial layers up to 6 mm due to non-homogeneous fluid (Panel A, arrows) was observed on the transthoracic echocardiography (Supplementary data online, Movie S1). Interventricular septum (IS) bounce towards RV during early diastole was evident. A 1.5 T cardiovascular magnetic resonance (CMR) SSFP sequence showed irregularly thickened (up to 7 mm) pericardia, with a small amount of fluid in between (Panel B, arrows; Supplementary data online, Movie S2). On a T2 fat-sat sequence, a hyperintense signal in the pericardia, corresponding with oedema (Panel C, arrows, arrowheads point to the fluid), was observed. LGE showed mild pericardial enhancement (Panel D, arrows) with a hypointense effusion signal in between (Panel D, arrowhead). The pericardia had irregular fine filling defects that projected into an effusion (compatible with granulomatous pericarditis). Pronounced mediastinal lymphadenopathy (Panel E, arrows), bilateral pleural effusions, and slight dilatation of the pulmonary artery (Panel E) were observed on T2 haste images. A chest CT was consistent with previous findings and showed no signs of heart calcifications (Panel F). Mycobacterium tuberculosis (TB) infection of the pericardium (causing effusive constrictive pericarditis) and tracheobronchial lymph nodes (LNs) was confirmed after video-mediastinoscopy and an examination of excised LNs. Follow-up CMR after 3 months of the specific anti-TB treatment revealed no evidence of pericardial thickening, nearly complete resorption of effusion (Panel G, SSFP; Supplementary data online, Movie S3) and almost no signs of oedema in the pericardia (Panel H, T2 fat-sat). The IS bounce had almost vanished, but pronounced mediastinal lymphadenopathy was present.

In summary, tomographic imaging modalities (CMR/CT) are very useful for comprehensive structural and functional assessment of the myocardium and pericardium along with perfect visualization of other thoracic structures and for safe (in case of CMR) ionizing radiation free follow-up.

Supplementary data are available at European Heart Journal – Cardiovascular Imaging online.

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doi:10.1093/ehjci/jes211