Identification and management of perioperative cardiovascular risk

Introduction

Approximately 25 000 patients die each year in the UK following 1.3 million surgical procedures (Pearse et al, 2006). More than 80% of these perioperative deaths occur in patients who are at significantly high risk for surgery (12.5%) (Pearse et al, 2006). This population tends to be older, have multiple co-morbidities and have undergone major surgery. Notably, 50% were never admitted to a general intensive care unit postoperatively (Campling et al, 1993). Approximately 75% of patients who suffer perioperative death have cardiovascular disease, so it is important to try and identify these patients preoperatively (Mangano, 1990; National Confidential Enquiry into Perioperative Deaths, 2002).

Key to obtaining informed consent for any surgical procedure is to advise the patient of the risks and benefits of the proposed intervention so that he/she may make an informed decision about treatment. Perioperative risk assessment plays a vital role in establishing surgical risk and thus obtaining valid informed consent, and also aids surgical intervention planning and critical care resource allocation. Improved preoperative assessment of surgical risk decreases both mortality and duration of intensive care unit admission (Older et al, 1999). This article examines preoperative cardiac risk assessment and explores validated assessment tools and the clinical applicability of risk scoring systems.

What is a high-risk patient?

The 30-day mortality following any operation is estimated to be between 0.7 and 1.7% (Campling et al, 1993). A patient may be considered at 'high risk' if his/her risk of death is ≥2 times that of the rest of the population or if he/she has an absolute risk of death of >5%. For some patients the risk of death associated with surgery is greater than that from their underlying condition. The challenge that faces anaesthetists and surgeons is to identify these patients and try to reduce that risk.

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How do we assess risk in a surgical patient?

Major surgery elicits a systemic inflammatory response accompanied by significant increases in tissue oxygen consumption, placing significant demands on the cardiorespiratory system. Shoemaker et al (1972) showed that patients unable to increase their oxygen delivery to meet these requirements have an increased mortality.

Preoperative assessment is usually conducted as an outpatient and entails a comprehensive history, examination and appropriate investigations with referral to a specialist, e.g. cardiologist, as required. Preoperative assessment aims to establish whether a patient can tolerate the physiological stresses of surgery and to more accurately measure an individual's risk in the context of pre-existing or concurrent disease. In 2002, the American College of Cardiology/American Heart Association (ACC/AHA) produced guidelines (revised in 2007) for the evaluation of cardiac risk in non-cardiac surgery (Fleisher et al, 2007). They divided patients into low, intermediate and high risk and introduced the concept of 'surgery-specific risk' (see below).

History

Medical co-morbidity increases the risk associated with anaesthesia and surgery. A full history should be taken to identify co-morbidities that place the patient within a high-risk group as defined by ACC/AHA guidelines (*Table 1*). Risk factors for coronary heart disease (smoking, hypertension, hypercholesterolaemia, diabetes mellitus, a family history of ischaemic heart disease) and related diseases, e.g. peripheral vascular disease, cerebrovascular disease or chronic kidney disease, should also be elicited.

The functional capacity of the patient should also be determined. This is probably the most important clinical surrogate of combined cardiorespiratory function. This can be readily ascertained using a simple set of questions adapted from the Duke Activity Status Index (*Table 2*) (Hlatky et al, 1989) which models a patient's physiological reserve using metabolic equivalent tasks (METS). One MET (3.5 ml/min/kg) is defined as the average resting oxygen consumption for a 70 kg, 40-year-old man. According to ACC/AHA

Table 1. The American College of Cardiology/American Heart Association clinical predictors of cardiac risk

Clinical predictors	Condition	Example
Major	Unstable coronary syndromes	Recent myocardial infarction (<1 month)
		Unstable or severe angina
	Decompensated heart failure	
	Significant arrhythmias	High-grade atrioventricular block
		Supraventricular arrhythmias with uncontrolled rate (>100 bpm at rest)
	Severe valvular disease	Severe aortic stenosis
		Symptomatic mitral valve disease
Intermediate	Mild angina pectoris	
	Previous myocardial infarction	
	Compensated heart failure	
	Diabetes mellitus	
	Renal insufficiency	
Minor	Advanced age	
	Rhythm other than sinus	
	History of stroke	
	Uncontrolled systemic hypertension	

guidelines, patients with a reported exercise tolerance >4 METS may proceed to major surgery without further investigation.

This method was developed in cardiac patients and is thought to correlate well with maximal oxygen uptake as assessed using treadmill testing. Although it has not been validated in general surgical patients, studies in patients following major non-cardiac surgery show patients with a poor exercise tolerance (<4 METS) have significantly more cardiovascular and neurological complications (20.4% *vs* 10.4%, $P<0.001$) (Reilly et al, 1999). Evaluation of METS is a useful subjective indicator of risk but more accurate and objective testing exists, e.g. cardiopulmonary exercise.

Examination

The physical examination should be tailored according to the medical history with the additional goal of identifying subclinical disease which would identify the patient as high risk, such as heart failure, valvular heart disease, arrhythmias and peripheral vascular disease. Patients with suboptimal exercise capacity may have underlying respiratory disease, cardiac disease or both and physical examination may direct initial investigations. Incidental findings that represent a greater risk to the patient may also be identified with a thorough physical examination, e.g. abdominal aortic aneurysm.

Table 2. Daily living tasks and the corresponding metabolic equivalent tasks (METS) generated

Energy levels	Activity
1 MET	Can you take care of yourself?
	Eat, dress, and use the toilet?
	Walk around the house?
	Walk a block or two on level ground at 2–3 mph?
	Do light work around the house like dusting or washing dishes?
4 METS	Climb a flight of stairs or walk up a hill?
	Walk on level ground at 4 mph?
	Run a short distance?
	Participate in moderate recreational activities like golf, bowling, dancing or doubles tennis?
>10 METS	Participate in strenuous sports like swimming, singles tennis, football, basketball or skiing?

Risk scoring systems

Surgery-specific risk

Cardiac complications after surgery occur as a result of a combination of patient and operative factors. The longer and more complex the operation the greater the post-operative stress and, therefore, also the risk of morbidity and mortality and vice versa. So a patient who may be considered at low risk for one operation, e.g. cataract repair, may be considered at high risk for another, e.g. open abdominal aneurysm repair.

To take this into account the ACC/AHA classified surgical procedures into high (combined risk of cardiac death and non-fatal myocardial infarction >5%), intermediate (1–5%) and low (<1%) risk (*Table 3*). The urgency of the operation (elective *vs* non-elective) is also taken into account as this will have an effect, e.g. elective open abdominal aneurysm repair has a reported mortality of 3.5%, while that for emergency ruptured aneurysms is approximately 42% (Mangano, 1990). Importantly, cardiac complications are 2–5 times more common in emergency than elective procedures (Reilly et al, 1999), reflecting the greater magnitude of the physiological insult sustained in the former.

Table 3. American College of Cardiology/American Heart Association classification of surgery-specific risk category

Surgical risk	Examples
High risk (>5%)	Aortic and other major vascular surgery
	Peripheral vascular surgery
	Anticipated prolonged surgery with large fluid shifts and/or blood loss
	Major emergency procedures, especially in the elderly
Intermediate risk (1–5%)	Major intraperitoneal (non-vascular)
	Intrathoracic
	Carotid endarterectomy
	Major head and neck surgery
	Radical prostatectomy
Low risk (<1%)	Ambulatory (day) surgery
	Superficial surgery
	Cataract surgery
	Breast surgery

American Society of Anesthesiologists scoring system

Originally introduced as a statistical tool in 1941, the American Society of Anesthesiologists (1963) scoring system (*Table 4*) is a good predictor of postoperative death (Taylor and Porter, 1987), despite its subjectivity and wide inter-observer variation (Wolters et al, 1996).

Goldman Index

Much of the early work on risk assessment focussed on perioperative myocardial infarction. In 1977 Goldman et al used nine preoperative factors (by multivariate analysis) elicited from the history, examination and electrocardiogram to estimate cardiac risk. These included myocardial infarction within the previous 6 months, age >70 years, rhythm other than sinus on electrocardiogram, aortic stenosis, intraperitoneal, intrathoracic, aortic or emergency surgery. Although this index has been validated in a large prospective study of general surgical patients, surgical and anaesthetic techniques and practice have since changed considerably. The Goldman Index has subsequently been refined by others including Detsky et al (1986) and Lee et al (1999) by adding other risk factors such as history of angina or pulmonary oedema.

Revised Cardiac Risk Index

In 1999 Lee et al formulated a simpler index for patients undergoing major, non-urgent, non-cardiac surgery known as the Revised Cardiac Risk Index. Six independent risk

Table 4. American Society of Anesthesiologists (ASA) classification of preoperative physical status

ASA	Status	Mortality (%)
1	Fit, healthy patient	0.1
2	Mild systemic disease	0.7
3	Severe systemic disease: limiting activity but not incapacitating	3.5
4	Incapacitating systemic disease: a constant threat to life	18.5
5	Moribund: not expected to survive	93.3

From Mangano (1990)

factors were identified: ischaemic heart disease, congestive heart failure, cerebrovascular disease, high-risk surgery, preoperative insulin treatment for diabetes mellitus and preoperative creatinine >2 mg/dl (176 µmol/litre), with the number of risk factors correlating with the risk of cardiac complications. Patients were divided into four classes (I to IV) according to risk; those with no risk factors were in class I, with cardiac complication rates of ~0.4%, while those with three or more risk factors were class IV and typically had complication rates of 9.1–11%.

Other scoring systems include the Physiological and Operative Score for the enUmeration of Mortality (POSSUM) (Copeland et al, 1998), the Acute Physiology and Chronic Health Evaluation (APACHE) score (Knaus et al, 1985) and the revised version APACHE II.

POSSUM score

The POSSUM score was specifically designed for comparative surgical audit to discount the effect of case mix on outcome. It requires intraoperative information so is less useful for preoperative risk assessment, although it has been used for this with reasonable accuracy in vascular surgery, using the physiological element and the total score alone (Prytherch et al, 2001).

APACHE scoring system

The APACHE scoring system was designed to assess outcome of patients on the intensive care unit based on chronic health data and physiological data collected in the first 24 hours of their intensive care unit stay. Although the APACHE score has been used to estimate risk preoperatively and, under certain circumstances (e.g. ruptured abdominal aortic aneurysm; Lazarides et al, 1997), is more accurate than POSSUM, it should only be used postoperatively.

There are also a number of operation-specific schemes, e.g. the EUROSCORE (Nashef et al, 1999) for elective cardiac surgery, the Boey score for perforated peptic ulcers and the Reiss index for elderly patients undergoing laparotomy.

Investigations

Preoperative investigations can either aid diagnosis or planning (e.g. computed tomography scanning, magnetic resonance imaging, angiography) or be 'routine'. The latter include baseline blood tests, chest X-ray, electrocardiography, as well as more invasive or specialist investigations. Tests required will be specific to both the patient and the proposed operation. Notably electrocardiographs, often performed in the initial workup, are poor predictors of risk in isolation but may be useful as part of a risk scoring system (see below). Similarly, serum creatinine forms part of the Lee or Revised Cardiac Risk Index.

In 2003, the National Institute for Clinical Excellence (NICE) produced guidance for judicious use of preoperative tests. These were largely grids based on age and American Society of Anesthesiologists grade as well as 'NICE grade' for surgical risk and recommendations were in the form of a traffic light system (*Figure 1*). The guidance document addressed the indications for so-called 'routine' investigations but was not intended as guidance on evaluation of the 'high risk patients'. A typical grid is shown in *Figure 1*.

Preoperative cardiac screening

There is no clear consensus regarding the extent to which patients should be investigated preoperatively, but if a test will not affect management then it should not be performed (Fleisher et al, 2007). Hence, for low-risk patients or low-risk surgery, additional investigations are not indicated. The ACC/AHA guidelines on investigations are based on clinical predictors, functional capacity and surgery specific risk. A patient with major clinical predictors for risk (based on Detsky cardiac risk index, *Table 1*) requires further investigations. A patient with intermediate risk factors and poor functional capacity or high surgery-specific risk (*Table 3*) should undergo further risk stratification via non-invasive stress testing.

Figure 1. Recommended investigations grid for an adult patient undergoing 'National Institute for Clinical Excellence-intermediate risk' surgery (low risk surgery based on American College of Cardiology classification). From National Institute for Clinical Excellence (2003). ASA = American Society of Anesthesiologists; ECG = electrocardiogram.

ASA grade 2: adults with comorbidity from cardiovascular disease

Test	Age (years) ≥16 to <40	≥40 to <60	≥60 to <80	≥80
Chest X-ray				
ECG	Yes	Yes	Yes	Yes
Full blood count				
Haemostasis	No	No	No	No
Renal function			Yes	Yes
Random glucose	No	No	No	No
Urine analysis				
Blood gases	No	No	No	No
Lung function	No	No	No	No

Test not recommended
Consider this test (see page 2)
Test recommended

Exercise electrocardiography

Exercise electrocardiography is widely used for the investigation of ischaemic heart disease and has a reported sensitivity of 81% for multi-vessel disease but a specificity of only 66% (Detrano et al, 1989). Patients with an estimated 7 METS or a heart rate of >130 beats/minute without demonstrable ischaemia are low risk (Hollenberg, 1999).

Echocardiography

Transthoracic echocardiography is non-invasive and easily performed. It cannot detect myocardial ischaemia, but it provides information about resting systolic and diastolic function, structural disease and wall motion. There is, however, a poor correlation between resting transthoracic echocardiography findings and functional capacity, leading the ACC/AHA to dismiss its usefulness as a consistent predictor of perioperative ischaemic events (Fleisher et al, 2007).

Cardiopulmonary exercise testing

Cardiopulmonary exercise testing is an objective, non-invasive method of determining preoperative fitness levels and correlates well with postoperative survival. Cardiopulmonary exercise requires a patient to follow an exercise programme on a bicycle ergometer while inspired and expired gases are measured through a face mask or mouthpiece. Data regarding oxygen consumption, carbon dioxide production and anaerobic threshold (the point at which oxygen delivery is insufficient and anaerobic metabolism occurs) are collected while the patient exercises and 12-lead electrocardiography is used to check for myocardial ischaemia or arrhythmias. Cardiopulmonary exercise provides a very helpful objective reflection of the combined effect of any degree of cardiorespiratory disease rather than an assessment of an organ system in isolation.

Anaerobic threshold also allows successful triage of patients to the general ward, high dependency or intensive care unit for the immediate postoperative period (*Figure 2*) and, together with known surgical specific risk, may be used to identify patients who are unfit for major surgery. In major abdominal surgery, patients with an anaerobic threshold <11 ml/kg/min have significantly higher mortality rates than those with higher anaerobic thresholds (18% *vs* 0.8%) (Older et al, 1993). Although cardiopulmonary exercise is considered by many as the gold standard method for assessing exercise tolerance (American Thoracic Society and American College of Chest Physicians, 2003) it is not widely used because of a lack of availability. The role of cardiopulmonary exercise testing in perioperative risk stratification is the subject of a clinical trial at University College London which is expected to complete in February 2011.

Conclusions

A number of systems can help clinicians stratify patients' risk for surgery. This facilitates preoperative optimization of the patient, allows more focussed perioperative care and, importantly, allows the patient to make more informed decisions about treatment. Objective tools are available to optimize use of critical care facilities through selection of the highest risk patients and attempting to modify their course. Clinicians need to be aware of the limitations of an individual test and have a clear pre-test plan of possible management modifications for more sophisticated tools to be effective. **BJHM**

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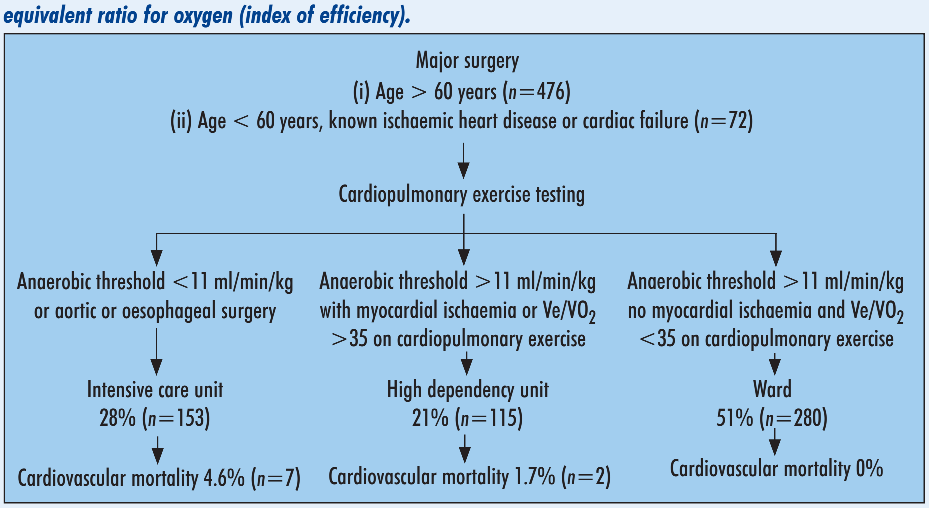
Figure 2. Postoperative triage following preoperative cardiopulmonary exercise stratification and outcome. From Older et al (1999). Ve=minute ventilation; VO_2= maximal oxygen uptake; Ve/VO_2=ventilatory equivalent ratio for oxygen (index of efficiency).



KEY POINTS

- All major surgery increases tissue oxygen consumption, and so puts extra demands on the patient's cardiovascular system.
- Those with poor cardiovascular reserve will have increased risk of cardiac morbidity and mortality.
- Identification of these at risk patients before surgery is essential.
- Once risk is determined then appropriate measures can be put in place to minimize it.