Perioperative risk

ABSTRACT

The high-risk surgical patient is a growing challenge to modern health care. This cohort, although comprising only 10–15% of surgical procedures, accounts for approximately 80% of postoperative deaths and suffers a high rate of postoperative morbidity. Developing robust systems to help identify and better manage this patient group should be a priority.

Risk stratification has become a valuable clinical tool for shared decision-making and the development of individualized care plans. Methods for stratifying individual risk include assessment tools, measures of functional capacity and plasma biomarker assays. Routine evaluation of perioperative risk is central to the delivery of high quality, appropriate surgical care.

Death is fortunately a rare consequence of surgery across heterogeneous populations (Pearse et al, 2012), but as a marker of quality of care it may only tell half of the story. In contrast, morbidity complicates the postoperative recovery of as many as half of patients, is itself associated with increased incidence of postoperative mortality, and its sequelae may extend long beyond the immediate operative period.

Patient outcomes (including morbidity and mortality) are often reported as averages across populations, but this masks the stark variation between patient groups that is frequently encountered. Fortunately, where variation is observed opportunities exist to improve quality of care and patient outcomes.

What is risk?

Risk is defined as the exposure to possible loss, injury, or other adverse or unwelcome circumstance (Oxford Dictionaries Online, 2017). A straightforward definition for what is a thoroughly complex and troublesome concept to navigate, particularly in health care.

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It is well established that our perception of risk is heavily influenced by factors outside of rational thought (Alaszewski and Horlick-Jones, 2003; Boyd and Jackson, 2005; Spiegelhalter et al, 2011). Emotional, social and cultural influences and personal experience all play a role – perceived risk may therefore differ from actual risk. In addition to discrepancies of risk perception is the problematic issue of risk communication (Alaszewski and Horlick-Jones, 2003; Spiegelhalter et al, 2011) – a quagmire of ratio bias, confusing terms (e.g. relative risk and absolute risk) and varying data (mis)representation can form a puzzling picture for patients and health-care professionals alike.

However, despite the misunderstandings, managing all aspects of risk forms the bedrock of medical management and decision making. Most challenging can be the risk–benefit analysis of an intervention:

- Does the potential benefit outweigh the possible risks?
- Are the risks too substantial to justify intervening at all?
- What is an 'acceptable risk' associated with the intervention against that of doing nothing?

This can be an enormously difficult evaluation process for both the patient and the clinician. Although subjectivity will play a significant role, it is important to have comprehensive quantification of those risks and benefits to inform decisions and to ensure the right management option is delivered to the right patient.

Earlier this decade, the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) (Findlay et al, 2011) found the UK wanting in the identification and management of the high-risk surgical patient. Consequently, deconstructing the components of risk in order to foster better decision making, effective patient education and improved quality of care across the perioperative period have been identified as major objectives for patients.

Which risk?

What should clinicians and patients be most concerned about when discussing perioperative risk? Historically, and understandably, perioperative risk focussed on short-term mortality at 30 days post-surgery. Thankfully, in the UK, medical advancement has kept the overall incidence of 30-day postoperative mortality very low (0.7–1.7%) (Boyd and Jackson, 2005; Pearse et al, 2006; Findlay et al, 2011), despite ever more complex patients undergoing high-risk surgery.

At such a low incidence, short-term mortality rates may have limited power to detect outliers and to drive quality improvement. In addition, how meaningful are

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these rates for the broader patient population, when considering surgeries aimed at improving quality of life and long-term survival? So, although mortality rates are undoubtedly important, and should remain a key outcome measure, they do not necessarily reflect quality of care. In contrast, postoperative morbidity may better illustrate burden of care.

The development of morbidity after surgery is associated with reduced long-term quality of life and survival, and as such receives ever-increasing scrutiny (Anthony et al, 2003; Khuri et al, 2005; Derogar et al, 2012; Bouras et al, 2014; Moonesinghe et al, 2014). The American College of Surgeons' National Surgical Quality Improvement Programme reported an association between the development of complications within the first 30 days of surgery and increased long-term mortality (Khuri et al, 2005). Moonesinghe and colleagues describe that prolonged postoperative morbidity is associated with an increased risk of premature death (relative hazard 3.51) in the first year after surgery, and that this excess mortality persists for many years after the surgical insult (Moonesinghe et al, 2014).

Furthermore, with several studies demonstrating the detrimental impact of postoperative morbidity on quality of life (Anthony et al, 2003; Derogar et al, 2012; Bouras et al, 2014), it is clear that risks of postoperative morbidity and long-term sequelae may in some cases negate the survival benefit of surgery. These observations serve to highlight that the outdated mantra of 'survival at all costs' should be done away with.

Alongside ongoing efforts to better understand risk of death, clinicians and researchers are focussing on methods to reliably assess risk of postoperative morbidity. This will help the development of interventions to minimize that risk, and instigation of models of care which ensure that complications are recognized early and managed accordingly.

The high-risk surgical patient

The high-risk surgical patient, with conglomerated risk from surgery-specific and patient-specific factors, may be defined as having an incidence of perioperative mortality of 4–5% or more (Pearse et al, 2006; Swart et al, 2017). Independent predictors of perioperative mortality have been consistently demonstrated to be patient age, comorbid load and immediacy or severity of surgery (Pearse et al, 2006; Story et al, 2010; Findlay et al, 2011). Although representing only 10–15% of surgical procedures, this high-risk population accounts for approximately 80% of postoperative deaths in heterogeneous cohorts (Pearse et al, 2006; Jhanji et al, 2008; Findlay et al, 2011).

Operative risk may be subdivided into 'intrinsic risk' and 'modifiable risk' (Riggs and Segal, 2016). Intrinsic risk denotes that which has no reversible element and over which clinicians have very little control (including inherent procedure-specific risk and patient age). In contrast, modifiable risk factors can be optimized or even eliminated (including smoking, cardiopulmonary fitness, elevated body mass index and poorly controlled comorbidities), thereby improving a patient's risk profile.

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However, in the face of overwhelming evidence that postoperative morbidity has profound and long-lasting negative impacts on health and life expectancy, perioperative mortality is increasingly recognized as a poor measure of quality of care and survival, which may misrepresent and substantially underestimate the size of high-risk populations (Ackland and Edwards, 2010). Overall, postoperative morbidity occurs in approximately 15% of patients (Ackland and Edwards, 2010), rising to up to 50% in high-risk populations (Ackland and Edwards, 2010; Royal College of Surgeons of England and Department of Health, 2011). Furthermore, failure to promptly identify and manage postoperative morbidity has been implicated in wide-ranging variation in mortality rates between institutions within the same country (Ghaferi et al, 2009). Clearly, defining high-risk populations must also incorporate morbidity, but this requires standardized outcome measures and an entrenched system of data collection.

The high-risk surgical patient represents a growing challenge to modern surgical care as an ageing population presents to theatre with increasingly complex medical conditions. With mounting pressures on health-care systems, there is a priority to develop robust systems to identify this high-risk cohort and deliver targeted perioperative care to improve long-term outcome.

Why assess surgical risk?

The primary rationale for assessing risk before surgery is to allow amelioration of that risk – to improve perioperative and postoperative patient outcomes. Although emergency surgical patients have a profoundly higher percentage risk of death, the sheer volume of elective work still means that most surgical deaths and morbidity follow elective procedures. For all surgical cases it is imperative to assess risk and do what is possible to modify that risk. In emergency cases these efforts may be limited by time pressure. However, for the majority of elective surgical patients (expedited cancer cases being an exception) there is ample time and opportunity to evaluate risk and use that information to guide decision making and management.

> **Use of such methods to assess perioperative risk has become an important part of assessment of patients and can be broadly categorized into risk assessment tools, measures of functional capacity and biomarkers.**

Risk stratification is a valuable decision-making aid. It is used to assess the suitability of an operation (is a modified or palliative procedure more appropriate?), to guide postoperative destination (intensive care unit or ward?) and to develop targeted, individualized care plans to further mitigate risk. It is a key tool in facilitating shared decision making between clinician and patient, to allow frank discussion and mutual agreement on the management option that is in keeping with the patient's priorities and expectations.

Evaluation of risk underpins international efforts to improve quality of care and surgical outcomes. It helps clinicians better understand which patient sub-groups will benefit most from an intervention, drives establishment of care pathways that aim to mitigate risk, facilitates audit and research, and allows a structured approach to better resource management.

How do we predict risk?

The last decade has seen a rapid growth in methods for assessing perioperative risk. They not only facilitate informed and shared decisions by patients and clinicians, but also allow fair comparisons to be made between centres on their surgical outcomes, if used for case mix adjustment. The use of such methods to assess perioperative risk has become an important part of assessment of patients and can be broadly categorized into risk assessment tools, measures of functional capacity and biomarkers.

Perioperative risk assessment tools

Predicting the likelihood of a specified outcome in the perioperative period can be considered in terms of risk scoring systems and risk prediction models (Oliver et al, 2015), both of which may use multivariable analysis to predict the likelihood of a specific outcome.

In scoring systems such as the Goldman Cardiac Risk Index, a weighting is assigned to independent predictors of outcome (risk factors) and summed to give a total score. The higher the score the greater the likelihood of the adverse outcome (Goldman et al, 1977). Scoring systems are often simple to use and easy to apply in clinical situations but do not provide individualized estimates.

Risk prediction models on the other hand involve entering patient data into a logistic regression model, giving an individualized estimate of percentage predicted risk. Traditionally this was more complex in execution than risk scores, resulting in a degree of reluctance by clinicians to use them (Moonesinghe et al, 2013). Both scoring systems and prediction models may be stratified into (sometimes arbitrarily defined) low, medium and high risk categories.

One of the most commonly used scoring systems is the American Society of Anesthesiologists Physiology Score, a subjective assessment of patients' preoperative physical status in which patients are stratified into one of five classes. Increasing American Society of Anesthesiologists Physiology Score grade positively correlates with an increased risk of mortality (Sankar et al, 2014). This simple test has become incorporated into assessments of all surgical patients and has, perhaps surprisingly, consistently demonstrated good discrimination of postoperative survival status despite being open to reporter variability (Oliver et al, 2015).

Surgery-specific scoring systems have also been devised such as the Thoracoscore to predict in-hospital death in patients having thoracic surgery. Based on 10 000 patients, this nine variable score looks at a combination of patient and clinical data to give a percentage score of morbidity and mortality (Falcoz et al, 2007).

The Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM) was designed to aid surgical audit. POSSUM combines 12 physiological and six intraoperative factors to calculate 30-day morbidity and mortality (Scott et al, 2014). A variety of POSSUM-based systems have subsequently been created to account for deficiencies in the original tool, including use with vascular and colorectal surgical patients (Prytherch et al, 2001) and the Portsmouth recalibration (P-POSSUM) (Oliver et al, 2015).

P-POSSUM provides individualized risk and has been assessed in multiple large patient populations. It has gained relatively wide cross-disciplinary acceptance and is currently used to assess risk in emergency laparotomy patients in England and Wales in the National Emergency Laparotomy Audit.

The Surgical Outcome Risk Tool, created in 2014, is a purely preoperative risk assessment tool developed and internally validated in the NCEPOD 'Knowing the Risk' dataset (Findlay et al, 2011; Protopapa et al, 2014). Using only six variables, it is a simple tool that only requires preoperative information to give a percentage mortality risk for patients. The Surgical Outcome Risk Tool has subsequently demonstrated reasonable performance in external validation cohorts, is available as a web-based calculator and has recently been configured to predict postoperative morbidity.

Possibly the most comprehensive tool is the American College of Surgeons National Surgical Quality Improvement Program risk calculator (Bilimoria et al, 2013). It was developed through rigorous data collection from over 500 centres, incorporating both preoperative risk factors and postoperative complications on over 1 million patients. This online calculator has 20 questions – one on the surgical procedure, and the rest looking at preoperative factors such as ascites, diabetes and ventilator

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dependence. It then calculates the risk of mortality and multiple morbidities such as renal failure and pneumonia. It goes on to compare individual risk to the average risk seen from their dataset and gives the option of 'surgeon adjustment' if the clinician feels that the risk is higher than estimated.

Functional capacity

The simplest way to assess functional capacity is through the Duke Activity Status Index. This patient-completed questionnaire, originally validated against 50 patients having peak oxygen measurements, assesses physical fitness using metabolic equivalents (Chatterjee et al, 2013). Patients who cannot manage at least one flight of stairs are said to have less than four metabolic equivalents and considered high risk. The 6-minute walk test is another non-invasive and simple tool to evaluate functional capacity. In practice these tests have been used as a benchmark for further tests (Sinclair et al, 2012).

Another independent risk factor for mortality postoperatively is frailty, which was reiterated in the NCEPOD report *An Age Old Problem* (Wilkinson et al, 2010). Despite being a recognized concept for several years, coming to a consensus on a definition has proved difficult and subsequently measuring its prevalence inaccurate. Multiple tools exist to assess frailty such as the Frail Elderly Functional Assessment Questionnaire, the Clinical Global Impression of Change in Physical Frailty, the Edmonton Frailty Score and Frailty Phenotype (Rolfson et al, 2006; Dasgupta et al, 2009; Partridge et al, 2012).

The most reliable and objective tool, however, is the cardiopulmonary exercise test. It involves a dynamic assessment of cardiac, respiratory and musculoskeletal function, taking measurements at both baseline and in response to increasing intensity of exercise to establish level of fitness. Using measured data, further variables can be calculated such as oxygen consumption (VO_2 litre/min) carbon dioxide production (VCO_2 litre/min), anaerobic threshold (ml/kg/min) and respiratory exchange ratio (Snowden et al, 2010).

As a risk prediction tool, studies published in the early 1990s suggested that patients with an anaerobic threshold greater than 11ml/kg/min were at a 1% risk of mortality compared to 18% if the anaerobic threshold was less than 11ml/kg/min. Repeated studies have validated this association between anaerobic threshold and postoperative outcomes (Snowden et al, 2010). Fewer studies have assessed VO_2 and VCO_2 and postoperative outcome, but a prospective study on 400 patients undergoing aortic aneurysm repair showed that a peak VO_2 less than 15 ml/kg/min is associated with an increased risk of early death within the 30-day and 90-day postoperative period (Hartley et al, 2012).

The 2014 joint guidelines by the American College of Cardiology and American Heart Association on perioperative cardiovascular evaluation of patients undergoing non-cardiac surgery advocate the use of cardiopulmonary exercise testing for the evaluation of functional capacity. It was also reported that a 'low anaerobic threshold was predictive of perioperative cardiovascular complications, postoperative death or midterm and late death after surgery' (Fleisher et al, 2014).

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Biomarkers

Interest in the use of biomarkers to aid stratification of perioperative risk continues to increase. A biomarker is defined as 'a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention' (Biomarkers Definitions Working Group, 2001). Currently the most commonly used perioperative biomarkers are B-type natriuretic peptide, high sensitivity C-reactive protein and troponin-T. Despite a lack of prospective studies on biomarkers, meta-analyses have repeatedly shown associations between perioperative increase in B-type natriuretic peptide and major adverse cardiac events postoperatively. An asymptomatic rise in troponin postoperatively is associated with increased long-term, all-cause mortality for patients having major vascular surgery (Lurati Buse et al, 2010; Gillmann et al, 2014; Ekeloef et al, 2016).

Equally, despite its use solely as a non-specific marker of inflammation for many years, evidence suggests that a raised baseline level of high sensitivity C-reactive protein is an independent predictor for cardiovascular events in the future, an association that has been extrapolated to perioperative patients (Rodseth et al, 2008; Ryding et al, 2009; Porapakkham et al, 2010; Edwards et al, 2011).

The right tool for the job?

Some methods for predicting risk are well validated with easy access and interpretation of their results. However, performance does vary and risk scores have been criticized for lack of individualized risk.

P-POSSUM has been externally validated multiple times across the globe. It gives individualized risk from the comprehensive nature of the model, but still has some limitations. Because it requires both preoperative and intraoperative measurements it cannot be reliably used for risk prediction before surgery. Equally some variables, such as chest radiograph, require subjective interpretation, risking measurement error and bias of the result, or are related to surgical performance like blood loss. In contrast with some other models, its deficiencies are well understood (Moonesinghe et al, 2013; Oliver et al, 2015).

KEY POINTS

- The incidence of adverse outcomes (morbidity and mortality) varies substantially within perioperative populations.
- Postoperative morbidity is associated with reduced long-term quality of life and survival, but is relatively poorly understood.
- Methods for assessing individual risk of adverse outcomes include risk assessment tools, assessments of functional capacity and plasma biomarker assays.
- Preoperative quantification of risk is at the heart of perioperative medicine, promoting informed shared decisions, individualized pathways of care and improvement initiatives.
- Risk should be evaluated, documented and discussed for every surgical patient. With the proliferation of risk calculators in mobile electronic devices, facilities to do so already exist.

The American College of Surgeons National Surgical Quality Improvement Program risk calculator is a model with multiple variables to be inputted but all are preoperative in nature and therefore can be used to assess risk before surgery. Web-based calculators are available for both P-POSSUM and the American College of Surgeons National Surgical Quality Improvement Program.

Finally the dynamic nature of cardiopulmonary exercise testing means that several measurements can be made at both baseline and during exertion, but it has practical limitations. Initial and maintenance costs of the machine are high and to run the clinic requires clinician supervision. The test uses a treadmill or cycle to incrementally load work rate, but this must be modified (for example to arm crank exercises) to accommodate physical limitations of the patient. Equally because of its physical nature there are several absolute and relative contraindications to the use of cardiopulmonary exercise testing, e.g. arrhythmias, angina, recent myocardial infarct and uncontrolled asthma (Snowden et al, 2010). As a preoperative assessment tool cardiopulmonary exercise test is useful in assessing physical status and determining aetiology of unexplained dyspnoea, but its financial costs and logistical challenges have meant that it has not had a widespread uptake by hospitals. Ultimately any prediction of risk based on cardiopulmonary exercise testing should be use to aid discussion between the patient and clinicians to agree on the most appropriate course of action for the patient. This can be in terms of surgical options, intraoperative techniques and postoperative destination for care.

These scores and models simply provide an estimate of how patients will respond to surgical stress but overall the main purpose should be to identify those at greater risk. The absolute value of risk is less important, instead categorising patients into moderate, high and very high risk can be beneficial. It is prudent that these tools are used to guide discussions with patients about the type of targeted care that they should be offered.

Conclusions

Likelihood of death and morbidity after surgery varies between patient groups and is associated with a host of patient-specific and surgery-specific risk factors. Individualized assessment of risk can guide treatment decisions throughout the perioperative period and it is a standard of care that risk should be assessed, documented and discussed for all surgical patients.

A host of methods exist to preoperatively quantify risk of death. Choice between these techniques should be informed by appropriateness (cardiopulmonary exercise test is unlikely to be appropriate in a moribund patient admitted acutely for surgery), local expertise, utility and performance. And these methods should always be used in conjunction with and to support clinical judgement.

In contrast, morbidity, patient-reported outcome measures and many long-term outcomes are currently poorly understood. Risk of 30-day mortality is clearly important and can guide clinical care, but the discussions that underpin shared decision-making are currently unlikely to be informed by quality of survival beyond the immediate postoperative period.

We live in an era in which an ageing population of ever-more complex patients undergoes highly invasive surgery. With mounting competition for decreasing resources, it is incumbent upon perioperative clinicians to strive to consistently deliver the highest quality care while most effectively directing the resources at their disposal. The routine assessment of perioperative risk to inform shared decision making supports the delivery of this goal. **BJHM**

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