Perioperative risk prediction scores

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QUESTIONS

Before continuing, try to answer the following questions. The answers can be found at the end of the article, together with an explanation. **Please answer True or False:**

1. **Regarding risk prediction tools:**
   a. They are routinely used
   b. Clinical judgement alone is enough to predict patients' outcomes after surgery
   c. Can be used across all patient populations
   d. Should be well validated
   e. Accurately predict post discharge outcomes
2. **Regarding specific risk prediction tools:**
   a. APACHE score uses three patient related categories (pre-existing disease, patient reserve and severity of acute illness) to predict outcomes
   b. V-POSSUM is commonly used to predict complications in high-risk patients undergoing vascular surgery
   c. The Child-Turcotte-Pugh is more accurate than the Model for End-Stage Liver Disease in predicting perioperative mortality in patients undergoing liver transplant surgery
   d. Objective functional assessment method is currently used routinely to assess high-risk patients undergoing major surgery
   e. There is no specific risk prediction tool for heart valve surgery
3. **Regarding patient specific risk assessment:**
   a. The American Society of Anaesthesiologists (ASA) physical status (PS) classification is the most widely used system to provide risk assessment for anaesthesia and surgery
   b. When predicting the likelihood of perioperative kidney injury, seven independent risk factors have been identified
   c. Cardiopulmonary exercise testing is applicable to all types of surgery
   d. Revised cardiac risk index can be used to predict different perioperative complications
   e. When predicting respiratory complications: most of the factors identified as predictors for developing pneumonia are also significant in predicting development of respiratory failure

Key Points

- Risk prediction systems use multiple patient specific variables and mathematical models calibrated against large data sets to provide quantitative assessment of risk
- Accurate risk prediction allows identification of high risk patients and improves decision making including allocation of critical care resources
- Risk stratification should be routinely documented for high risk patients
- No risk stratification tool fulfils all the characteristics of an ideal scoring system and should be used bearing in mind their limitations

INTRODUCTION

In the UK, the first report by the National Emergency Laparotomy Audit (NELA), published in June 2015, highlighted the fact that patients, who were not risk assessed prior to surgery, did not receive the required standard of care[1]. The report also emphasised that risk documentation helps patients and their families to appreciate the implications of surgery and helps multi-disciplinary decision-making.
It has been shown that whilst clinical judgement is important, alone it is not enough to predict adverse outcomes postoperatively[2]. Therefore, a variety of risk prediction tools have been developed to identify high risk patients. These tools include exercise testing, biomarkers assays and risk stratification calculators. However, as exercise testing is not routinely available and biomarkers assays are still in their infancy, risk stratification tools allow rapid assessment of these patients.

As well as assessing patients, scoring systems have been used to stratify or compare baseline characteristics in clinical trials. They have also been used to compare observed and expected outcomes for surgeons, different centres, regions and have been used to track performances.

There are different scoring systems available, which can be broadly categorised into surgery specific and patient specific risk scoring tools. The ideal scoring system should fulfil the following criteria:

- Uses routinely available patient characteristics/variables
- Easily accessible
- Extensively validated in different populations
- Applicable to different patient populations and across demographics
- Able to accurately predict post-operative outcomes including after discharge, having both a high sensitivity and specificity

No risk prediction system currently satisfies all the above criteria.

RISK ASSESSMENT

The goal of risk assessment is to quantify risk for patients undergoing surgery to enable clinical decision-making, including postoperative care and discussion of risk with the patient and surgeon. Preoperative risk assessment starts by identifying the type of surgery that is going to be performed and the characteristic of a patient that will have it. These two factors will determine the risk of complications – a patient with several co-morbidities is at a relatively low risk (<1%) of developing major adverse cardiac events from cataract surgery; on the other hand, a patient without co-morbidities is at a relatively high risk (>5%) if undergoing major surgery such as aortic repair. Figure 1 demonstrates the surgery specific risk according to which type of surgery the patient is having.

Low risk surgery Cardiac risk <1%	Intermediate risk surgery Cardiac risk <5%	High risk surgery Cardiac risk >5%
Ophthalmological surgery	Major intra-abdominal (non vascular)	Aortic repair (aneurysmal, dissection)
Minor head and neck	Intra-thoracic (non-endoscopic)	Non-carotid major vascular
Biopsies and superficial procedures	Major orthopaedic	Peripheral vascular surgery
Minor prostate operations (e.g. cystoscopy)	Major head and neck	Major emergency procedures
	Radical prostatectomy	Prolonged procedures with large fluid shifts/blood loss

Figure 1. Surgery specific risk

SURGERY SPECIFIC RISK STRTIFICATION SCORES

Below is the description of different risk prediction scores currently used for different types of surgery.

General surgery

Since the NELA report publication, risk prediction tools such as the Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM), specifically Portsmouth (P)- POSSUM have been adopted to risk stratify high risk patients in many centres[3]. P-POSSUM is designed to calculate the risk preoperatively. Other similar scores such as the Surgical Outcome Risk Tool (SORT)[4], the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP)[5] and the widely used ICU scoring system Acute Physiology and Chronic Health Evaluation (APACHE II) score have also been adopted[6]. APACHE score is calculated post-operatively. Figure 2 summarises the pros and cons of these risk prediction tools.

Cardiac surgery

The most commonly used risk prediction score in cardiac surgery in the UK is the European System for Cardiac Operative Risk Evaluation (EuroSCORE)[7]. This was developed in the late 1990s and it provides a robust assessment, which can be readily calculated at the bedside for patients undergoing coronary artery bypass grafting (CABG). The score is based on 17 clinical characteristics from three categories (patient factors/cardiac-related factors/operative related factors), each weighted accordingly. The EuroSCORE has been validated in the UK, Europe and North America and has been shown to be accurate in predicting major complications. There are two models of calculations- the simple additive EuroSCORE and the full logistic EuroSCORE[8]. The latter has been shown to provide a more accurate prediction for high risk patients. However, since 2011, both the additive and logistic scores have been replaced by the more accurate EuroSCORE II[9]. The EuroSCORE II is based on 18 clinical characteristics.

The Society of Thoracic Surgeons mortality risk score (STS)[10] is the other risk stratification system that is currently used in cardiac surgery and was developed using the data from the Society of Thoracic Surgeons database of patients undergoing cardiac surgery in USA. The STS score uses of over 40 clinical parameters to calculate the mortality figure.

From the literature, both EuroScore and STS score appear to be on par in predicting post-operative mortality, however, EuroScore is more commonly used in UK.

Risk prediction tool	Description	Advantages	Disadvantages
APACHE II	12 variables measured over first 24 hours • Physiological indices • Co-morbidities • Type of admission	Well known Individual risk of morbidity and mortality	Designed for critical care, not for perioperative use Requires multiple variables and data entries entered over first 24hrs of admission
POSSUM	12 physiological and 6 operative variables	Best known Well validated	Problems with over and underestimation of mortality
SORT	Six preoperative variables • Type of surgery • Urgency of surgery • ASA of the patient UK developed system	Easy and quick to use	New tool therefore no external validation Not patient specific, only provides general risk of procedure
ACS NSQIP Surgical Risk Calculator	21 pre-operative risk factors	Patient specific risks	Does not account for urgency of procedure Not widely publicised Not validated for emergency surgery

Figure 2. Comparison of risk prediction systems for patients undergoing general surgery

Heart valve surgery

Heart valve surgery is the second most common type of cardiac surgery. Although, both the EuroScore and STS score can be used to calculate the mortality for heart valve surgery as well, a specific risk stratification model for aortic and/or mitral valve with or without concomitant CABG has been developed. The so-called Ambler[11] score has been developed specifically to calculate in-hospital mortality for patients undergoing heart valve surgery. This model was developed in the UK using the national database and included over 32000 patients to develop and validate this risk stratification system.

Vascular Surgery

Vascular-POSSUM has been developed in order to facilitate risk prediction of hospital mortality in patients undergoing major vascular surgery. It has been developed by the Vascular Surgical Society of Great Britain and Ireland, where the original POSSUM mortality regression equation was modified to produce a regression equation (V-POSSUM) that can be specifically used in major vascular surgery. During the development and validation of this tool it was found that V-POSSUM score did overestimate the predicted mortality. Although, it is uncommonly used it is still a specific risk tool available for this type of surgery.

PATIETN SPECIFIC RISK STRATIFICATION SCORES

The second part of the risk equation is influenced by the patient's health. The American Society of Anaesthesiologists (ASA) physical status (PS) classification gives a global impression of the clinical state of the patient that correlates with post-operative outcomes. It was originally developed in 1941 in the attempt to provide a basis for comparing anaesthesia statistical data[12]. However, it is now the most widely used system to provide risk assessment of anaesthesia and surgery. The different ASA classes have been shown to be good predictors of mortality[13] and it has also been shown that post-operative morbidity also varies with different ASA class[14]. In addition to having a global assessment, specific traits have been identified that may predispose patients to poor post-operative outcomes and the most common of these are discussed below.

Cardiac risk assessment

Cardiac risk is the most studied complication of surgery. The well-known and widely used risk prediction tool is the Revised Cardiac Risk Index[15]. Six independent risk factors were identified but rather than weighting each of these factors, the authors designated risk classes by the number of risk factors (Figure 3). Patents without any risk factors are assigned the lowest risk class (I), while those with three or more are assigned to the highest risk class (IV). The revised cardiac risk index is a simple and well-validated system; however, it can only be used to predict major cardiac complication risk after non-cardiac surgery.

Respiratory risk assessment

Pulmonary function is greatly affected in patients undergoing surgery. Pulmonary complications are common after surgery and result in significant morbidity post-operatively. Unlike cardiac risk prediction, there are currently no validated models of pulmonary risk stratification. However, the American College of Physicians have adopted several scales for

assessing the risk of developing specific respiratory complications such as acute respiratory failure (Figure 4)[16] and pneumonia (Figure 5)[16].

These scales were composed from two cohort studies by Arozullah and colleagues[17,18]. These cohort studies were conducted at separate time using the patient data from the department of Veterans Affairs NSQUIP. Authors analysed the data of patients who underwent a variety of surgical non-cardiac procedures, including lung resections. Transplant surgeries were not included. The data was analysed using logistic regression model and variables that were independently related to outcomes were used to develop the two systems. To produce the scores, each variable was assigned a value depending on the regression coefficients with higher values being more significant in determining outcomes. The type of surgery was the most significant predictor in both developing both postoperative respiratory failure and pneumonia. Most of the factors identified as predictors for developing pneumonia were also significant in predicting development of respiratory failure.

Independent predictors of postoperative complications
High risk surgery
History of ischemic heart disease
History of congestive cardiac failure
Insulin therapy for diabetes
History of cerebrovascular disease
Pre-operative serum creatinine >2.0mg/dl (176.8µmol/L)

Risk class	Number of risk factors	Risk of major complications
I	0	0.4%
II	1	0.9%
III	2	7.0%
IV	3 or more	11%

Figure 3. Revised cardiac index

Risk factor	Score
Abdominal aortic aneurysm repair	27
Thoracic	14
Upper abdominal, peripheral vascular or neurosurgery	21
Neck	11
Emergency surgery	11
Albumin <3.0 mg dL^{-1}	9
Plasma urea >30 mg dL^{-1}	8
Totally or partly dependent functional status	7
COPD	6
Age ≥70 years	6
Age 60–69 years	4

Class	Score	%Risk
1	≤10	0.5
2	11–19	1.8
3	20–27	4.2
4	28–40	10.1
5	≥40	26.6

Figure 4. Risk factors for acute respiratory failure in postoperative period of general non-cardiac surgery.

Risk factor	Score
Type of surgery	
Abdominal aortic aneurysm repair	15
High thoracic	14
High abdominal	10
Neck or neurosurgery	08
Vascular	03
Age (years)	
≥80	17
70–79	13
60–69	09
50–59	04
Functional status	
Totally dependent	10
Partially dependent	6
Weight loss over 10% in the last 6 months	7
COPD	5
General anaesthesia	4
Altered sensorium	4
Prior stroke	4
Urea (mg dL−1)	
<8	4
22–30	2
≥30	3
Blood transfusion greater than 4 units	3
Emergency surgery	3
Chronic use of corticosteroids	3
Smoking in the last year	3
Alcohol intake >2 doses in the previous 2 weeks	2

Class	Score	%Risk
1	0–15	0.24
2	16–25	1.2
3	26–40	4.0
4	41–55	9.4
5	>55	15.8

Figure 5. Risk factors for postoperative pneumonia in general non-cardiac surgery

Perioperative kidney injury risk assessment

Acute kidney injury is associated with increased length of stay, cost, morbidity and mortality. The seven independent risk factors were identified by a single centre prospective study that included over 15000 patients with normal renal function, who underwent non-cardiac surgery[19]. These were: age >59, emergency surgery, chronic liver disease, BMI >32, high risk surgery, peripheral vascular disease and COPD needing bronchodilator therapy. The study also identified three intra-operative factors: total vasopressor dose administered, use of a vasopressor infusion, and diuretic administration. Following this publication, the American College of Surgeons-National Surgical Quality Improvement Program identified other risk factors (Tables 6)[20] and created the General Surgery Acute Kidney Injury Risk Index Classification System (Figure 6). However, intra-operative risk factors were not investigated and this system has not been validated in other populations or countries.

Risk factors
Age >56 yr
Male sex
Active congestive heart failure
Ascites
Hypertension
Emergency surgery
Intraperitoneal surgery
Renal insufficiency – mild or moderate
Diabetes mellitus – oral or insulin therapy

Risk class	Number of risk factors	Risk of major complications
I	0-2	0.2%
II	3	0.8%
III	4	2.0%
IV	5	3.6%
V	6+	9.5%

Figure 6. General surgery acute kidney injury risk index classification system

Risk assessment in patients with liver disease

Since the 1970s the main tool for assessing the perioperative morbidity and mortality in patient with liver cirrhosis has been the Child-Turcotte-Pugh (CTP) score which is based on patient's levels of bilirubin, albumin, the international normalised ratio (INR) and the severity of encephalopathy and ascites. Most of the studies have consistently reported the same perioperative outcomes e.g. mortality rates for patients undergoing surgery were 10% for those with Child class A, 30% for those with Child class B, and 76–82% for those with Child class C cirrhosis[21].

Recently, a different model has been used to predict perioperative mortality. MELD (Model for End-Stage Liver Disease) is now used to risk stratify patients awaiting liver transplantation and more recently used to predict perioperative mortality. The MELD score is a linear regression model based on serum bilirubin and creatinine, and INR. The MELD score has several advantages over the CTP score: it weights the variables; it does not rely on arbitrary cut off values and appears to be more objective. Each point increase in the MELD score makes an incremental contribution to the risk and thus appears to be more precise in predicting perioperative mortality[22]. The use of the MELD score and Child class are not mutually exclusive and can complement each other.

PATIENT FUNCTIONAL ASSESSMENT

One area of assessment that is quite popular at present is the functional assessment of the patient. Although, functional assessment has played a big part in preoperative assessment prior to organ removal (e.g. pulmonary testing before lung resection), recently it has been used to assess patients with long-standing co-morbidities to predict their post-operative morbidity and mortality. Cardiopulmonary exercise (CPEX) testing assesses patients' functional status through the use of incremental physical exercise. The end point is to calculate how well the patient's cardiopulmonary system can oxygenate the body and therefore cope with stress of surgery. Cardiopulmonary exercise testing has been shown to have good morbidity predictive value in pulmonary resection surgery and it is being increasingly validated in vascular, liver and other high-risk surgery, including preparation for transplants[23, 24]. However, it is not routinely available in many centres and its applicability to all types of surgery is questionable.

SUMMARY

New evidence is emerging that risk assessment makes a significant difference to patient outcomes. It helps to improve multi-disciplinary decision-making, allocation of critical care resources and communication with patients. Risk documentation is important and should be made a routine practice, especially in high risk patient groups. With the improvements in validation and accessibility of different risk stratification tools, it is now the time to consider their use as part of the standard pre-operative assessment.

ANSWERS TO QUESTIONS

1. Regarding risk prediction tools:

a. **False:** According to NCEPOD 'Knowing the risk', only 37/496 (7.5%) patients who were viewed as high-risk by their anaesthetist had an estimate of the risk of death after surgery documented in their hospital notes.
b. **False:** Clinical judgement is important but it is not enough to predict adverse outcomes postoperatively.
c. **True**
d. **True**
e. **False:** No such prediction exists at this time.

2. Regarding specific risk prediction tools:

a. **True:** APACHE score uses three patient related categories (pre-existing disease, patient reserve and severity of acute illness) to predict outcomes.
b. **False:** It is uncommonly used as it overestimates mortality.
c. **False:** MELD score has several advantages over the CTP score: it weights the variables; it does not rely on arbitrary cut off values and appears to be more objective.
d. **False:** Functional assessments such as CPEX are not routinely available in all centres.
e. **False:** Ambler score has been developed specifically to calculate in-hospital mortality for patients undergoing heart valve surgery.

3. Regarding patient specific risk assessment:

a. **True**
b. **True:** The seven independent risk factors are age >59, emergency surgery, chronic liver disease, BMI >32, high risk surgery, peripheral vascular disease and COPD needing bronchodilator therapy.
c. **False:** Its applicability to all types of surgery is questionable.
d. **False:** It only predicts cardiac complications.
e. **True**

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