

Preoperative evaluation of the patient with cardiorespiratory diseases

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Abstract

Cardiorespiratory complications are among the most common causes of postoperative morbidity and mortality and impose a significant financial burden on the NHS. Patients with premorbid cardiorespiratory diseases can be identified preoperatively with a thorough history taking along with targeted investigations. Preoperative evaluation, risk assessment and stratification allows for clear identification of higher risk patients who would benefit from preoperative medical optimization, appropriate planning of perioperative care including anaesthetic management, modification of surgical procedure and the level of postoperative care required as a part of risk reduction strategies.

Keywords Arrhythmia; biomarkers; cardiopulmonary exercise testing; cardiorespiratory; functional capacity; heart failure; high-risk patients; non-cardiac surgery; perioperative care; postoperative pulmonary complications; preoperative assessment; pulmonary function testing; respiratory failure; risk assessment; risk stratification; spirometry

Introduction

It has been estimated by the National Institute of Health Research Global Health Research Unit on Global Surgery that 4.2 million people die within 30 days of being operated on, accounting for 7.7% of the deaths worldwide, annually.¹ The 2011 National Confidential Enquiry into Patient Outcome and Death (NCEPOD) reported around 20,000–25,000 deaths per year occur in hospital, after a surgical procedure, across the UK. Of these, approximately 80% occur in a small population of patients known as ‘high-risk patients’ who make up 10% of the overall inpatient surgical workload. Respiratory diseases and ischaemic heart disease were the two most common comorbidities associated with mortality and accounted for the highest number of perioperative deaths. However, patients with congestive cardiac failure and arrhythmias accounted for a high percentage of 30 days postoperative fatalities, second only to patients with hepatic cirrhosis.² Approximately 30% of the patients who undergo general anaesthesia experience postoperative pulmonary complications (PPCs) of varying severity classified as minor or

major.³ These are shown in [Box 1](#). The management of symptomatic and asymptomatic patients with a history of cardiorespiratory diseases consists of systematic preoperative assessment of both the individual patient and the surgical risk factors, investigating and optimizing the patient’s condition preoperatively, appropriate intraoperative anaesthetic and surgical management along with planned, multidisciplinary, postoperative care.

Identification and risk assessment

Patients may present for surgery in an elective setting having gone through a doctor- or nurse-led preassessment clinic with a known diagnosis with ample opportunity to allow a detailed clinical evaluation. On the other hand, admission for emergency surgery may result in insufficient time to investigate and optimize a patient’s pre-morbid state. In either case, a detailed history and clinical examination followed by investigations, directed by the findings, and medical optimization based on these results should occur in each case, adjusted to the time available prior to surgery.

Patient factors

History: a thorough medical history is essential for all patients planned for surgery, elective or emergency, to estimate preoperative cardiopulmonary reserve, the severity of ongoing compromise and the incidence of postoperative cardiopulmonary complications. At the time of the initial preoperative evaluation, the clinician should inquire about symptoms such as cough with expectoration, chest pain, breathlessness, dizzy spells and palpitations, as well as look for signs suggestive of heart and lung diseases. A history of asthma, chronic obstructive pulmonary disease (COPD), respiratory tract infections, tuberculosis, obstructive sleep apnoea (OSA), the patient’s functional status, smoking history, environmental/occupational exposure to substances such as coal dust and asbestos may contribute to the patient’s perioperative outcome ([Box 2](#)). A focus on coexisting hypertension, ischaemic or valvular heart disease, cardiac failure, diabetes, chronic kidney disease and peripheral and cerebrovascular disease is important. A current medication history with an emphasis on cardiovascular (antihypertensives, antianginals, antiarrhythmics, antiplatelets and anticoagulants) and respiratory medications (bronchodilators and steroids), previous cardiothoracic surgery and the presence of pacemakers and internal cardioverter defibrillator is mandatory.

Current risk prediction models strongly weight coronary artery disease (CAD) in calculating perioperative risks. Heart failure and atrial fibrillation (AF) are associated with twofold to threefold higher postoperative mortality than CAD, for noncardiac surgical procedures, even if minor.⁴ This is especially true if diagnosis of these cardiac conditions has only been established in the 4 weeks prior to surgery.

Functional capacity of the patient: functional status is a reliable predictor of perioperative and long-term cardiac events. An estimate of a patient’s exercise capacity before they report shortness of breath is reflective of their cardiopulmonary status and reserve. An informal and simple ‘exercise test’ during a preoperative evaluation consists of walking with the patient during the interview to judge their ability to exercise without dyspnoea.⁵

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Major and minor PPCs in patients undergoing non-cardiothoracic surgery³

Minor

- Clinically significant atelectasis
- Purulent tracheobronchitis
- Bronchospasm/exacerbation of underlying chronic obstructive pulmonary diseases

Major

- Acute or worsening respiratory failure
- Requirement of mechanical ventilation and/or intubation for >48 hours
- Pneumonia
- Postoperative arrhythmia/heart failure, especially in patients with pulmonary hypertension
- Hemodynamic instability in patients with pulmonary vascular disease
- Worsening of obstructive sleep apnoea

PPCs, postoperative pulmonary complications.

Box 1

In most cases, determination of whether the patient has a good functional capacity will be obvious on the basis of clinical history. A patient who never leaves a single-level house because of cardiorespiratory symptoms has a poor functional capacity. By contrast, a patient who regularly plays singles tennis has excellent functional capacity.

Patients with reduced functional status preoperatively are at increased risk of complications. In these patients, the presence and number of risk factors (Box 2 and Table 1) in relation to the risk of surgery will determine preoperative risk stratification and perioperative management.

Risk factors for PPCs⁵

- Patient related risk factors
- Pre-existing lung pathology including COPD and ILD, previous spirometric changes (FEV₁ < 1 L)
- Age ≥60 years
- Current smoker especially >20 pack-years
- Preoperative congestive cardiac failure, chronic liver disease or NYHA-2 pulmonary hypertension
- Poor functional status
- Poor nutritional status and hypoalbuminaemia <30 g/dl
- Moderate/severe OSA, obesity (BMI >40 kg/m²)
- American Society of Anesthesiologist class ≥2
- Chronic steroid use or immunosuppression

COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in the first second; ILD, interstitial lung disease; NYHA, New York Heart Association; OSA, obstructive sleep apnoea; PPC, postoperative pulmonary complications.

Box 2

Lee's revised cardiac risk

Lee's revised Cardiac Risk Indices ⁶	Examples
High-risk surgery	Intrathoracic/intraperitoneal/major vascular
History of Ischaemic heart disease	Q waves on ECG Positive results on stress testing
History of congestive cardiac failure	S3, raised JVP or fine rales bilaterally on auscultation Radiological (chest X-ray or echocardiogram) evidence
History of cerebrovascular disease	Recent stroke or TIA Syncope attacks Carotid bruits, uncontrolled hypertension
Renal insufficiency	Serum creatinine >170 µmol/l or CrCl <60ml/min CKD requiring long term dialysis
Diabetes mellitus requiring insulin therapy	End organ involvement such as Retinopathy, nephropathy or PVD Frequent admissions with ketoacidosis

CKD, chronic kidney disease; JVP, jugular venous pressure; PVD, peripheral vascular disease; TIA, transient ischaemic attack.

Table 1

Conversely, in those with good functional status preoperatively, the prognosis is excellent, even in the presence of stable IHD or risk factors.⁴ Moreover, in highly functional asymptomatic patients, it is often appropriate to proceed with planned surgery without further cardiovascular testing.

If a patient has not had a recent exercise test before non-cardiac surgery, the patient's cardiorespiratory functional capacity can be estimated from activities of daily living by assessing patients using a standardized structured questionnaire, e.g. Duke Activity Status Index (DASI) (Table 2) and the Specific Activity Scale.⁴ The DASI grades exercise ability on the basis of a series of questions related to exercise equivalences ranging from the ability to wash and dress without breathlessness to strenuous activity such as swimming and singles tennis.⁷

The capacity to perform a range of common daily activities correlate well with maximum oxygen uptake by treadmill testing. Functional capacity is often expressed in terms of metabolic equivalents (METs), where 1 MET is defined as the uptake of 3.5 ml O₂/kg/min, which is the resting or basal oxygen uptake of a 40-year-old man, weighing 70 kg in a sitting position.⁷ A DASI questionnaire score above 11.6 is roughly equivalent to an oxygen consumption of 14 ml O₂/kg/min.⁷ The European society of Cardiology (ESC) and the American College of Cardiology/American Heart Association (ACC/AHA) guidelines recommend using the METs, as an estimate of functional capacity.

In the perioperative literature, functional capacity is classified as excellent (>10 METs), good (7 METs to 10 METs), moderate (4 METs to 6 METs), poor (<4 METs) or unknown.⁴ In patients undergoing elective non-cardiac surgery, perioperative cardiovascular, pulmonary and long-term adverse events are increased in

Estimated energy requirements in METs based on DAS1 questions⁴

METs	Questions
1–3	Can you... Walk indoors around the house? (1.75) Do light work around the house like dusting or washing dishes? (2.70) Take care of yourself, i.e. eat, dress or use the toilet? (2.75) Walk 1–2 blocks on level ground at 2–3 mph? (2.75)
4–7	Can you... Do moderate work around the house like vacuuming, sweeping floors or carrying in groceries? (3.50) Do yard work around the house like raking leaves, weeding or pushing a power mower? (4.50) Walk on level ground at 4 mph? (5.25) Climb a flight of stairs or walk up a hill? (5.50) Participate in moderate recreational activities like golf, bowling, dancing, doubles tennis or throwing a baseball? (6.00)
>7	Can you... Participate in strenuous sports like swimming, singles tennis, football, basketball or skiing? (7.50) Do heavy work around the house like scrubbing floors, lifting or moving heavy furniture? (8.00) Run a short distance? (8.00)

METs, metabolic equivalents.

Table 2

patients unable to perform 4 METs of work during daily activities (defined as the inability to walk 4 blocks or about 0.4 miles or 350–400 m at a reasonable pace (3.5 miles/hour) or climb a flights of stairs without dyspnoea) even after adjustment for other risk factors.⁵ This holds true especially for thoracic surgeries, reflecting the importance of pulmonary function, which is strongly related to functional capacity, as a major predictor of survival after thoracic surgery. However, in comparison with thoracic surgery, a poor functional status was not associated with an increased mortality after other noncardiac surgery and in fact showed a relatively weak association with postoperative cardiac events or death.⁶

Activities associated with >4 METs surpasses the threshold required for elective surgery and the ability to achieve >4 METs of activity without symptoms is thought to be a good prognostic indicator. The exertion at a level of 4–5 METs, is typically equivalent to the physiologic stress of most non-cardiac surgical procedures requiring general anaesthesia.

The likelihood of a serious complication is inversely related to the number of blocks that can be walked or flights of stairs that could be climbed. Analyses from the American College of Surgeons National Surgical Quality Improvement Program dataset

have shown that dependent functional status, based on the need for assistance with activities of daily living rather than on METs, is associated with significantly increased risk of perioperative morbidity and mortality.⁴

The 2018 METs prospective cohort study concluded that subjectively assessed preoperative functional capacity did not accurately identify patients with poor cardiopulmonary fitness or predict postoperative morbidity or mortality,⁸ i.e. predicting the inability to attain four metabolic equivalents during CPET and resulted in a substantial misclassification of high-risk patients as low risk. Only DAS1 scores were associated with successfully predicting the primary outcome.

Physical examination: the physical examination should also screen for cardiopulmonary disorders and include heart rate (HR), blood pressure (BP) and respiratory rate measurements, inspection of the trachea and thorax and abdomen, palpation and percussion of the thorax and precordium, auscultation of the heart and lungs, abdominal palpation if indicated, and examination of the extremities for nutritional status, oedema and peripheral perfusion.

Surgical factors

The surgical neuro-hormonal stress response leads to sympathetic stimulation, proportional to the stimulus, which in turn increases the myocardial oxygen demand. It also induces a procoagulant state by increasing plasma levels of fibrinogen, increasing platelet activation and aggregation and reducing fibrinolysis. Both sympathetic stimulation and hypercoagulability predisposes to coronary thrombosis. The clinician must consider two factors when assessing the patient's cardiovascular risk: (1) the type of surgery, and (2) the hemodynamic stress associated with the procedure. Generally, the more extensive the surgical procedure, the greater the physiological stress (changes in body temperature, fluid shifts and blood loss), the more significant the postoperative pain, and the greater the incidence of cardiac complications. Surgical interventions can be divided into three different groups (Table 3) depending on estimated 30-day cardiac event, i.e. cardiac deaths and myocardial infarction (MI) rates.

Surgical stress requires an increase in respiratory work as the patient becomes catabolic. These increased metabolic demands lead to a failure of oxygen delivery and consequent organ damage in the surgical patient with severe respiratory disease. This is exacerbated by the supine position, causing a reduction in functional residual capacity, alveolar collapse and atelectasis, hypoventilation, caused either by neurological impairment or drugs, mucus hypersecretion and alveolar oedema which accompanies the generalized inflammatory response. The cumulative effect is to reduce the capacity for gas exchange.

The patient becomes more susceptible to organ failure and sepsis at a time when natural defences are also breached by invasive surgical and anaesthetic procedures. Classical surgical or intraoperative risk factors for PPCs are given in Box 3.

Investigations

The incremental shuttle walk test

This is used for the assessment of cardiopulmonary reserve and involves a patient walking up and down a usually 10-m course

Estimation of risk of cardiac events for proposed surgery⁶

Low risk: < 1%	Intermediate risk: 1–5%	High risk: > 5%
Superficial surgery	Intrathoracic: minor	Total cystectomy
Breast	CEA/CAS: symptomatic	Adrenal resection
Dental	Peripheral arterial angioplasty	Duodeno-pancreatic surgery
Endocrine: minor (thyroid)	EVAR	Repair of perforated bowel
Eye	Head and neck surgery	Oesophagectomy
Reconstructive: skin grafts and flaps	Orthopaedic and neurological: major	Liver resection, bile duct surgery
CEA/CAS: Asymptomatic	Gynaecological and urological: major	Open lower limb revascularization or amputation
Gynaecology and urological: minor	Intraperitoneal: splenectomy, cholecystectomy	Aortic and major vascular surgery
Orthopaedic: minor	Renal transplant	Pulmonary and liver transplantation

Table 3

(shuttle) at a speed dictated by an audio signal, with the walking speed being slowly increased at timed intervals. The test is terminated either by the patient who is too fatigued to continue walking at the speed set by the audio signal or by the operator when the patient fails to complete the 10-m course within the allotted time. The distance completed by the patient when the test is terminated is a measure of functional capacity and correlates with peak oxygen consumption (VO_2) in various conditions. Cut-off values for walking distance predicting adverse post-operative outcome will depend on the type of surgery and have been reported as <350–400 m in patients undergoing pneumonectomy or oesophagostrectomy.⁷

Six-minute walk test (6MWT)

This is an objective evaluation of the functional capacity of a patient by testing the maximum distance a patient can walk in 6 minutes on a flat surface. One recommendation is that patients walking more than 563 m during the test do not normally require further testing, while patients walking less than 427 m are at higher risk for complications following a range of major surgical procedures and should be referred for further evaluation. Patients walking the intermediate distance should be assessed on individual basis considering number of clinical risk factors and magnitude of surgery.⁹

Cardiopulmonary exercise testing (CPET)

This is a gold standard objective assessment of both the cardiac and respiratory components of the functional capacity. In this, a patient exercises on a bicycle ergometer, and a range of physiological variables including the SpO_2 , ECG, BP, oxygen uptake and carbon dioxide (CO_2) elimination are measured. As exercise intensity increases, so does oxygen uptake to a maximum value, the VO_2 peak/max. With more extreme exercise, aerobic metabolism switches to anaerobic and the amount of CO_2 excreted increases. This point is termed the anaerobic threshold (AT).

Patient with an AT of >11 ml O_2 /kg/min (considered high) can undergo major surgery and can receive ward-based post-operative care with minimal postoperative cardiac complications. Those with an AT < 11 ml O_2 /kg/min or VO_2 peak of <15 ml O_2 /kg/min benefit from high dependency or intensive care postoperatively. Patients with an AT < 8 ml O_2 /kg/min are considered very high risk, especially with associated myocardial ischaemia.⁹

CPET provides additional data on cardiovascular performance during exercise, which have prognostic importance and may directly or indirectly influence risk stratification and includes parameters such as aerobic efficiency (VO_2/W), oxygen pulse (VO_2/HR), and minute-volume/ CO_2 output ratio (VE/VCO_2).

Cardiac investigations

Non-invasive testing provides information on left ventricular (LV) function, detects ischaemia and valvular dysfunction.

Electrocardiography (ECG): the ACC/AHA guidelines recommend a preoperative resting 12-lead ECG for patients with known CAD, significant arrhythmia, peripheral and cerebrovascular disease, or other significant structural heart disease, except for those undergoing low-risk surgery and maybe considered for asymptomatic patients without known CAD, undergoing high-risk surgery. ECG abnormalities of prognostic significance include arrhythmias, pathological Q waves, LV hypertrophy, ST depression, QTc prolongation and bundle branch blocks.

In the UK, the National Institute for Health and Care Excellence (NICE) recommends an ECG for all ASA 3 or 4 patients undergoing minor surgery, for those with cardiovascular or renal disease or diabetes (ASA 2–4) undergoing intermediate surgery and those older than 65 (ASA 1) or ASA 2–4 undergoing major surgery if an ECG from the previous 12 months is unavailable.

Stress testing: detects ischaemia using non-invasive methods. It is recommended before high or intermediate risk surgery in

Intraoperative risk factors for PPCs⁵

- Site of surgery (open intrathoracic, upper abdominal procedures)
- Duration of surgery/general anaesthesia >3 hours
- Emergency surgery
- General anaesthesia especially with the use of long acting neuromuscular blocking drugs
- Nonselective nasogastric tube placement
- Transfusion of >4 units of blood

PPCs, postoperative pulmonary complications.

Box 3

patients with three or more clinical risk factors and <4 METs (Tables 1–3) and may be considered before high or intermediate risk surgery in patients with one or two clinical risk factors and <4 METs if the test results are likely to alter perioperative management in these patients. Exercise (bicycle or treadmill) stress testing is most commonly used, providing data for HR and BP response along with analysis of ST segment changes, if present. It is of limited value in patients with pre-existing ECG changes and limited exercise capacity. Pharmacological stress testing (dobutamine/dipyridamole/adenosine) with imaging (echocardiogram/thallium nuclear perfusion scan) is an alternative for patients with physical limitations who do not have significant arrhythmias, severe hypertension or are unstable. It provides information on LV function, valvular diseases and the presence and extent of stress inducible ischaemia. Reversible or ‘at risk’ defects are the key important prognostic findings in stress imaging, with greater extent of reversibility being indicative of higher postoperative risk for death or MI.⁴

Inflammatory biomarkers: perioperatively, biomarkers can be divided into markers focusing on myocardial ischaemia and damage, inflammation, and LV function.

Cardiac troponins T and I (cTnT and cTnI) are the preferred markers for the diagnosis of MI because they demonstrate sensitivity and tissue specificity better than other available biomarkers. The prognostic information complements other important cardiac indicators of risk, such as ST deviation and LV function. Even small increases in cTnT perioperatively reflect clinically relevant myocardial injury with worsened cardiac outcome. Assessment of cardiac troponins in high-risk patients, both before and 48–72 hours after major surgery, may therefore be considered.⁶

Inflammatory markers might preoperatively identify those patients with an increased risk of unstable coronary plaque. High sensitivity C-reactive protein (hs-CRP), B-type natriuretic peptide (BNP) and N-terminal pro-BNP (NT-proBNP) are produced in cardiac myocytes in response to increases in myocardial wall stress thus result in raised plasma concentrations in ischaemic heart disease reflecting the inflammatory component of the disease. Preoperative BNP and NT-proBNP levels have additional prognostic value for long-term mortality and for cardiac events after major non-cardiac vascular surgery. Based on the existing data, assessment of serum biomarkers for patients undergoing non-cardiac surgery may be considered in high-risk patients (METs ≤ 4 or with a revised cardiac risk index value of 1 for vascular surgery and of 2 for non-vascular surgery).⁶ Patients with ASA grade 3 and above undergoing intermediate to high-risk elective surgery would benefit from testing plasma levels of NT-pro-BNP and hs-CRP, in addition to other testing. ASA grade 2 patients undergoing high-risk emergency surgery should also be offered this test. ESC guidelines recommend that NT-proBNP and BNP measurements may be considered for obtaining independent prognostic information for perioperative and late cardiac events in high-risk patients.

The results of several recent systematic reviews, meta-analyses, have shown that elevated preoperative serum concentrations of hs-CRP and NT-proBNP are independent predictors of postoperative short- and intermediate-term adverse cardiac outcome in major non-cardiac surgery. In patients undergoing

elective major non-cardiac surgery, both NT-proBNP (cutoff >301 ng/l) and CRP (cutoff >3.4 mg/l) predicted major perioperative cardiac events better than the Lee’s Revised Cardiac Risk Indices (RCRI) (cut-off >2). The predictive power of the RCRI was improved threefold by including preoperative concentrations of NT-proBNP and CRP.⁷

Coronary angiography: is an invasive, diagnostic procedure. It is rarely indicated for assessing the risk of patients undergoing non-cardiac surgery as there is no convincing evidence from randomized trials relating to its usefulness in such patients. Invasive coronary angiography assessment may cause an unnecessary and unpredictable delay in an already planned surgical intervention, as well as adding small, but potentially life-threatening procedural risks to the overall risk.

The indications for preoperative coronary angiography are identical to those in the non-operative setting. Before performing a preoperative coronary angiography, a consultation between cardiologist, surgeon, anaesthetist, and patients is required to decide whether the patient is a potential candidate for subsequent preoperative coronary revascularization, the implications of preoperative coronary revascularization (e.g. possible postponement of surgery and need for anti-platelet therapy) and if the coronary anatomy found on coronary angiography fulfils the indications for coronary revascularization, then, on the appropriate method of coronary revascularization (i.e. surgical versus interventional; if interventional, balloon angioplasty versus bare-metal stenting versus drug-eluting stenting). Preoperative coronary angiography merely to confirm the existence of coronary artery disease is rarely indicated.

The 2014 ESC/ESA guidelines recommend urgent angiography in patients with acute ST-segment elevation myocardial infarction and non ST-segment elevation acute coronary syndrome requiring non-urgent, non-cardiac surgery according to risk assessment.

Preoperative angiography is also recommended in patients with proven myocardial ischaemia and unstable angina (Canadian Cardiovascular Society Class III–IV) with adequate medical therapy requiring non-urgent, non-cardiac surgery.

Respiratory investigations

Pulse oximetry: this is recorded in all patients before surgery on room air as a baseline reference against which postoperative saturations are assessed. Patients with chronic respiratory conditions may function well despite chronically low oxygen saturations.

Pulmonary/thoracic imaging: Chest imaging with radiography or computed tomography (CT) is one of the most commonly used methods for confirming findings from clinical examination and evaluating the severity and extent of lung disease. Findings of routine chest imaging are rarely unexpected and in only 0.1–0.3% of cases, the pre-established medical approach is changed. Occasionally, CT scans may provide information useful to the anaesthetist regarding tracheal size and estimation of total lung capacity.¹⁰ Imaging may be considered in patients with prior cardiopulmonary disease or who will undergo major surgeries, particularly thoracic and abdominal or surgical correction of aortic aneurysm. Quantitative radionuclide scanning and CT

are newer methods to estimate postoperative pulmonary function following lung resection surgery.

Arterial blood gases (ABG): analysis provides values for O₂ and CO₂ tensions as well as bicarbonate, base excess and pH.

Preoperative gases can provide a baseline reference against which subsequent serial blood gas results can be assessed, help determine the severity of respiratory disease, type of respiratory failure adequacy of compensatory mechanisms and whether the proposed surgery is appropriate but are not independent predictors of postoperative respiratory complications.

Pulmonary function tests: among the recognized tests to assess lung function, spirometry is the most requested one during preoperative evaluation. A spirometer can be used to measure lung volumes. From the measurements, a number of clinically significant values can be measured or derived.

FEV₁ is the volume that can be forcibly expired in the first second of expiration. This will be reduced in patients with obstructive lung disease.

Forced vital capacity (FVC) is the volume of gas that can be exhaled following a maximal inspiration. Following this manoeuvre volume of gas remaining in the lung is the residual volume (RV).

The FEV₁/FVC ratio is normally greater than 70%. In COPD, the FEV₁ will be reduced whilst FVC is maintained, thus lowering the ratio. In restrictive disease both FEV₁ and FVC will both be reduced, thus maintaining the ratio.

Functional residual capacity (FRC) is the sum of the RV and expiratory reserve volume (ERV). Functionally it represents the 'space' in the lung where gas exchange is occurring. Therefore, loss of this volume of the lung will impair gas exchange.

A test of the diffusing capacity of the lungs for carbon monoxide (DLCO, also known as transfer factor for carbon monoxide or TLCO), measures the ability of the lungs to transfer gas from inhaled air to the red blood cells in pulmonary capillaries. The ten seconds of breath holding required for the DLCO manoeuvre is easier for most to perform than the FVC manoeuvre required for spirometry.

A decreased DLCO may be seen in Emphysema, interstitial lung disease (ILD), pulmonary vascular diseases and anaemia and increased values may be seen in asthma, obesity, polycythaemia and pulmonary haemorrhage.

Preoperative identification of patients with asthma or COPD is important, as some individuals may benefit from specific preoperative interventions and most can probably be detected by history, physical examination, and symptom-directed physiologic testing. Although spirometry is of value in diagnosing obstructive lung disease, recent data on risk prediction for individual patients are contradictory.

Data from several retrospective studies of routine preoperative pulmonary function test (PFT) indicated that although patients with severe COPD (FEV₁ <40% predicted) undergoing lung resection have an overall high risk (six times more likely) of major postoperative complications (29%), the degree of physiologic impairment (FEV₁ or FVC) does not always correlate with the risk of postoperative pulmonary complications. Therefore, non-resectional surgery should never be withheld based solely on results from PFTs and as such preoperative diagnostic spirometry as a general measure to predict the risk of postoperative complications in non-cardiothoracic patients is not

recommended. Rather, testing should be restricted to those with unexplained dyspnoea or exercise intolerance.

Preoperative spirometry has been found to be beneficial in intra-abdominal and thoracic procedures without pulmonary resection and may be considered in the patients with chronic lung disease, heavy smokers, those with a history of exposure to inhalants long enough to cause structural lung injury, those with chronic respiratory symptoms or findings on physical examination or radiological imaging, bariatric surgery patients, patients with scoliosis/kyphoscoliosis or neuromuscular disease undergoing general anaesthesia and patients with chronic lung disease under-going neurosurgery.

In patients with neuromuscular disease or kyphoscoliosis, measurements of maximal inspiratory and expiratory pressures should also be ordered. FVC below 40% of the predicted value and/or maximum pressures below 30 cmH₂O significantly increases the risk of extubation failure in postoperative period.¹¹ Contrary to what occurs in lung resection surgery, there are no FEV₁ prohibitive limits for performing general surgery.

Tests in specific conditions

Obstructive sleep apnoea (OSA): patients with OSA are significantly increased risk of PPCs such as aspiration pneumonia, ARDS and pulmonary embolization and the risks are greater when the condition is undiagnosed. Starting treatment for OSA before surgery could lead to an overall reduction in complications and hence screening is recommended.¹¹

In patients who may have sleep apnoea, the diagnosis should be confirmed and the severity should be assessed preoperatively with a formal polysomnographic sleep study, which is the gold standard. As obtaining preoperative polysomnography in all patients at risk presents a challenge, the use of questionnaires to identify patients at risk of moderate-to-severe obstructive sleep apnoea may be useful to select higher-risk patients for preoperative testing. Although various screening questionnaires for the detection of OSA patients are available (the Berlin questionnaire), the STOP-BANG questionnaire is the most sensitive, specific and best validated scoring system and is recommended when polysomnography is not available.¹¹

STOP-BANG questionnaire³

STOP-BANG	Analysed variable question to be asked/ examination findings
S (Snoring)	Do you snore loudly? Louder than talking or loud enough to be heard through a closed door?
T (Tiredness)	Do you often feel tired? Do you sleep during the daytime?
O (Observed apnoea)	Has anyone observed you stop breathing during sleep?
P (Pressure)	Do you have high blood pressure?
B (BMI)	>35 kg/m ²
A (Age)	Over 50 years
N (Neck)	Circumference >40 cm
G (Gender)	Male

High risk for OSAS: ≥3 positive responses.
Low risk for OSAS: <3 positive responses.

Table 4

The STOP-BANG questionnaire includes eight questions as shown in Table 4, with three or more positive answers being associated with a high risk of OSA. The additional presence of a serum bicarbonate level ≥ 28 mmol/L improves the specificity for diagnosis.⁵

The severity of sleep apnoea is judged based on the apnoea-hypopnoea index and the lowest oxygen saturation value during sleep.

Nocturnal oximetry testing is another option to identify patients with clinical features suggestive of OSA at increased risk of complications if polysomnography cannot be performed preoperatively. Specifically, those with ≥ 5 desaturation events per hour had a 15% incidence of complications (mostly pulmonary), while those with fewer desaturation events had a complication rate around 3%.

Pulmonary hypertension (PH): patients with PH have an increased risk of congestive heart failure, hemodynamic instability, sepsis, and respiratory failure, and longer intensive care unit and hospital length of stay. Features associated with an

increased risk in patients with PH include: history of pulmonary embolism, OSA, CKD, CAD, NYHA class 2 or above, right-axis deviation or right ventricular hypertrophy on ECG, and poor hemodynamic parameters (including right atrial dilation, decreased left ventricular ejection fraction). Preoperative evaluation should include ECG at rest and echocardiography, in addition to the 6MWT and CPET to establish prognosis and assess therapeutic response. The presence of right atrial pressure >77 mmHg at the last hemodynamic assessment before surgery, 6MWT distance walked <399 m, greater clinical severity, and emergency surgery signify greater postoperative morbidity and mortality.³

Tests for lung resection surgery: a comprehensive preoperative assessment of patients scheduled for pulmonary resection requires spirometry testing and, if necessary, CPET, combined with functional imaging data from computed tomography, pulmonary perfusion scintigraphy, and bronchoscopy. These tests assess whether the area to be resected still participates in pulmonary

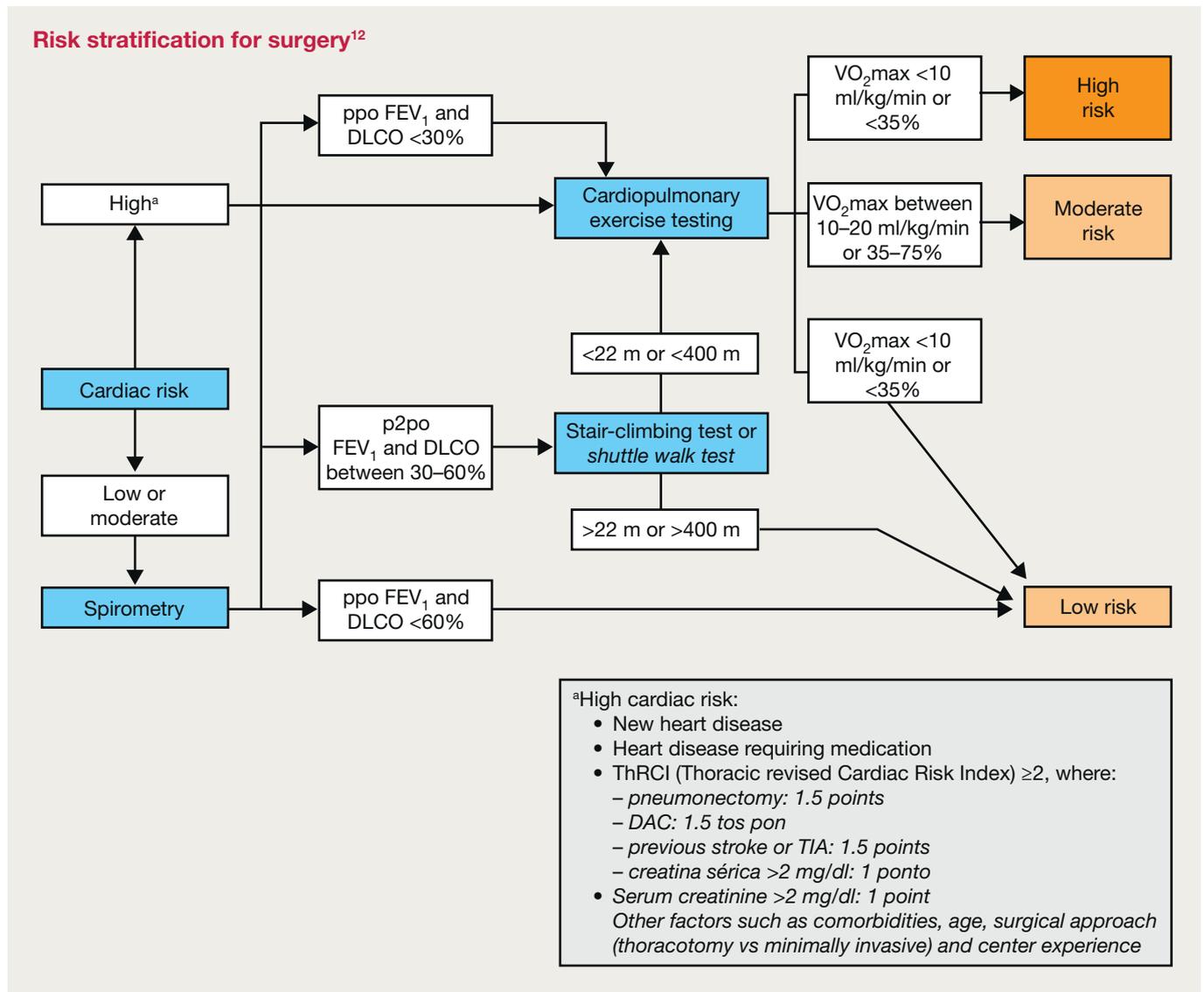


Figure 1

gas exchange and should estimate the residual values of pulmonary function after resection. The FEV₁, DLCO and VO₂max obtained in CPET are the parameters commonly assessed. The postfix ppo is added to indicate that the estimated parameter refers to the late postoperative period; i.e. 3–6 months after the surgical procedure (FEV₁-ppo, DLCO -ppo, and VO₂max-ppo).

The calculation uses the number of functioning lung segments (right upper lobe = 3, middle lobe = 2, right lower lobe = 5, left upper lobe = 5 and left lower lobe = 4) and assumes that all segments contribute equally to gas exchange, which is rarely true in diseased lungs. This method is used to estimate the function after lobectomy and the following formulas maybe applied:

$$\text{ppo value} = (\text{preoperative value}/T) \times R$$

where $T = 19 - \text{number of obstructed segments}$; $R = T - \text{number of functioning segments to be resected}$.

$$\text{ppo value} = \text{preoperative value} \times (1 - a/b)$$

where $a = \text{number of non-obstructed segments to be resected}$; $b = \text{total number of non-obstructed segments}$.

For pneumonectomy, the calculations are made using the results of perfusion scintigraphy or pulmonary ventilation perfusion examination and is the most commonly used method for this purpose. In this case, the formula used for the calculation is:

$$\text{ppo value} = \text{preoperative value} \times (1 - \text{perfusion fraction of the lung to be resected})$$

Minimally invasive surgical techniques, such as video-assisted thoracic surgery (VATS) and viable lung parenchyma sparing resection procedures have allowed patients with ppo FEV₁ and/or DLCO <40% to undergo these procedures with morbidity rates relatively low (15–25%) and reported postoperative mortality ranging from 1% to 15%, compared to the traditional cut off values of >40%. In these patients, surgery to treat lung cancer in stage I, even with minor resections (sub-lobar resections) result in increased survival compared to patients who did not undergo the procedure. Moreover, tumour resection in patients with severe COPD may improve functional outcome in two situations:

- tumour is located in the upper lobe, which is also the site of major involvement of centrilobular emphysema and, therefore, with less functional loss
- if there is the possibility of combining tumour resection with lung volume reduction surgery, if feasible.

The American College of Chest Physicians have developed a broader method of preoperative evaluation for lung resection surgery, allowing risk stratification based on a patients cardiopulmonary reserve rather than only on pulmonary function parameters depicted in [Figure 1](#).

Under the new guidelines, patients at low risk for surgery, have an estimated mortality rate <1%, and do not require additional pulmonary evaluation. Patients at a high risk for surgery have an estimated mortality rate of >10% and are generally considered a contraindication to surgery.

Patients with Thoracic Revised Cardiac Risk Index (ThRCRI) ≥ 2 , who are unable to climb two flights of stairs or have heart disease requiring medication or newly diagnosed, should be initially seen by a cardiologist and undergo further tests and treatment if necessary before having a formal CPET.³

Conclusion

Further evidence from high-quality research in the field of preoperative cardiac-respiratory assessment is required. Physicians, surgeons and anaesthetists all have important roles in stratifying patient risk using initial clinical risk assessment and selective use of investigations to aid in decision making regarding if and when surgery should proceed after weighing up the potential benefits and harm of surgery. Generally, the use of any investigation is not advised when the results of such test do not aid in the perioperative management of the patient.

Preoperative cardiac–respiratory evaluation is only one aspect of overall perioperative care in addition to preoperative optimization, use of appropriately suitable anaesthetic and surgical techniques and optimum postoperative care, all of which play equally important roles in improving patient outcomes. ♦

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