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PREOPERATIVE EVALUATION (BJ SWEITZER, SECTION EDITOR)

Preoperative Pulmonary Evaluation

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Abstract

Purpose of Review The purpose of this article is to provide a brief review of the preoperative pulmonary evaluation of patients undergoing non-thoracic surgery, focusing on risk factor identification, assessment of specific high-risk populations, and strategies to minimize postoperative pulmonary complications (PPCs).

Recent Findings Along with traditional risk factors, recent risk stratification indices have been developed and validated to help quantify risk of PPCs. Careful history and physical examination are key elements in the pulmonary evaluation of all pre-surgical patients. Patients with chronic obstructive pulmonary disease (COPD) are at increased risk and require more intensive optimization and perioperative monitoring. Well-controlled asthma has not been associated with increased risk of PPCs but the potential for life-threatening bronchospasm and status asthmaticus cannot be ignored. In general, the literature does not support delaying surgery for preoperative diagnosis and management of obstructive sleep apnea (OSA). Exceptions to this rule are patients presenting with evidence of obesity-hypoventilation syndrome or pulmonary hypertension. Recent literature provides more evidence of benefits of regional anesthesia and analgesia to decrease the risk of pulmonary complications, particularly in COPD patients.

Summary PPCs are major contributors to perioperative morbidity and mortality. A thorough preoperative evaluation must identify high-risk patients, optimize chronic and acute respiratory diseases, and establish a clear perioperative plan to minimize PPCs.

Keywords Preoperative evaluation · Chronic obstructive lung disease · Asthma · Obstructive sleep apnea · Postoperative pulmonary complications

Introduction

The preoperative pulmonary evaluation consists of a thorough assessment of pre-existing respiratory diseases and estimation of the perioperative risk of respiratory complications. The goals are to prognosticate perioperative risk, to optimize pulmonary disease before surgery, and to plan perioperative care in order to minimize complications.

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PPCs have long been recognized as major contributors to perioperative morbidity and mortality both in thoracic and non-thoracic surgical patients. The definition of PPCs varies in the literature but generally includes atelectasis, respiratory infections, exacerbation of underlying lung disease, hypoxemia, and need for invasive or non-invasive mechanical ventilation. Its incidence also depends on the studied population and the perioperative and surgical practice but is generally estimated to be around 3–6%. Some studies report incidences similar or higher than cardiac complications, with significant association with long-term mortality [1••].

The patient's comorbidities and the effects of anesthesia and surgery may lead to a common pathophysiologic pathway that is shared by many of these complications. The residual effects of intravenous and volatile anesthetics, neuromuscular blocking drugs, opioids, and other respiratory depressants, combined with the pain, splinting, and diaphragmatic dysfunction caused by surgical trauma, lead to reduced lung volumes (functional residual capacity, vital capacity, and tidal

volumes) and reduced ability to clear secretions. This eventually results in atelectasis, ventilation/perfusion (V/Q) mismatch, hypoxemia, and increased risk of respiratory infections. This pathophysiologic process is particularly at play in thoracic and upper abdominal surgeries. Other perioperative events may also contribute to adverse respiratory events: micro-aspirations, excessive administration of fluids, blood product-related complications (e.g., transfusion-related acute lung injury), the systemic inflammatory response, and a relative state of immunosuppression [2].

Risk Factors for Postoperative Pulmonary Complications

Many risk factors associated with PPCs have been identified and relate to patient comorbidities, the type of surgery, and the anesthetic care as detailed in Table 1 [1••, 2, 5]. Another population that carries a significantly increased risk of pulmonary and cardiac complications as well as perioperative mortality is patients with pulmonary hypertension [6].

A quantitative estimation of the risk of PPCs allows more precise prognostication and may help in preparation for a safe management plan (e.g., choice of anesthetic, invasiveness, and location of postoperative monitoring). For that purpose, multiple risk stratification indices have been developed. Of those, the ARISCAT and Gupta risk calculators are relatively simple to use in clinical practice and have been validated prospectively. The ARISCAT score takes into account seven patient and surgery-related risk factors (Table 2) and is intended to predict the overall risk of PPCs defined as respiratory infection or failure, bronchospasm, atelectasis, pleural effusion, pneumothorax, or aspiration pneumonitis [7•]. Patients are stratified into low (score < 26 points), intermediate (score 26 to 44 points), and high risk (score ≥ 45 points). On an external validation study, predicted versus observed PPC rates for low, intermediate, and high-risk groups were 0.87 vs 3.39%, 7.82 vs 12.98%, and 38.13 vs 38.01% respectively, demonstrating good discrimination. The Gupta surgical risk calculator uses multiple risk factors derived and validated from the American College of Surgeons' National Surgical Quality Improvement Program (NSQIP) data to predict the risk of requiring mechanical ventilation more than 48 h after surgery or unplanned intubation within 30 days of surgery [8]. The calculator takes into account the surgical site, the

Table 1 Risk factors associated with PPCs

Patient-related risk factors
Age > 50 years old
Chronic obstructive pulmonary disease
Smoking (especially current smoking)
Obstructive sleep apnea
Heart failure
American Society of Anesthesiologists' Physical Status class ≥ 2
Functional dependence
Serum albumin < 3.5 mg/dL
Surgery-related risk factors
High-risk surgical site (intrathoracic, intraabdominal, head and neck, neurosurgery)
Duration of surgery > 3 h
Emergency surgery
Anesthesia-related risk factors
General anesthesia
Long-acting neuromuscular blockers and residual neuromuscular blockade [3]
Postoperative epidural analgesia (protective against PPCs) [4••]

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Table 2 The ARISCAT scoring system [7•]

Risk factor	Assigned points
Age	
≤ 50	0
51–80	3
> 80	16
Preoperative pulse oximetry saturation	
≥ 96%	0
91–95%	8
≤ 90%	24
Respiratory infection in the last month	
No	0
Yes	17
Preoperative hemoglobin ≤ 10 g/dL	
No	0
Yes	11
Surgical incision site	
Peripheral	0
Upper abdominal	15
Intrathoracic	24
Duration of surgery (hours)	
< 2	0
2–3	16
> 3	23
Emergency procedure	
No	0
Yes	8

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American Society of Anesthesiologists' Physical Status class, whether surgery is an emergency or not, the patient's functional status, and the presence of sepsis preoperatively. This tool can be accessed for free at www.qxmd.com/calculate-online/respirology/postoperative-respiratory-failure-risk-calculator or via mobile app.

For every patient, the perioperative risk must be balanced against the potential benefits of surgery. Even in patients with very severe pulmonary disease or considered high risk, no level of respiratory dysfunction should be viewed as an absolute contraindication to surgery.

Chronic Obstructive Pulmonary Disease

COPD is *a common, preventable, and treatable disease, characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases*, as defined by the Global Initiative for Chronic Obstructive Lung Disease [9]. By far, the most important risk factor associated with COPD is the amount and duration of cigarette smoking. Other risk factors include environmental or occupational exposures, genetic causes (α-1 anti-trypsin deficiency), and childhood illnesses (neonatal bronchopulmonary dysplasia, asthma). COPD is associated with chronic inflammation, parenchymal destruction, and enhanced airway reactivity that is not fully reversible. This leads to clinical manifestations including chronic bronchitis, emphysema, and asthmatic features.

In the proper clinical context, confirmation of diagnosis requires spirometry demonstrating a post-bronchodilator forced expiratory volume in 1 s (FEV_1)/forced vital capacity (FVC) ratio of less than 0.7, confirming airflow limitation that is not fully reversible. Severity of disease is then based on post-bronchodilator FEV_1 [9].

Medical management includes a combination of non-pharmacological interventions (smoking cessation, vaccination, pulmonary rehabilitation, and long-term oxygen therapy) and pharmacotherapy (inhaled and/or oral bronchodilators, inhaled glucocorticoids, and phosphodiesterase-4 inhibitors).

The preoperative assessment of COPD patients includes a thorough clinical history and physical examination to evaluate the patient's baseline symptoms and functional capacity and rule out active COPD exacerbation or respiratory infection. Reports of new or worsening shortness of breath, changes in cough and sputum, oxygen saturation lower than baseline, systemic signs of infection, active wheezing, or respiratory distress require further investigation. In these cases, strong consideration should be made to postponing elective surgery, referring the patient to his primary care physician or respirologist, or even directing the patient towards an emergency department for further evaluation and management.

Preoperative laboratory investigations are based on disease severity, current respiratory status, and the planned surgery. Recent pulmonary function testing (PFT) is warranted in patients with changes from baseline symptoms and patients undergoing lung resection surgery. In the majority of COPD patients, a preoperative arterial blood gas (ABG) analysis will not change perioperative management significantly. However, it may be useful in patients with known or suspected hypoxemia or hypercapnia (e.g., low oxygen saturation, elevated serum bicarbonate, and severe COPD) and those at increased risk of PPCs or need for postoperative mechanical ventilation. This helps establish a safe perioperative management plan including adequate postoperative monitoring, maintenance of P_aCO_2 levels close to baseline during mechanical ventilation, and targeted oxygen therapy. Other laboratory investigations are based on specific indications related to comorbidities, medications, and planned surgical procedure.

The potential value of preoperative chest radiograms (X-ray) is to identify abnormalities that would necessitate cancelation or modification of the perioperative plan and to serve as a baseline for comparison with postoperative abnormalities. However, current evidence does not support the routine use of preoperative chest X-rays as it rarely impacts perioperative care [10]. Nonetheless, it is reasonable to obtain a chest X-ray in COPD patients exhibiting changes from baseline status, those with other known cardiorespiratory comorbidities, and those over the age of 50 years old undergoing intrathoracic or major intraabdominal surgery [1••]. All chest radiologic examinations should be reviewed and features with specific perioperative concerns such as bullae should be noted.

Both preoperative patients with stable COPD and those presenting with exacerbations should be optimally managed according to most recent clinical guidelines [9]. For patients with a recent or prolonged course of glucocorticoids, perioperative supplementation may be indicated.

Asthma

Asthma is a chronic inflammatory airway disease characterized by bronchial hyper-responsiveness and airflow obstruction. The disease most commonly presents before age 20 with intermittent symptoms of bronchoconstriction (cough, wheezing, and dyspnea) and is characterized pathologically by chronic airway inflammation, bronchial smooth muscle hypertrophy, increased secretions, and luminal narrowing. Specific triggers of bronchoconstriction may be identified such as exercise, emotional stress, irritants (e.g., smoke, dust), medications (e.g., aspirin, non-steroidal anti-inflammatory drugs, and β-blockers), or respiratory tract infections. The diagnosis is primarily confirmed by spirometry and usually shows variable expiratory airflow obstruction and significant

improvement (i.e., more than 12% and 200 mL increase) in FEV_1 with bronchodilators. However, normal spirometry does not exclude the diagnosis of asthma and bronchoprovocation testing (e.g., methacholine challenge) may be required [11, 12••].

The long-term goals of asthma therapy are to achieve good chronic symptom control and to minimize the risk of exacerbations and need for emergency care via both non-pharmacological (e.g., smoking cessation, trigger avoidance, immunotherapy, and vaccination) and pharmacological options. Pharmacological management of asthma is introduced in a stepwise approach starting with short-acting β_2 agonists and escalating as needed with inhaled and oral corticosteroids, long-acting β_2 agonists, oral bronchodilators (e.g., theophylline), and leukotriene modifiers. Additional options include anti-IgE therapy (i.e., omalizumab) for patients with allergic sensitivity and anti-IL-5 antibodies for patients with eosinophilic asthma [11].

Most studies have reported low perioperative risk of PPCs in patients with asthma [1••, 13]. This observation may be partly related to the confounding effect of a younger age and reduced comorbidities in this patient population. Nevertheless, the peri-anesthetic period can be associated with life-threatening bronchospasm and status asthmaticus, particularly during airway manipulation and endotracheal intubation. Therefore, preoperative evaluation is essential and should ideally be scheduled a few weeks prior to elective surgery to allow sufficient time for medical optimization.

Even patients with severe asthma can be asymptomatic at the time of presentation to the preoperative clinic. It is essential to elicit a detailed history of the disease, with particular attention to perioperative adverse events, specific triggering factors, previous exacerbations, need for hospitalizations, and mechanical ventilation. The patient's current pharmacotherapy, including use of systemic or high-dose inhaled glucocorticoids and need for short-acting rescue bronchodilators, is reviewed. Asthma control should be assessed and clues to poorly controlled disease include daytime symptoms more than twice/week, nighttime awakening, use of short-acting bronchodilators for symptom relief more than twice/week, and limitation in activity [11]. As with other chronic respiratory illnesses, evidence of recent respiratory tract infection (fever, change in cough, or sputum) warrants further evaluation before surgery.

Physical examination focuses on signs of active bronchoconstriction or respiratory tract infection. Pulmonary auscultation is performed to rule out prolonged expiratory phase, wheezing or diminished/absent breath sounds indicative of ongoing expiratory airflow obstruction. With longstanding respiratory disease and hypoxemia, evidence of pulmonary hypertension and right heart failure may be present.

PFTs are usually normal in between asthma attacks but are indicated if there is doubt about the degree of asthma control or for lung resection surgery. A chest radiograph will usually not alter perioperative management unless indicated by concerns of pulmonary infection or other comorbidities. Similarly, ABG analysis is typically normal in asymptomatic patients. Use of high doses of β_2 agonists may result in hypokalemia and hypomagnesemia and these parameters should be tested if needed. Further investigations are guided by history and physical examination.

For elective surgery, asthmatic patients with active wheezing or clues to poorly controlled asthma need to be optimized and referral to an asthma specialist may be beneficial. A short course of systemic glucocorticoids (e.g., methylprednisolone 40 mg per day orally for 5 days) combined with preoperative bronchodilators may be beneficial in non-compliant patients or those with newly diagnosed asthma and has been shown to decrease the risk of post-intubation wheezing in a small randomized controlled trial [14]. In patients with well-controlled disease, current therapy is maintained up to the time of surgery. Some authors have expressed concerns regarding the perioperative use of xanthine derivatives such as theophylline due to various drug interactions and the risk of ventricular arrhythmias, particularly during halothane administration [15]. However, this is much less of a concern with the advent of newer and less arrhythmogenic inhalational anesthetic agents. Asthmatics taking oral or high-dose inhaled steroids may be at risk of hypothalamo-pituitary-adrenal suppression and perioperative stress doses should be considered.

The day of the surgery, judicious anxiolytic premedication may be beneficial, as painful procedures before anesthesia induction have the potential to trigger bronchospasm. Additionally, in cases where airway manipulation may be required, we routinely administer 2 to 4 puffs of short-acting β_2 agonists before induction of anesthesia.

Obstructive Sleep Apnea

OSA is characterized by repetitive episodes of apnea or hypopnea resulting from upper airway obstruction during sleep. There is wide variation in the reported prevalence of the disease, depending on the study population and the diagnostic methods, but it is certainly the most common type of sleep-disordered breathing, affecting 10–25% of the population [16]. The disease is strongly associated with multiple comorbidities including systemic hypertension, pulmonary hypertension, coronary and cerebrovascular disease, arrhythmias, and heart failure. Of specific concern to the perioperative period, undiagnosed OSA may be present in a significant proportion of patients presenting for surgery [17]. Multiple studies have confirmed that OSA is associated with increased perioperative risk, including higher risk of PPCs, adverse

cardiac events, intensive care admission, and prolonged length of stay [18, 19]. The general management of OSA includes education, weight loss, alcohol abstinence, and positive airway pressure (PAP) therapy in an attempt to improve sleep quality, nocturnal oxygen saturation, and long-term cardiovascular risk.

Identification of OSA before surgery is therefore essential and screening should be performed on all patients. The gold standard for diagnosis of OSA is overnight polysomnography with determination of the apnea-hypopnea index (AHI, i.e., the number of abnormal respiratory events per hour of sleep) in accordance to the American Academy of Sleep Medicine [20]. However, this diagnostic technique is time-consuming, costly, and often poorly accessible, making it inconvenient in the preoperative setting. Consequently, multiple screening tools have been developed and validated. One of the most studied and clinically used screening tool in surgical patients is the STOP-Bang questionnaire [21]. It consists of 8 "yes" or "no" responses to questions related to the following risk factors: **S**noring, **T**iredness, **O**bserved apnea, high blood **P**ressure, **B**MI > 35 kg/m^2, **A**ge > 50 years, **N**eck circumference > 40 cm, and male **G**ender. Each "yes" answer adds 1 point to a total score ranging from 0 to 8. Using a cut-off score of ≥ 3 to predict moderate and severe OSA, the test has a sensitivity of 87% and a specificity of 31%. As the STOP-Bang score increases from 0 to 2 to 7–8, the probability of severe OSA rises from 4 to 38%. Its modest specificity may yield a relatively high rate of false positives (leading to potentially unnecessary diagnostic testing and treatment) but may be improved using a two-step algorithm [21].

Preoperative evaluation of patients with confirmed OSA includes assessment of severity of the disease and adequacy of management. The severity of OSA based on AHI, the settings of PAP device, the problems with adherence to treatment, and the residual symptoms should be documented. Additionally, OSA-associated conditions of particular perioperative concern such as airway abnormalities, obesity, cardiovascular disease, and gastroesophageal reflux should be evaluated.

In patients with undiagnosed and untreated OSA, the decision to delay surgery and direct the patient towards formal diagnosis and treatment must take into account the urgency and overall risk of the planned procedure as well as the perceived risk and severity of suspected OSA and associated comorbidities. According to the recent Society of Anesthesia and Sleep Medicine Guidelines, current literature does not provide evidence to support canceling or delaying surgery unless the patient demonstrates evidence of uncontrolled systemic disease or additional problems with ventilation or gas exchange [22••]. Of particular concern are patients showing signs and symptoms of obesity-hypoventilation syndrome (e.g., hypersomnolence, resting hypoxemia, and elevated serum bicarbonate) or pulmonary hypertension (e.g., exertional dyspnea, signs of right ventricular dysfunction). In these cases, preoperative cardiopulmonary assessment (ABG analysis, formal sleep study, and echocardiography) and optimization should be strongly considered. More generally, the rationale for diagnostic confirmation and initiation of treatment prior to surgery comes mostly from non-surgical trials demonstrating improvement in systemic blood pressure, nighttime oxygen saturation, and AHI in patients treated with CPAP [23, 24], although the long-term cardiovascular benefit is still unproven [25]. One perioperative randomized controlled trial found that auto-titrated PAP initiated only 2–3 days before surgery and continued after surgery reduced the AHI on the third postoperative night, despite a low compliance rate to the device (45%) [26]. However, another randomized trial failed to show significant improvements in clinical outcomes with postoperative auto-titrated PAP in patients at high risk of OSA [27].

When the decision is made to proceed to surgery without additional evaluation, a strategy should be implemented to minimize postoperative complications [22••]. The perioperative care team should be made aware that the high probability of OSA increases perioperative risk. Useful management options include regional anesthesia and analgesia, use of short-acting anesthetics, opioid-sparing analgesic methods, and careful postoperative monitoring. The patient should be directed for further evaluation of sleep-disordered breathing after surgery.

Patients with diagnosed OSA should be instructed to bring their personal PAP device to the hospital the day of surgery and to wear it at appropriate times during the perioperative period [22••].

The suitability of ambulatory surgery in patients with known or suspected OSA remains controversial. The decision to schedule outpatient surgery is made on a case-by-case basis, considering the patient's comorbidities, the planned procedure and anesthetic, the severity of OSA, and the requirements for postoperative opioids and sedatives. Ambulatory surgery is generally considered safe in OSA patients with optimized comorbidities who are able to use their PAP appropriately after discharge and do not require a significant amount of opioids [28].

Perioperative Management for Minimizing PPCs

In high-risk patients, once a thorough pulmonary evaluation has been performed, a clear perioperative strategy should be established to reduce PPCs.

The patient's underlying respiratory disease should be optimized as time permits. Respiratory tract infections should be treated and strong consideration should be made to postponing elective surgery (ideally for 6 weeks), as airway reactivity may

persist past elimination of the infectious pathogen. The preoperative consultation offers an excellent opportunity to promote smoking cessation. The current literature does not provide evidence of harm related to preoperative short-term smoking cessation [29]. An intensive smoking cessation strategy has been shown in meta-analyses to reduce pulmonary and wound-healing complications and improve long-term abstinence [30, 31]. Smoking cessation management may include pharmacotherapy (e.g., nicotine replacement, varenicline) and behavioral interventions. Preoperative chest physical therapy and inspiratory muscle training may also reduce PPCs in high-risk patients [32, 33].

Particular anesthetic management strategies should be considered to minimize pulmonary complications. When both general anesthesia and regional/neuraxial anesthesia are appropriate and safe, the latter is favored to avoid the adverse respiratory effects of general anesthetics, neuromuscular blockers, and airway manipulations. A recent large retrospective study based on the NSQIP database demonstrated reduced rates of postoperative pneumonia, ventilator dependence, and unplanned postoperative intubations in COPD patients receiving regional compared to general anesthesia [34••]. When general anesthesia is employed, judicious titration of short or intermediate acting neuromuscular blockers and complete reversal of neuromuscular blockade at the end of the surgery is key [3]. A lung-protective ventilation strategy with low tidal volume, moderate levels of positive end-expiratory pressure, and recruitment manoeuvers has been shown to reduce pulmonary complications and length of hospital stay in intermediate- to high-risk patients undergoing abdominal surgery [35••]. It is also prudent to minimize the amount of fluids administered, particularly in patients at risk of perioperative lung injury and pulmonary edema [36]. Minimally invasive surgical techniques (e.g., laparoscopic or video-assisted versus open surgery) minimize certain adverse pathophysiologic processes discussed earlier and should be considered, if surgically appropriate.

In the postoperative period, adequate pain control is essential to allow early patient mobilization, deep-breathing, and clearing of respiratory secretions. Regional anesthesia techniques with potential opioid-sparing effects may be used when safe and appropriate. Epidural analgesia has been shown to reduce the rates of pneumonia and respiratory failure in randomized trials in major surgery [4••, 37]. Chest physiotherapy, deep-breathing exercises, and incentive spirometry may provide respiratory benefits with minimal adverse effects and cost. Routine use of nasogastric tubes after abdominal surgery has been associated with increased risk of atelectasis and pneumonia and should be used only in patients who develop a specific indication for it (e.g., postoperative nausea and vomiting, inability to tolerate oral intake, and abdominal distention) [38].

Conclusions

Postoperative pulmonary complications arise from expected pathophysiologic changes associated with anesthesia and surgical trauma along with predisposing patient-related factors. They are significant contributors to perioperative morbidity and mortality. The preoperative pulmonary evaluation is a complex process that may require the involvement of a multidisciplinary team in order to properly estimate perioperative risk, optimize underlying respiratory disease, and establish a care plan to minimize PPCs.

Compliance with Ethical Standards

Conflict of Interest Florin Costescu and Peter Slinger declare they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any original studies with human or animal subjects performed by any of the authors.

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