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REVIEW ARTICLE

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Preoperative pulmonary evaluation to prevent postoperative pulmonary complications

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Abstract

Postoperative pulmonary complications (PPCs) arise from a complex interplay of patient, surgical, and anesthesia-related factors. Despite their significant impact, there are currently no standardized guidelines recommending a comprehensive preoperative approach to assessing patients with PPC risk factors. Preoperative pulmonary evaluation (PPE) plays a pivotal role in identifying underlying patient conditions, undiagnosed diseases and optimal treatments. PPE involves systematic identification of patient, surgical, and anesthesia-related risk factors. Severe PPCs include atelectasis, pneumonia, respiratory failure, pulmonary embolism, and worsening chronic lung disease. Surgical urgency, type, duration, approach of the surgical procedure, and comorbidities influence PPC rates, with cardiac, thoracic, abdominal, and vascular surgeries being particularly vulnerable.

Patient-related risk factors encompass non-pulmonary and pulmonary factors. Aging populations increase surgical demand, with advanced age and frailty predicting higher morbidity and mortality risks. Conditions like congestive heart failure, obesity, obstructive sleep apnea, and smoking heighten PPC risks. Asthma, chronic obstructive pulmonary disease, interstitial lung diseases, pulmonary hypertension, previous pulmonary thromboembolism, acute respiratory infections, and COVID-19 impact pulmonary risk profiles. Surgery and anesthesia-related risk factors include the site of surgery, operation time, and emergency surgery. Surgery near the diaphragm elevates PPC risk, while longer operation times correlate with increased PPC incidence. Emergency surgeries pose challenges in risk assessment. Anesthetic techniques influence outcomes, with regional anesthesia often preferable. Neuromuscular blocking agents impact PPCs, and protective ventilation strategies can mitigate complications.

As current literature lacks a comprehensive approach to PPE, in this review, we present a comprehensive approach to preoperative pulmonary approach to surgical patients to help in risk stratification, further optimization, as well as shared decision making between the surgeon and the patients and their family prior to consenting for a major surgical procedure.

Keywords Postoperative pulmonary complications, Perioperative care, Preoperative procedures, Preoperative pulmonary evaluation, Preoperative pulmonary risk assessment, Risk factors, Smoking cessation, Sleep apnea syndromes

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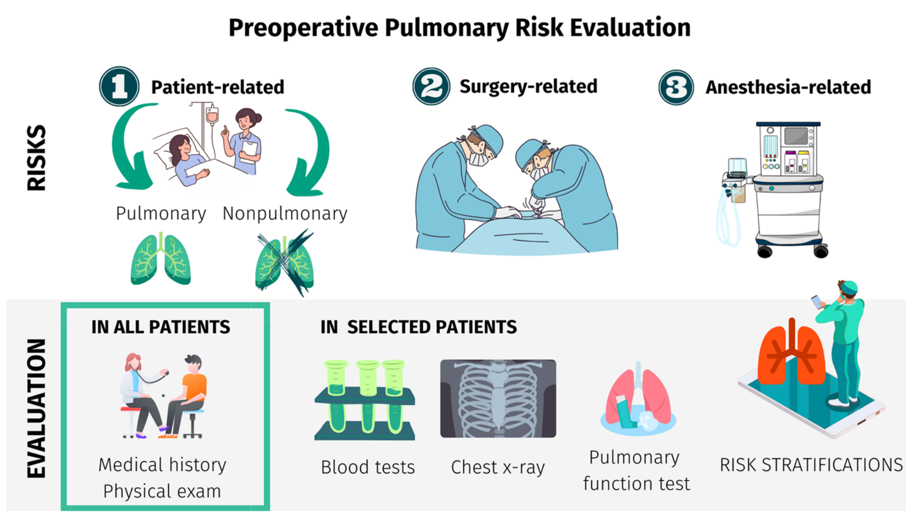
Graphical Abstract



1 Introduction

The landscape of major surgeries has witnessed a substantial surge, with a 34% increase between 2004 and 2012, encompassing nearly 5% of the global population, predominantly involving non-cardiac procedures [1, 2]. Many of these procedures are carried out in nations that spend a significant amount of money on healthcare per capita. This number, when extrapolated to the 27 member states of the European Union (and their combined population of 448 million in 2020), corresponds to a rough estimate of nearly 22 million major procedures performed annually. In 2020, the combined population of these countries is projected to be 448 million [3]. The urgency, type, duration, and approach of the surgical procedure, as well as the prevalence of comorbidities, all play a role in the likelihood of peri-operative complications. Within this context, preoperative pulmonary evaluation (PPE) emerges as a critical opportunity for optimizing perioperative outcomes. The significance of this evaluation stems from its potential to identify patient-specific risk factors, guide surgical and anesthetic decisions, and reduce the occurrence of postoperative pulmonary complications (PPCs) [4]. However, the challenge lies in comprehensively assessing these factors across diverse patient populations, surgical types, and clinical settings PPE is a methodical approach that identifies risk variables connected with the patient, the surgery, and the anesthetic that have a role in the development of PPCs [5].

In acknowledging the prevailing gap in surgical research, it's evident that while strides have been made in preventing PPCs, gaps and challenges persist. The primary goal of PPE is to identify patients are susceptible to PPCs and subsequently reduce morbidity and mortality [5]. PPCs are a significant clinical concern in current practice, competing in terms of frequency and severity with perioperative cardiac morbidity in non-cardiac surgery [6]. The incidence of PPCs varies according on the type of surgery: PPCs are most common in cardiac surgery (40%), followed by thoracic (30%), abdominal (7%), and vascular (6%) surgery [7]. In addition to this, PPCs have been associated to roughly 25 percent of postoperative mortality during the first week after surgery [8]. They are also predictors of short- and long-term health outcomes after surgery, as well as a higher probability of being admitted to critical care and staying in the hospital for a prolonged amount of time [9, 10]. In addition, PPE is helpful for making decisions about surgery, anesthesia, timing, patient consent, and shared decision making. When making decisions about the risks and benefits of surgery, it is crucial to take the patient's values and preferences into account. This is especially vital when deciding whether to have elective surgery, when to have it, and which surgical and anesthetic methods to use.

PPCs refer to a variety of respiratory disorders that often appear within the first week following surgery [11]. The most severe and morbid PPCs include atelectasis, pneumonia, respiratory failure, pulmonary embolism, and deterioration of pre-existing chronic lung disease [12]. There is some overlap between several PPCs definitions; nevertheless, this overlap is insufficient to provide reliable comparisons. For instance, one study defined postoperative pneumonia as increased sputum, presence of radiological opacity on chest radiograph and computerized tomography, fever, elevated white blood cell (WBC) count, and C-reactive protein increase [13], whereas another study defined it as fever, productive cough, elevated WBC count, and localized findings on chest examination or chest radiograph [14]. In the realm of perioperative medicine, efforts have been made to create standard criteria for PPCs to be utilized in randomized research [15–17].

Because PPCs are linked with mortality, efforts in the evaluation of perioperative risk factors, as well as quality and process improvement in surgery should be addressed toward PPCs prevention [9, 18]. Although new evidence is constantly emerging in this area, randomized controlled trials are scarce in comparison to non-surgical settings.

In this narrative review, we aimed to delve into the multifaceted realm of PPE, encompassing non-pulmonary and pulmonary risk factors, surgery- and anesthesia-related considerations, and the role of preventive strategies. By synthesizing insights from recent research, systematic reviews, guidelines, randomized controlled trials, and meta-analyses, this review aims to present a comprehensive understanding of PPE's role in preventing PPCs.

We searched for articles published in the last ten years that included the phrases "perioperative pulmonary evaluation" and "postoperative pulmonary complication" or their variants in Web of Science, PubMed, and Google Scholar. We paid special attention to systematic reviews and guidelines, as well as the articles they cited, and to randomized controlled trials and meta-analyses.

2 Preoperative pulmonary risk evaluation

To ascertain the patient's level of risk before surgery and the necessary precautions in terms of preoperative preparation, anesthetic management, and optimization of medical comorbidities, preoperative assessment is essential (Fig. 1). Getting a thorough medical, surgical, familial, and social history should be the initial step, followed by a thorough physical examination. Wheezing, hemoptysis, dyspnea, exertional dyspnea, paroxysmal nocturnal dyspnea, orthopnea, and upper respiratory tract infection symptoms (rhinorrhea, postnasal drip, and sore throat) should all be questioned when assessing pulmonary symptoms, along with cough, purulence, color, and amount of sputum, if any. The incidence of post-operative PPCs rises by 5.34 times on average when there are respiratory symptoms [19]. It is critical to evaluate the presence, severity, and stability of current chronic medical conditions. In this scenario, the medical complexity of surgical patients is increasing, and medical specialties are commonly asked to assist with perioperative surgical patient management [20]. Further testing is required when there is any evidence of pre-existing pulmonary

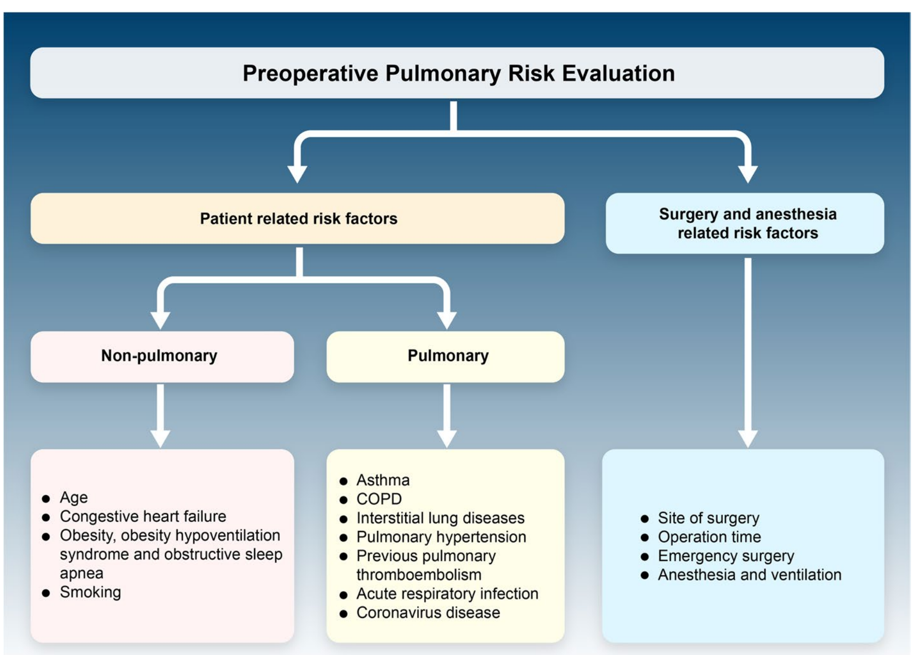


Fig. 1 Preoperative pulmonary risk evaluation. It includes risk factors associated with the patient, both pulmonary and non-pulmonary, as well as risk factors associated with surgery and anesthesia. COPD, chronic obstructive pulmonary disease

disease, evidence of active pulmonary symptoms, or the presence of other comorbidities that may increase the risk of postoperative pulmonary complications like cardiac disease, congestive heart failure, functional dependence, regardless of the type of operation, duration, or age of the patient [21].

2.1 Preoperative tests

Typically, a medical history and physical examination are enough to determine the pulmonary risk associated with surgery. Blood tests, chest radiography, and pulmonary function testing should only be performed if the results might influence the initial evaluation approach [22]. Chest radiography rarely identifies an unexpected or unknown problem aside from the patient's history [23].

Arterial blood gas (ABG) testing is rarely needed in the routine preoperative evaluation of a surgical patients with pulmonary risk factors, expect in cases of suspected respiratory failure or to confirm SpO_2 values, ascertain elevated CO_2 levels, and differentiate between acute and chronic changes. Elevated preoperative $PaCO_2$ levels could assist in identifying obesity hypoventilation syndrome, enabling the implementation of preoperative positive airway pressure therapy for at-risk patients, potentially leading to reduced morbidity and mortality. [24]. Baseline oxygen saturation and PaO_2 values, in addition to hemoglobin levels, can help determine oxygen administration and plan perioperative (supplementary) oxygen and blood replacement. [23]. The measurement of SpO_2 is an easy and non-invasive method of determining the oxygen balance of the patient [23]. Values of preoperative SpO_2 below 90% are related with at least one lung problem, making it a reliable predictor of the presence of PPCs [25].

Although there is consensus about the usefulness of spirometry prior before lung resection and in identifying whether or not a patient is a candidate for coronary artery bypass surgery, the use of the test in prior to extrathoracic surgery has not been proven [26]. When evaluating a patient for thoracic surgery, the forced expiratory volume measured in one second (FEV_1) is an important assessment tool. However, its value for the other surgeries remains to be elucidated.

The cardiopulmonary exercise test (CPET) is used to evaluate oxygen transport abnormalities that are masked during rest. When used as a screening test in patients undergoing cardiothoracic and nonthoracic surgery, it was found to predict mortality. The shuttle walk and 6-min walk tests are concise to perform although mostly subjective. As a result, CPET has established itself as the gold standard for determining fitness prior to surgery. CPET calculates maximum oxygen consumption, a cardiorespiratory fitness indicator that can be used to predict a patient's ability to tolerate certain thoracic surgical procedures [8, 27, 28]. However, CPET is not widely available, requires specialized training, and more research is needed to determine its usefulness for other types of surgical procedures.

Serum albumin levels below 3.5 mg/dL are a significant risk factor for PPCs [12]. Increased risk for PPCs has been linked to a high blood urea nitrogen (BUN) level (> 30 mg/dL) [26]. The risk of PPCs is raised by having low serum hemoglobin (hemoglobin concentration lower than 10 g/dl), which also has implications for the anesthetic strategy and fluid/blood replacement during the perioperative period [23, 25].

2.2 Patient related risk factors

2.2.1 Non-pulmonary risk factors

Age The need for surgical services increases as a country's population ages. More than half of all surgical procedures in the United States are done on patients aged 65 and over. [29]. The peri-operative care of patients will be drastically altered by the aging of the population in the next 30 years. Patients undergoing non cardiac surgery tend to be of a more senior demographic. In addition, it is predicted that by the year 2030, one in five people aged 75 and up will have surgery annually[3]. Elderly patients, on average, require more care and incur higher perioperative costs than younger patients [30]. It's been known for some time that people of advanced age may have a higher risk of mortality and morbidity after surgery. New research has shown that frailty, the gradual decline in several physiological systems that comes with aging, is an even better predictor of mortality and morbidity than chronological age alone. Individuals in the same age group do not all share the same risk profile [31].

As we age, our respiratory systems undergo several changes that may increase our vulnerability to PPCs. Alveolar dead space and air trapping (senile emphysema) increase, but compliance of the chest wall and FEV_1 decrease with age. Respiratory failure is more likely to occur in elderly individuals during periods of high demand because of their impaired breathing response to hypoxia and hypercapnia (e.g. heart failure, pneumonia, etc.) [32].

Congestive heart failure Congestive heart failure (CHF) is a common cause of PPCs, which affects 10% of those over the age of 65 [33]. It is an independent risk factor for PPCs and is linked to a higher frequency of postoperative respiratory failure [25, 34]. In a systematic review, CHF found as a substantial risk factor for PPCs (OR (Odd Ratio), 2.93; 95% CI (confidence interval), 1.02–8.43) [26].

Obesity, obesity hypoventilation syndrome and obstructive sleep apnea Obesity significantly impacts PPCs [35, 36], as surgical procedures can reduce lung volumes [37], further exacerbated by obesity-related factors. Ventilating obese patients following surgery presents challenges because of restrictive adiposity, potential comorbidities like asthma or sleep apnea, and altered pharmacokinetics. Inaccurate tidal volume calculations due to weight predictions using height worsen the issue, potentially leading to inappropriate ventilation settings [38, 39]. Managing PPCs in obese patients requires tailored strategies considering their unique respiratory mechanics and associated conditions. Obesity is a key risk factor for sleep-disordered breathing such as obesity hypoventilation syndrome (OHS) and obstructive sleep apnea (OSA) [40]. While many anesthesiologists are familiar with the guidelines for managing for surgical patients with OSA, anesthesiologists or surgeons may miss or delay the diagnosis of OHS [41]. Studies show that 11% of persons who have OSA also have OHS, and that around 90% of those who have OHS also have OSA [42]. Both OHS and OSA have the potential to contribute to pulmonary hypertension and right heart dysfunction. Those suffering from this disease are at a very high risk of respiratory failure, mechanical ventilation, and a long stay in an intensive care unit [43].

Smoking Smokers have a greater risk of substantial morbidity in the perioperative period, including surgical site infection, intensive care unit admissions, neurological diseases, and septic shock. Additionally, the 30-day mortality rate for smokers is higher than the rate for non-smokers [44, 45]. Cigarette smoking is an independent risk factor for the development of PPCs irrespective of absence of underlying chronic lung disease. According to the 2006 American College of Physicians analysis, smoking cessation may enhance short-term pulmonary risk due to greater mucus production from improved mucociliary function and less coughing from less bronchial irritation [12]. Concerns over increased sputum production leading to higher pulmonary problems following smoking cessation were disregarded in a recent meta-analysis [46]. Smoking cessation for more than four weeks reduces PPCs by 23%, and cessation for more than eight weeks reduces PPCs by 47%, with research indicating that PPCs are decreased as preoperative smoking cessation duration is earlier [47, 48]. According to one study, all clinicians should consider surgery as a "teachable moment" to quit smoking [49].

2.2.2 Pulmonary risk factors

Asthma Determining whether or not the patient's asthma is under control is the first stage in the preoperative evaluation The presence of wheeze during a physical examination and/or poorly controlled asthma are both risk factors for PPCs [50]. Thorough preoperative examination, medication, and safe anesthetic protocols throughout the perioperative phase are the keys to reducing complications. Elective surgery should be postponed until the asthma control is achieved [51]. Asthma emergency visits, hospitalizations, intensive care unit stays, intubation, and a history of systemic corticosteroid usage are all independent contributors to severe postoperative complications in asthma patients and should be addressed by the anesthetist prior to surgery [52]. In a study, 29 (7.0%) of 346 asthmatics had PPCs mild/moderate bronchospasm, which improved with treatment. PPCs significantly were associated with poor control scores. In the univariate analysis, PPCs were risked by longer operation times. Smoking history > 20 pack-years, peripheral blood eosinophil count > 200/mm^3 and GINA STEP > 3 were PPCs risk factors in asthma patients in multivariate analysis [52].

Chronic Obstructive Pulmonary Disease Prior to surgery, evaluation of patients with Chronic Obstructive Pulmonary Disease (COPD) helps to ascertain their baseline symptoms and functional level and rule out recent COPD exacerbation or infection. Depending on the disease severity, the patient's present respiratory condition, and the intended operation, preoperative laboratory tests should be carried out [53]. Testing on a routine basis is not necessary in people who have chronic COPD that is stable. A chest radiograph, spirometry, or an ABG analysis may be useful in the case that new symptoms develop or if the physical examination reveals abnormalities [4]. COPD is a separate risk factor that can increase the likelihood of complications and even mortality after surgery. Having surgery involving the cardiothoracic surgery increases this risk [54, 55]. In a study Seven (7.9%) of the 89 COPD patients had PPCs, primarily pneumonia with respiratory failure. The following PPCs risk factors were associated with COPD: age, the introduction of COPD treatment, upper abdominal surgery, and an operation time ≥ 5 h [52].

Interstitial lung diseases Patients with interstitial lung disease (ILD) who undergo surgery are considered extremely high risk due to their significant burden of comorbidity, clinical progression of their underlying disease, and increased susceptibility to postoperative acute exacerbations, all of which contribute to increased mortality. Despite the scarcity of data on cardiac surgery outcomes in ILD patients, poor results in ILD patients after non-cardiac surgery have been reported [56–58]. ILD-related PPCs risk factors include preoperative hypoxemia, rapidly progressive ILD, emergency surgery, male gender, advanced age, recently diagnosed disease, and ILD due to connective tissue disease [4]. Depending on the study, PPCs rates in individuals with ILD who have surgical lung biopsy and lung cancer excision might be anywhere from 0 to 66%. Many PPCs are caused by acute exacerbations, which have extraordinarily high fatality rates that can be directly attributed to their severity [59].

Pulmonary hypertension Patients with pulmonary hypertension (PH) who are sedated for surgical operations, particularly those with pulmonary arterial hypertension (PAH) and chronic thromboembolic PH (CTEPH), have a greatly higher risk of complications, including death. Tachycardia, hypotension, third space fluid movement, and an increase in pulmonary vascular resistance (PH crisis) can all lead to acute right ventricular decompensation and mortality [60]. In group 3 PH having the condition as a result of chronic lung disease (such as COPD, ILD, or overlap syndromes) or hypoxemia (from diseases like OSA or alveolar hypoventilation disorders), aggressive treatment of the underlying condition is needed [61]. The therapies include smoking cessation, inhaler medication, anti-fibrotic or anti-inflammatory treatments suitable for ILD, diuretics, oxygen therapy, and vaccination. Patients in group 4 with CTEPH require anticoagulant medication on an ongoing basis. Because pulmonary thromboendarterectomy is a potentially curative surgical therapy, thorough imaging and interdisciplinary pulmonary vascular evaluation of anatomical distribution are required [62, 63]. When assessing peri-operative risk in PAH patients, patient-related and surgery-related factors should be considered [64]. Because anesthesia and surgery can be complicated by acute right heart failure and pulmonary hypertensive crisis, elective surgery in PAH patients should be thoroughly discussed in a multidisciplinary team. Patients with PAH undergoing surgery should ideally receive optimal medical treatment prior to surgery and be managed in a PAH-experienced center[65]. Patients who are scheduled for surgery should consult with a pneumologist, cardiologist, surgeon, and anesthesiologist [66].

Consideration of undiagnosed PH may also be useful in the preoperative evaluation. In diagnosing PH, a three-step approach is recommended: suspicion, detection, and confirmation [65]. The initial step may raise a suspicion of a cardiac or respiratory disorder as the cause of the symptoms, with dyspnea upon increasingly mild exertion being the cardinal symptom. The second step consists of conventional, noninvasive lung and cardiac testing. Among these tests, echocardiography is a crucial step in the diagnostic algorithm because it assigns a probability of PH regardless of the underlying cause. In addition, it is a crucial step in the identification of other cardiac disorders. In the third step, patients should be referred to a PH center for further evaluation in the following circumstances: (1) when an intermediate/high probability of PH is determined; (2) when risk factors for PAH or a history of pulmonary embolism are present [65].

Previous pulmonary thromboembolism If anticoagulation is stopped within three months following thromboembolism, there is a substantial risk of recurrent thromboembolism in the perioperative period. Early withdrawal of anticoagulation in the first month following acute venous thromboembolism (VTE) is expected to be related with 40% of the risk of recurrent VTE at one month and 10% for the next two months. After three months of anticoagulant medication, the annual incidence of recurrent VTE is reduced to 15% [67, 68]. As a general rule, patients who have been diagnosed with VTE should wait at least three months before undergoing elective surgery [69]. If surgery is required immediately in the case of acute VTE, a temporary inferior vena cava filter is indicated. However, inferior vena cava filter insertion is not necessary for a small surgery like central venous catheter implantation, which can be achieved by skipping an anticoagulant dose [70].

Acute respiratory infection No concrete recommendations exist for the management of pneumonia in surgical patients; thus, surgeons may be recommended to postpone elective procedures for their patients who develop a significant infection [71]. Patients with postoperative respiratory failure were much more likely to have been treated for pneumonia prior to surgery than patients without postoperative respiratory failure [72]. Postoperative deep vein thrombosis and pulmonary embolism were more common in individuals with preexisting pneumonia who underwent major general surgery [73]. A retrospective cohort study was conducted using data from the American College of Surgeons National Surgical Quality Improvement Program Database from 2008 to 2012. Preoperative pneumonia patients were matched with controls who did not have the disease. Preoperative pneumonia has been proven to significantly increase the incidence of postoperative morbidity and mortality in a range of surgical settings and patient demographics, thus elective surgery should be postponed until the pneumonia resolves [71].

Coronavirus disease The global epidemic of Coronavirus Disease (COVID-19) has seriously affected surgical procedures all over the world. In numerous studies, several researchers have noticed and commented on the impact of the present crisis on outpatient surgical services, elective surgery, and emergency operations. The increased surgical risks associated with SARS-CoV-2 infection must be evaluated against the delay in surgery during preoperative assessment [65]. There is compelling evidence linking COVID-19 surgery to considerable incidence of postoperative complications, particularly those of a pulmonary or thrombotic character [66, 67]. The patients who underwent surgery during SARS-CoV-2 infection had a greater risk of postoperative pneumonia, respiratory failure, pulmonary embolism, and sepsis. Surgery in the early post-COVID-19 period was related with a higher risk of postoperative pneumonia, but surgery in the late COVID-19 period was not [74].

2.3 Surgery and anesthesia-related risk factors

2.3.1 Site of surgery

The risk of PPCs can be best predicted by the location of the surgery [75]. The likelihood of developing PPCs decreases with increasing distance from the incision to the diaphragm during surgery. It is well established that diaphragmatic dysfunction is a cause of PPCs, and that this dysfunction is a direct result of major abdominal surgery, especially upper abdominal procedures [76, 77]. In predicting whether diaphragmatic dysfunction will occur, the surgical site is more important than the surgical technique. A laparotomy with an incision in the upper abdomen may raise the incidence of PPCs by up to 15 times compared to an incision in the lower abdomen [78]. Laparoscopic surgery leads to fewer PPCs for both upper and lower gastrointestinal procedures than open surgery. Laparoscopic procedures induce less pain, less impairment in abdominal and diaphragmatic muscle action, and less postoperative pain, resulting in a faster recovery [79–83].

2.3.2 Operation time

Between 2005 and 2012, 5.8% of 165, 196 patients who had major abdominal surgery acquired PPCs. Their mean surgery time and anesthetic duration were substantially longer than the group without PPCs. However, the type of anesthetic employed in the two groups did not differ significantly [75]. Longer surgical times have been proven to be an independent predictor of PPC [84]. A multicenter cohort study involving 268 major elective abdominal operations found that the incidence of PPCs increased with each minute of operating time [85].

2.3.3 Emergency surgery

Because patients cannot be medically optimized before to surgery, emergency surgery has been linked to the development of PPCs [86]. A preoperative pulmonary risk assessment is often ineffective in patients receiving emergency surgery since the procedure must be performed regardless of the risk [87].

2.3.4 Anesthesia and ventilation

Studies comparing the increased risk of pulmonary problems associated with general anesthesia against spinal or epidural (neuraxial) anesthesia have yielded inconsistent findings [88–90]. When both general anesthesia and regional/neuraxial anesthesia are safe and acceptable, regional/neuraxial anesthesia is recommended to minimize the unfavorable respiratory effects of general anesthetics, neuromuscular blocking agents (NMBAs), and airway manipulations [91].

The use of NMBAs for surgical relaxation may be a major cause of pulmonary complications including postoperative hypoxemia. This is due to the presence of residual neuromuscular block [92]. Their use of during anesthesia is related with an increased incidence of PPCs, regardless of dose, according to a prospective European cohort analysis of 22,803 surgical patients receiving general anesthesia for non-cardiac surgery [93]. Nondepolarizing NMBAs with short or intermediate half-lives (for example, cisatracurium, mivacurium, rocuronium, vecuronium) are favored over longer-acting agents because they are less likely to cause PPCs [94].

General anesthesia-induced atelectasis may impair respiratory function. Positive end-expiratory pressure (PEEP) is a mechanical approach that increases functional residual capacity to prevent airway collapse and, as a result, minimizes atelectasis. However, Cochrane studies revealed that there is insufficient evidence to evaluate if intraoperative PEEP lowers postoperative mortality and PPCs in a variety of surgical patients [95]. Following tracheal intubation, lung protective ventilation with a tidal volume of 6–8 ml/kg predicted body weight, PEEP of 6–8 cmH_2O, and recruitment maneuvers every 30 min may lower the rate of non-invasive ventilation or intubation for acute respiratory failure [96].

2.4 Risk stratification for PPCs

2.4.1 Specific risk scores

Patients at high risk of complications are identified using risk prediction models. As a result, it may allow for more informed consent and perioperative treatment [97]. While pulmonary risk assessment is effective at predicting whether a specific patient undergoing surgery will develop PPCs, it is frequently not performed for a variety of reasons, including: a lack of understanding of what such an assessment might predict; and a lack of time. Because there are no explicit guidelines outlining which tests should be conducted on which patients, it is unclear whether postoperative care will include measures to lower PPCs in all patients, regardless of potential dangers [98].

Arozullah respiratory failure index In the year 2000, Arozullah et al. created the first lung-specific risk index [72]. This index, which predicts the relative risk of postoperative respiratory failure (PRF) based on available clinical data and the type of surgery, was developed using data from a cohort of patients who were all male and undergoing major non-cardiac surgery; as a result, it is of no use in any other patient groups. As measured by this index, the probability of prolonged mechanical ventilation (greater than 48 hours) after surgery or unplanned intubation within 30 days after surgery is considered to be a PRF. Type of operation, serum albumin (30 g/L), BUN levels (> 30 mg/dL), dependent functional status (partially or fully), COPD history, and advanced age are the six preoperative criteria used to categorize patients into five groups [72].

Gupta postoperative respiratory failure risk & gupta postoperative pneumonia calculators The Gupta PRF calculator (GPRFC) analyzes the chance of being unable to wean from mechanical ventilation within 48 h following surgery or of unplanned post-operative intubation/reintubation [99]. The Gupta postoperative pneumonia calculator (GPPC), like the GPRFC, was created in the same way [100]. These two calculators, developed in 2011 and 2013, can estimate PPCs risk. Both consider American Society of Anesthesiologists (ASA) physical status, dependent functional status, type of surgery, and preoperative sepsis features. While GPRFC includes emergency surgery, GPPC includes age, COPD diagnosis, and smoking history.

The ARISCAT score The Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score considers seven patient and surgical risk factors to predict the overall risk of PPCs, which include respiratory tract infection/failure, bronchospasm, atelectasis, pleural effusion, pneumothorax, or aspiration pneumonia [101]. Each component is weighted, and PPCs risk is rated low, moderate, or high [8]. ARISCAT calculates PPCs risk easily. Even though the ARISCAT Risk Index was eventually validated in a large surgical population, its effectiveness varied across geographic areas in the PERISCOPE (Prospective Evaluation of a RIsk Score for postoperative pulmonary COmPlications in Europe) study in Europe [101].

2.4.2 Other risk scores

In addition to the specific risk scores listed above, other risk scores and general scores developed to estimate the risks for non-cardiac surgery may also be used.

STOP-Bang The ASA advises that all surgical patients be screened for OSA before to surgery [102]. Preoperative OSA diagnosis affects perioperative management. Using a pre-determined screening procedure, such as the STOP-Bang Screening tool, may increase patient safety and quality care outcomes [103]. A polysomnography sleep study is the diagnostic gold standard for OSA. However, this procedure is expensive and time-consuming [104]. The STOP-Bang Questionnaire was initially created for surgical patients but has now been validated across several patient groups. The Berlin Questionnaire is more time-consuming and difficult and requires patient's full cooperation. The ASA checklist may also be used but STOP-Bang is easier to conduct [105].

STOP-Bang is an eight-question screening technique. The first portion (STOP) covers snoring, daytime fatigue, not breathing while sleeping, and hypertension treatment. The Bang portion includes a BMI above 35 kg/m2, being over 50, having a neck circumference over 40 cm, and being male. Total "yes" replies determine the STOP-Bang score. Scores 0 to 2 indicate a low OSA risk, 3 to 4 a moderate risk, and 5 to 8 a high risk. [106]. STOP-Bang score prognostic value in surgical patients studied. A meta-analysis of three studies in surgical patients found that a STOP-Bang score of three raised the risk of moderate to severe OSA (confirmed by polysomnography) from 15 to 65% [107].

Caprini score Audits show that thromboprophylaxis is not administered as efficiently as it should be to prevent VTE. Surgeons fear bleeding concerns, which might lead to poor clinical outcomes. All patients should receive a preoperative assessment of thrombosis and bleeding risk, according to VTE prophylaxis guidelines. Thrombosis risk may be assessed with patient- and procedure-specific models like the Caprini score. Individual and procedure-specific risk variables imply prophylaxis in populations where the Caprini score has not been proven (such as orthopedic surgery). Caprini's risk model was released in 1991. It was upgraded in 2005 to accommodate new findings and a better understanding of VTE predictors and is currently the most widely used version. More than 100 studies have validated this score by comparing it to 30-day VTE event rates [108–110].

The Surgical Outcome Risk Tool (SORT) The Surgical Outcome Risk Tool (SORT) is comprised of six different factors that together estimate the 30-day mortality rate following non-cardiac surgery [111]. These factors include the American Society of Anesthesiologists Physical Status grade, the urgency of surgery, the surgical specialty and severity, cancer, and age greater than 65 years.

It is suggested that using both the SORT and subjective assessment together was significantly more effective than using either method separately [112].

3 Preoperative PPCs preventive strategies

The preoperative evaluation process involves a comprehensive assessment to ensure the best possible outcomes for patients undergoing major surgical procedures. This multifaceted approach involves considering various factors, such as smoking cessation, management of bronchial hyper-reactivity in patients with COPD and asthma, addressing respiratory tract infections, and implementing respiratory physiotherapy techniques. Each of these components contributes to minimizing postoperative complications and optimizing patient well-being (Fig. 2).

3.1 Smoking cessation

Smoking status should be evaluated and recorded for all patients having major surgery at each preoperative clinic visit since smoking is linked to an increased risk of unfavorable postoperative outcomes. Prior to surgery, all surgical patients who smoke should be asked to stop, and their willingness to cease should be evaluated to determine the next course of action. To get the best improvements in postoperative outcomes, a quit date should be planned more than 8 weeks before surgery. Prior to surgery, all smokers should get short counseling on the risks of smoking and the rewards of quitting [113].

3.2 Decreasing bronchial hyper-reactivity in patients with COPD and asthma

Specific therapy should be designed to ensure the best clinical and functional outcomes. Exacerbations may require corticosteroids alone or in combination with antibiotics, and surgery should be postponed for 30 days. Stable patients shouldn't discontinue their medicines, even on operation day. Even with appropriate treatment, hospitalization three to five days before major or midsize elective surgery may be useful in symptomatic individuals because it allows for the administration of intravenous corticosteroids and rapid acting inhaled bronchodilators on a defined schedule [22]. One to two days of systemic glucocorticoid medication may be recommended to prevent acute bronchoconstriction during intubation. Acute bronchoconstriction, on the other hand, is uncommon in people with well-controlled asthma. In the absence of clinical trial data, it is recommended that individuals with poorly controlled asthma get preoperative systemic glucocorticoids. Numerous studies have established the safety of perioperative systemic glucocorticoid treatment in asthmatic patients [114, 115]. Lung disease patients often use corticosteroids for maintenance or exacerbation. Those who received prednisone for more than 30 days or 20 mg for more than two weeks in the prior year are at risk for postoperative adrenal insufficiency. They should be assessed for diagnostic purposes before surgery, but if there is insufficient time, empirical corticosteroid supplementation is indicated [116]. Patients

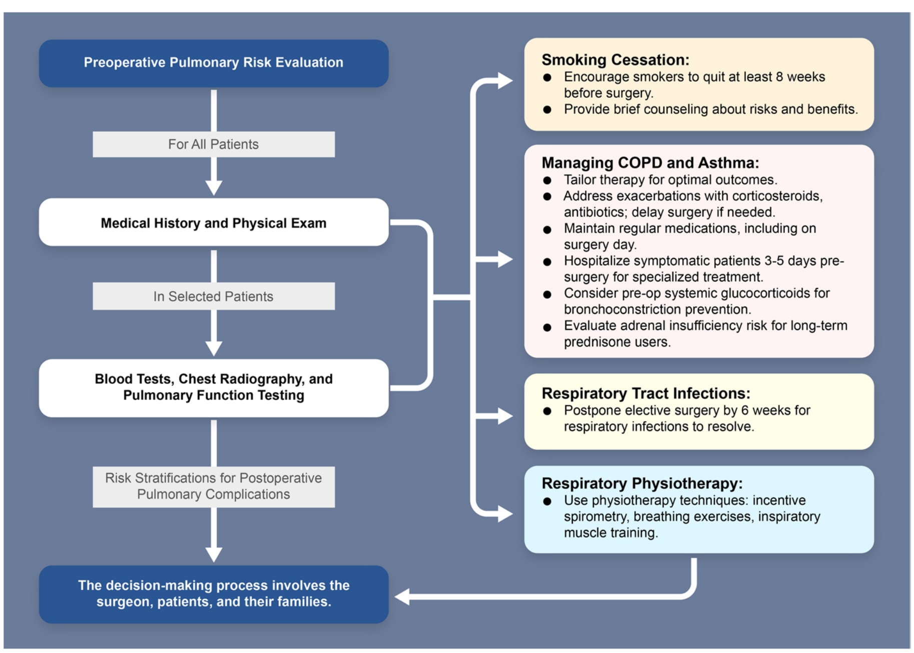


Fig. 2 It illustrates a sequential approach for preoperative pulmonary risk evaluation

taking high doses of inhaled glucocorticoids have occasionally acquired hypothalamic-pituitary-adrenal suppression. However, stress-dose glucocorticoids should not be used routinely in these patients [117].

3.3 Respiratory tract infections

Since airway responsiveness may persist after the infectious pathogen has been eradicated, elective surgery should be delayed (ideally for 6 weeks) in patients with respiratory tract infections [53]. However, much of the research examining the impact of preoperative respiratory infections on surgical outcomes has concentrated on upper respiratory tract infections, leaving lower respiratory tract infections and their implications relatively unexplored [118]. However, preoperative pneumonia was linked with higher postsurgical mortality [71], postoperative morbidity [71–73, 119], and increased surgical care costs in a few studies among adults [120].

3.4 Respiratory physiotherapy

Postoperative alterations in lung volumes, respiratory muscle function, mucociliary clearance, and pain suppression of respiratory muscles result in PPCs such pneumonia and severe atelectasis [97]. The majority of research have focused on the therapies that primarily aim to improve respiratory function: incentive spirometry, deep breathing exercises and physiotherapy, and inspiratory muscle training. [121]. A single preoperative physiotherapy session (30 min) dramatically decreased PPCs, including atelectasis on chest radiographs, in patients having upper abdominal surgery [122]. Inspiratory muscle training typically consists of five to seven 15-to-30-min supervised sessions each week for two weeks prior to surgery. When post-operative pain and other symptoms make it too difficult to do this task, inspiratory muscle training is stopped. A Cochrane review found that preoperative inspiratory muscle training programs in cardiac and major abdominal surgery significantly reduced postoperative atelectasis and pneumonia, and shortened hospital stays, in 695 patients across 12 studies [123].

4 Conclusion

PPE is a critical opportunity to improve perioperative clinical outcomes. When the patient's risk factors are well defined prior to the operation, it ensures that the patient undergoes the operation under the most clinically appropriate conditions. As a result, the best surgical procedure, anesthesia, and ventilation method are chosen for the patient. The goal of this procedure is to reduce the possibility of PPCs. The most important preoperative evaluation should be obtaining a throughout clinical history, determining the presence of symptoms, and performing a proper physical examination. Additional tests should be ordered based on the patient's underlying lung disease and newly developing symptoms. There is no need for additional testing if they will not change the postoperative outcome. Smoking and sleep apnea symptoms should be investigated prior to any surgical procedure. Preoperative evaluation should be viewed as a chance to quit smoking. Because polysomnography is not always easily accessible, some predictive tools, such as STOP-Bang, can be used to determine obstructive sleep apnea syndrome risk. Although pulmonary risk indices, which calculate the likelihood of developing respiratory failure, pneumonia, or other pulmonary problems, have advantages and disadvantages, they may be useful in assessing the risk of PPCs. They can aid in the direction of conversations between the patient, the patient's relative, and the surgeon.

The PPE shows promise for enhancing perioperative outcomes but has limitations and prospects. Variations in patient populations, surgical procedures, and diagnostic tools affect PPE's effectiveness and generalizability. While valuable, tools like the STOP-Bang questionnaire may not replace comprehensive diagnostics like polysomnography. Accessibility issues hinder comprehensive assessment in some settings. Risk indices' predictive accuracy varies, and they may not consider all patient factors. Future research aims to refine risk assessment tools and conduct outcome studies. Standardized guidelines and patient education could enhance PPE's consistency and effectiveness. Addressing limitations and pursuing these avenues can elevate PPE's utility and impact on patient outcomes.

Abbreviations

ABG	Arterial blood gas
ARISCAT	Assess respiratory risk in surgical patients in Catalonia
ASA	American Society of Anesthesiologists
BUN	Blood urea nitrogen
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
COVID-19	Coronavirus Disease
CPET	Cardiopulmonary exercise test
CTEPH	Chronic thromboembolic pulmonary hypertension
FEV_1	Forced expiratory volume measured in one second
GPPC	Gupta postoperative pneumonia calculator
GPRFC	Gupta postoperative respiratory failure calculator
ILD	Interstitial lung disease
NMBAs	Neuromuscular blocking agents
OHS	Obesity hypoventilation syndrome
OSA	Obstructive sleep apnea
PAH	Pulmonary arterial hypertension
PEEP	Positive end expiratory pressure
PH	Pulmonary hypertension
PPE	Preoperative pulmonary evaluation
PPCs	Postoperative pulmonary complications
PRF	Postoperative respiratory failure
SORT	Surgical outcome risk tool
VTE	Venous thromboembolism
WBC	White blood cell

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