Identification and Evaluation of the Patient with Lung Disease

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KEYWORDS

• Postoperative pulmonary complications • Preoperative testing
• Asthma • Chronic obstructive lung disease
• Dyspnea • Cigarette use • Preoperative evaluation
• Obstructive sleep apnea

Preoperative pulmonary evaluation and optimization improves patient outcomes. Patients with pulmonary disease are at increased risk for pulmonary and nonpulmonary perioperative complications. Identification of diseases and risk stratification will inform discussion among anesthesiologists, surgeons, and hospitalists who care for patients in the perioperative period. Postoperative pulmonary complications (PPCs) occur frequently and increase costs, morbidity, and mortality. In addition, recent evidence indicates that patients who develop PPC have decreased long-term survival.[1] For example, in a study of patients older than 70 years undergoing noncardiac surgery, pulmonary complications predicted long-term mortality (hazard ratio = 2.41).[2] Somewhat unexpectedly, PPC are more costly than thromboembolic, cardiovascular, or infectious complications.[3] As the entire scope of pulmonary disease is too broad for a comprehensive review, this article focuses on the most common conditions encountered in the preoperative population, including unexplained dyspnea, asthma, chronic obstructive pulmonary disease (COPD), obstructive sleep apnea (OSA), smoking history, and risk factors for PPC (**Table 1**).[4] The evaluation of patients with these

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conditions, risk stratification for PPC, and strategies to reduce PPC for high-risk patients are discussed.

A thorough history and physical examination are the foundation of preoperative assessment of patients who have known pulmonary disease, and others who are at risk for PPC. Important components of this history include age, a history of smoking, asthma, COPD, OSA, congestive heart failure (CHF), previous pulmonary complications during or after surgery, exercise tolerance, general health, and the type and urgency of the planned procedure. Symptoms such as cough, wheezing, sputum production, dyspnea, snoring, and orthopnea should be noted. The physical examination focuses on the cardiopulmonary system, looking for the presence of rales, wheezes, rhonchi, decreased breath sounds, prolonged expiratory phase, murmurs, S_3, S_4, and edema. Preoperative testing is necessary only in limited circumstances. There is no role for routine tests. The tests that may be valuable in specific conditions are discussed in this article.

DYSPNEA

Dyspnea, a common symptom, has been defined as the "subjective experience of breathing discomfort that consists of qualitatively distinct sensations that vary in intensity."[5] Dyspnea occurs in conditions in which the respiratory drive is increased or the respiratory system is subject to an increased mechanical load. The most common causes of acute dyspnea are COPD, asthma, and CHF (**Fig. 1**). In a group of patients with chronic dyspnea who were evaluated in a pulmonary clinic, two thirds of the patients had asthma, COPD, interstitial lung diseases, or a cardiomyopathy.[6] Generally, the 2 broad categories of cardiovascular dyspnea (ie, conditions of increased cardiac filling pressures or inadequate oxygen delivery) and pulmonary dyspnea (ie, conditions of increased respiratory drive, abnormal chest wall or pulmonary mechanics, muscle weakness, or gas exchange limitations) should be distinguished.[7] Dyspnea may be intermittent (eg, with asthma), recurrent (eg, with CHF), or persistent (eg, with COPD or interstitial lung disease) and may be influenced by body position (eg, supine, lateral, or upright). Nighttime orthopnea typically occurs in patients with CHF, OSA, gastroesophageal reflux disease (GERD), or asthma.

Clinicians should inquire about the quality of the respiratory discomfort by quantifying the intensity of the sensation, the frequency and duration of occurrence, and precipitating factors. These symptoms may provide clues to the cause of dyspnea. Chest tightness may indicate bronchospasm, rapid shallow breathing is associated with interstitial disease, and heavy breathing or fatigue suggests deconditioning.[7] Patient history alone is correct approximately two thirds of the time; and the negative predictive value of characteristic physical findings is higher than the positive predictive value of the same findings on examination.[6] Clinicians should obtain specific preoperative tests for patients with dyspnea based on results of the history and physical examination (see **Fig. 1**). Pulmonary function testing (PFT), including a methacholine challenge, can diagnose airflow obstruction. Chest radiography is useful to uncover acute disease such as pneumonia or to diagnose CHF or interstitial lung disease. Echocardiography may demonstrate reduced left ventricular ejection fraction, evidence of diastolic dysfunction, or pulmonary hypertension. Testing for anemia, hypothyroidism, or renal failure will occasionally establish the cause of the patient's dyspnea. Cardiopulmonary exercise testing (CET) may be helpful if the basis for dyspnea remains uncertain after clinical evaluation and initial diagnostic testing as noted above. In such cases, deconditioning may ultimately prove to be the basis for dyspnea.[6] CET is particularly useful in confirming deconditioning or psychogenic factors as the cause of dyspnea.

Table 1
Strength of the evidence for patient- and procedure-related risk factors for postoperative pulmonary complications

Factor	Strength of Recommendation[a]	Odds Ratio[b]
Potential patient-related risk factor		
Advanced age	A	2.09–3.04
ASA class ≥II	A	2.55–4.87
CHF	A	2.93
Functionally dependent	A	1.65–2.51
COPD	A	1.79
Weight loss	B	1.62
Impaired sensorium	B	1.39
Cigarette use	B	1.26
Alcohol use	B	1.21
Abnormal findings on chest examination	B	NA
Diabetes	C	
Obesity	D	
Asthma	D	
Obstructive sleep apnea	I	
Corticosteroid use	I	
HIV infection	I	
Arrhythmia	I	
Poor exercise capacity	I	
Potential procedure-related risk factor		
Aortic aneurysm repair	A	6.90
Thoracic surgery	A	4.24
Abdominal surgery	A	3.01
Upper abdominal surgery	A	2.91
Neurosurgery	A	2.53
Prolonged surgery	A	2.26
Head and neck surgery	A	2.21
Emergency surgery	A	2.21
Vascular surgery	A	2.10
General anesthesia	A	1.83
Perioperative transfusion	B	1.47
Hip surgery	D	
Gynecologic or urologic surgery	D	
Esophageal surgery	I	
Laboratory tests		
Albumin level <35 g/L	A	2.53
Chest radiography	B	4.81
BUN level >7.5 mmol/L (>21 mg/dL)	B	NA
Spirometry	I	

Abbreviations: ASA, American Society of Anesthesiologists; BUN, blood urea nitrogen; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; NA, not available.

[a] Recommendation: A, good evidence to support the particular risk factor or laboratory predictor; B, at least fair evidence to support the particular risk factor or laboratory predictor; C, at least fair evidence to suggest that the particular factor is not a risk factor or that the laboratory test does not predict risk; D, good evidence to suggest that the particular factor is not a risk factor or that the laboratory test does not predict risk; I, insufficient evidence to determine whether the factor increases risk or whether the laboratory test predicts risk, and evidence is lacking, is of poor quality, or is conflicting.[12]

[b] For factors with A or B ratings. Odds ratios are trim-and-fill estimates. When these estimates were not possible, the pooled estimate is provided.

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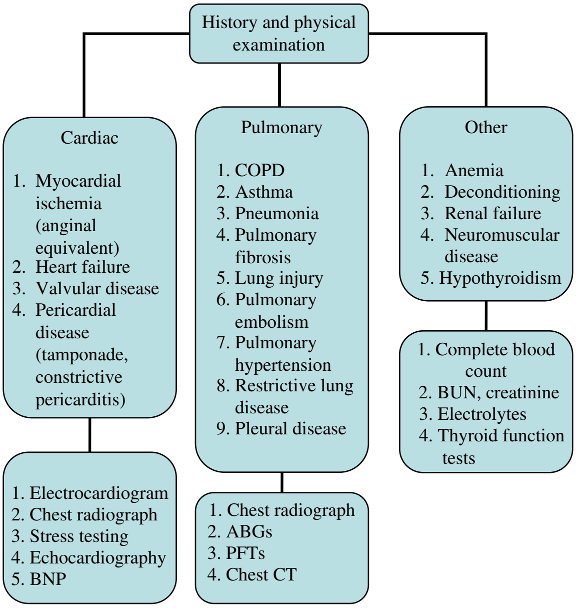

Fig. 1. Evaluation of dyspnea. ABGs, arterial blood gases; BNP, brain natriuretic peptide; BUN, blood urea nitrogen; COPD, chronic obstructive pulmonary disease; CT, computerized tomography; PFTs, pulmonary function tests.

Most of the conditions that cause dyspnea, except for the psychogenic ones, increase the risk of PPC, especially if the condition is poorly controlled or unknown to the anesthesiologist. Therefore, preoperative evaluation that yields a proper diagnosis will allow for effective treatment and optimization of patient status.

ASTHMA

Well-controlled asthma does not seem to be a risk factor for either intraoperative or postoperative complications.[8,9] However, patients who are poorly controlled, as shown by wheezing at the time of anesthesia induction, have a higher risk of perioperative complications.[9] The medical history also provides clues that indicate higher risk. For example, in the study of Warner and colleagues, asthma severity, as determined by use of asthma medications and emergency room or office visits in the 30 days before surgery, influenced PPC rates. Tracheal intubation in patients with obstructive airways disease can trigger severe bronchospasm with hypoxia, rarely leading to brain damage or death.[10] The actual incidence of such events is unknown.

Preoperative corticosteroids and inhaled beta-agonists markedly decrease the incidence of bronchospasm after tracheal intubation.[8,9,11] The combination of corticosteroids and salbutamol attenuates intubation-induced bronchoconstriction to a greater degree than inhaled β_2 agonists alone.[8] Short courses of preoperative steroids (up to 1 week) are safe and do not seem to increase postoperative infections or delay wound healing.[12] The authors recommend prednisone 0.5 to 1 mg/kg orally for 1 to 4 days before surgery for patients who are likely to require endotracheal intubation and who have persistent airway obstruction despite use of inhaled medications. Before elective surgery, clinicians should treat patients with asthma according to a stepwise approach as outlined in a report by the National Asthma Education and Prevention

Program (NAEPP) Expert Panel Report.[13] This approach stratifies patients based on severity and provides guidance regarding the selection of specific agents and treatment intensity based on severity.

Before elective surgery, patients should be free of wheezes, cough, or dyspnea and have peak expiratory flows greater than 80% of predicted, or their personal best. Well-controlled asthma is characterized by daytime symptoms no more than twice per week and nighttime symptoms no more than twice per month.

CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Unlike asthma, COPD does increase the risk of PPC (odds ratio = 1.79) (see **Table 1**).[4] The more severe the COPD, the greater the risk, but there is no prohibitive degree of severity that precludes surgery. If contemplating surgery in patients with COPD, clinicians should weigh the benefit of the proposed surgery against a lower risk procedure, or the natural course of the underlying condition. Alternatives to surgery and other risk factors need to be considered. Although COPD increases PPC, surprisingly the risk is less than that associated with other patient-related risk factors including CHF, advanced age, and poor general overall health status. Patients with COPD also have higher risk for nonpulmonary complications such as wound infections and atrial arrhythmias.[14]

In patients with COPD, preoperative spirometry may be useful to assess the disease severity and adequacy of bronchodilator therapy, but only in patients in whom it is difficult to determine this from the history and physical examination. Even before high-risk surgery, there is no role for routine PFTs. The rationale for this recommendation is that spirometry usually adds no information beyond that obtained by a careful history and physical examination. Patients with severe COPD as determined by spirometric values are unlikely to escape clinical detection.

As a general rule, the preoperative management of patients with COPD is the same as for patients with COPD who are not preparing for surgery. Routine preoperative antibiotics do not reduce PPC rates for patients with COPD; their use is restricted to patients with bacterial lower respiratory infections. Long-acting inhaled anticholinergics, long-acting β-agonists, and inhaled corticosteroids each can improve lung function in symptomatic patients.[15]

Patients with respiratory symptoms and significant airway obstruction benefit most from therapy. Combinations of inhaled agents have not been shown to have a distinct advantage over monotherapy. Long-acting bronchodilators are more effective and convenient than short-acting β-agonists.[16] Inhaled corticosteroids in addition to β-agonists are appropriate in symptomatic patients with airway obstruction. Chronic therapy with systemic steroids should be avoided because of long-term risks. Preoperative systemic corticosteroids for patients with COPD, when indicated, may shorten hospital and intensive care unit stays, and do not seem to adversely affect wound healing.[12,14] Clinicians should use preoperative corticosteroids in the same fashion as for patients with asthma. Patients with COPD can improve exercise tolerance, and reduce dyspnea and fatigue, by participating in exercise training programs.[16] Preoperative chest physiotherapy, including inspiratory muscle training, decreases PPC rates.[17,18]

OBSTRUCTIVE SLEEP APNEA

Sleep-disordered breathing affects up to 9% of women and 24% of men; most patients are unaware of their diagnosis.[19] During the preoperative assessment, one should question the patient about snoring and daytime somnolence, which may suggest undiagnosed obstructive sleep apnea (OSA). OSA has implications for anesthesia management and probably increases the risk of PPC. A history of snoring, daytime sleepiness, hypertension, obesity, and a family history of OSA are each risk factors for OSA (**Fig. 2**).[20] A large neck circumference (>17 inches in men, >16 inches in women or >60 cm in anyone) predicts a greater chance of OSA.[21] Various questionnaires have been developed to assist in identifying patients who may have sleep apnea but the only validated ones in the preoperative population are the STOP and STOP-Bang forms (**Boxes 1** and **2**).[22] The gold standard for diagnosis of OSA is sleep laboratory polysomnography, but this method is costly, time-consuming, and has limited availability.[23] Home nocturnal oximetry is a potential screening tool that is simpler, less costly, and more readily available.[24] To date, no studies have specifically evaluated the test characteristics of this more limited study in the preoperative setting.

Patients with OSA have increased rates of comorbidities including diabetes, hypertension, atrial fibrillation, bradyarrhythmias, ventricular ectopy, endothelial damage, stroke, heart failure, pulmonary hypertension, dilated cardiomyopathy, coronary artery disease, and myocardial infarction (see **Fig. 2**).[25,26] Mask ventilation, direct laryngoscopy, endotracheal intubation, and even fiber-optic visualization of the airway are more difficult in patients with OSA than in healthy patients. Potential postoperative complications in patients with OSA include airway obstruction, tachyarrhythmias, hypoxemia, atelectasis, ischemia, pneumonia, and prolonged hospitalizations.[27–30]

Preoperative evaluation should aim to identify patients at risk for OSA and optimize associated comorbid conditions. Echocardiography may be indicated if CHF or pulmonary hypertension is suspected, however no data suggest that this preoperative test improves perioperative outcomes. One should encourage patients to lose weight, as a decrease in body weight of as little as 10% can result in clinically significant improvements in the apnea-hypopnea index.[31,32] Whether continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BPAP) therapy does more than improve daytime sleepiness is debatable, but some evidence suggests that it may reverse comorbid disease manifestations such as hypertension, CHF, and ischemia.[32,33] Patients should bring their CPAP devices to the hospital on the day of operation. Communication with the anesthesia team is important to improve patient outcomes. The American Society of Anesthesiologists has published recommendations for the perioperative care of patients with OSA.[34] Adherence to these guidelines will minimize practice variation and potentially improve patient outcomes.

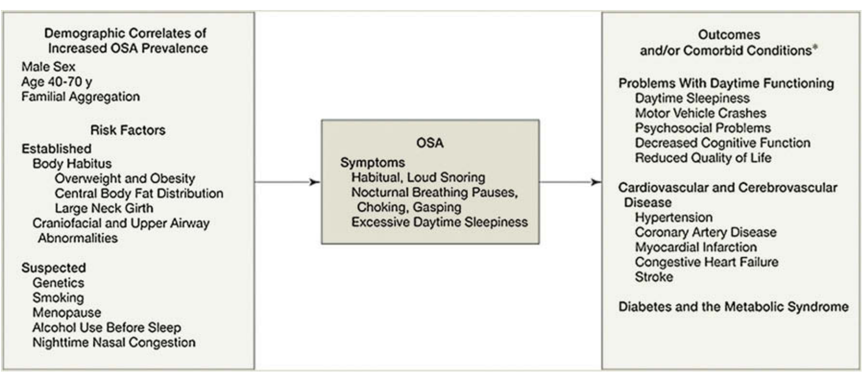

Fig. 2. Obstructive sleep apnea. (*Reprinted from* Young T, Skatrud J, Peppard PE. Risk factors for obstructive sleep apnea in adults. JAMA 2004;291:2014; with permission.)

Box 1
STOP questionnaire to screen for obstructive sleep apnea

1. *S*noring
   Do you *s*nore loudly (louder than talking or loud enough to be heard through closed doors)?
2. *T*ired
   Do you often feel *t*ired, fatigued, or sleepy during the day?
3. *O*bserved
   Has anyone *o*bserved you stop breathing during your sleep?
4. Blood *p*ressure
   Do you have or are you being treated for high blood *p*ressure?

- High risk of OSA: answering YES to 2 or more questions
- Low risk of OSA: answering YES to less than 2 questions

From Chung F, Yegneswaran B, Liao P, et al. STOP questionnaire. A tool to screen patients for obstructive sleep apnea. Anesthesiology 2008;108:812; with permission.

CIGARETTE USE

Patients who smoke are at risk for pulmonary and nonpulmonary perioperative complications even in the absence of chronic lung disease (see **Table 1**).[35–37] However, the absolute magnitude of risk for PPC is small (OR = 1.40).[4] A smoking history greater than 20 pack-years predicts greater risk than lesser amounts of smoking.[37]

Box 2
STOP-Bang questionnaire to screen for obstructive sleep apnea

1. *S*noring
   Do you *s*nore loudly (loud enough to be heard through closed doors)?
2. *T*ired
   Do you often feel *t*ired, fatigued, or sleepy during daytime?
3. *O*bserved
   Has anyone *o*bserved you stop breathing during your sleep?
4. Blood *p*ressure
   Do you have or are you being treated for high blood *p*ressure?
5. *B*MI
   *B*MI more than 35 kg/m^2?
6. *A*ge
   *A*ge greater than 50 years?
7. *N*eck circumference
   *N*eck circumference greater than 40 cm?
8. *G*ender
   *G*ender male?

High risk of OSA: answering YES to 3 or more items

Low risk of OSA: answering YES to less than 3 items

From Chung F, Yegneswaran B, Liao P, et al. STOP questionnaire. A tool to screen patients for obstructive sleep apnea. Anesthesiology 2008;108:812; with permission.

Smokers are more likely than nonsmokers to develop wound infections, oxygen desaturation, laryngospasm, and severe coughing with anesthesia.[38] Smoking decreases macrophage function, negatively affects coronary flow reserve, and causes vascular endothelial dysfunction, hypertension, tachycardia, and ischemia.[39,40] In one study, patients without a history of ischemic heart disease who smoked shortly before operation had significantly more episodes of rate-pressure, product-related, ST-segment depression than did nonsmokers, former smokers, or chronic smokers who did not smoke in the immediate preoperative period.[41] Although smoking increases the risk of postoperative intensive care admission (OR = 1.55),[42] it does not seem to be a risk factor for clinically significant cardiac complications such as postoperative myocardial infarction or cardiac death.[43]

Abstinence from smoking before surgery reduces PPC rates, but the ideal duration of preoperative abstinence remains the subject of study and controversy. The preponderance of the evidence suggests a need for at least 2 months of preoperative cessation to maximally reduce PPC risk. However, selection bias may have been a factor in studies that have reported greater perioperative risk in recent quitters. In contrast, PPC rates did *not* increase in patients who stopped smoking within weeks before thoracotomy for lung resection.[44] Within 12 hours after a patient quits smoking, carbon monoxide levels decrease, improving oxygen delivery and utilization.[45] Cyanide levels decrease, which benefits mitochondrial oxidative metabolism, and ciliary function improves. Quitting tobacco dramatically reduces surgical wound infections.[46] Sputum production increases in the first 1 to 2 months after cigarette cessation. This observation may contribute to the higher risk among recent quitters in some studies. The authors recommend that truly elective surgery be postponed for at least 8 weeks after smoking cessation to provide maximum reduction of PPC.[47]

The US Public Health Service recommends that physicians strongly advise smokers to quit because a physician's advice to quit smoking increases abstinence rates.[48] Effective interventions include medical advice and pharmacotherapy, such as nicotine-replacement therapy (NRT), which is safe in the perioperative period.[49] NRT is safe in patients with ischemic heart disease, and has been shown to decrease ischemia seen on stress testing in smokers with coronary artery disease.[50] Individual and group counseling may also increase rates of long-term abstinence. Varenicline is another option that has been proved to be even more effective than NRT as a strategy for smoking cessation. Excellent resources are available on the Internet and from the US Surgeon General.[51]

POSTOPERATIVE PULMONARY COMPLICATIONS

Postoperative pulmonary complications (PPC) occur in 6.8% of patients undergoing major noncardiac surgery.[4] Patient- and procedure-related risk factors influence PPC rates. Surgical factors that may affect risk are the site and duration of surgery and the type of anesthesia. PPC rates are higher after major abdominal, thoracic, and open abdominal aortic aneurysm (AAA) repair and surgeries longer than 3 hours (see **Table 1**). Head and neck procedures, neurosurgery and emergency surgeries confer greater risk than peripheral operations.[4,52] Recovery time, pain, and reduction in lung volumes are less after laparoscopic procedures, but it is unclear whether this translates into lower PPC rates.[4] In contrast, PPC risk is lower for percutaneous interventions. For example, in a study of patients undergoing endovascular versus open AAA repair, PPC rates were 3% and 16%, respectively.[53]

General anesthesia carries greater risk than peripheral nerve conduction blocks. Whether centroneuraxial (spinal or epidural) anesthesia is less risky is debatable.[54]

Two large meta-analyses, and retrospective and randomized trials, suggest that PPC rates are lower for patients who have spinal or epidural anesthesia for surgery or epidural analgesia postoperatively.[55–58] The ultimate choice of anesthesia is left to the anesthesiologist, but effective communication among medical, surgical, and anesthesia colleagues will help to guide this choice and reduce risk.

Patient-related predictors of PPCs include advanced age, COPD, smoking, general health status, OSA, and certain metabolic factors.[4,27] The 2006 review by Smetana and colleagues for the American College of Physicians (ACP) established for the first time that advanced age, regardless of other medical conditions, is an independent risk for PPC, and in fact, was the strongest patient-related predictor. When compared with patients younger than 50 years, those aged 50 to 59 years had an odds ratio (OR) of 1.50; those aged 60 to 69 years had an OR of 2.28, 70 to 79 years OR 3.90, and those 80 years or more had an OR of 5.63 for developing PPC. CHF (OR = 2.93) also proved to be a predictor of PPC in this same review. CHF is an especially important risk in the elderly.[59,60] Poor general health status, including impaired sensorium and functional dependency, increases PPC risk. In the American Society of Anesthesiologists (ASA) physical status classification, risk increases at each level, starting with ASA 2 patients (**Table 2**). Risks of PPC with COPD, smoking history, and OSA are discussed in the appropriate sections of this article.

Recently, Johnson and colleagues[61] updated and validated a previously published complex preoperative risk index for predicting postoperative respiratory failure (**Table 3**). Each risk factor receives a score of 1 to 4 based on the strength of the association between the factor and the risk of respiratory failure. A score less than 8 predicts low risk; 8 to 12, medium risk; and greater than 12, high risk. Age, general health status, COPD, and low albumin levels were found to be significant predictors. New risk factors not previously confirmed were sepsis, ascites, creatinine greater than or equal to 1.5 mg/dL, and dyspnea. The same group previously developed a risk index to predict postoperative pneumonia.[52] These helpful tools will be of use primarily to stratify risk and ensure accurate classification in research studies, as they are too complex for use in clinical practice.

Clinicians should not obtain routine preoperative spirometry, chest radiography, or arterial blood gas determination to predict PPC risk.[62] For most patients, these studies offer little more than can be determined by clinical evaluation. Results of spirometry and chest radiography can usually be predicted from clinical assessment and rarely change management.[63,64]

Many of the risk factors for PPC are nonmodifiable, so emphasis is on generic risk reduction strategies and postoperative surveillance. When possible, clinicians should also implement interventions that are specific to the particular risk factor. Pre- and postoperative pulmonary rehabilitation has been shown to decrease PPC in moderate

Table 2
American Society of Anesthesiologists physical status classification

Class 1	A normal healthy patient
Class 2	A patient with mild systemic disease
Class 3	A patient with severe systemic disease
Class 4	A patient with severe systemic disease that is a constant threat to life
Class 5	A moribund patient who is not expected to survive without the operation

Emergency cases are designated by the addition of "E" to the classification number.

Data from ASA Physical Status Classification System. 2008. Available at: http://www.asahq.org/clinical/physicalstatus.htm.

Table 3
Independent predictors of respiratory complications (development set)

Step no.	Factor	Odds Ratio (95% CI)	Score
1	ASA class (3 versus 1–2)	2.878 (2.463–3.362)	+3
1	ASA class (4–5 versus 1–2)	4.900 (4.105–5.849)	+5
2	Emergency	2.416 (2.170–2.690)	+2
3	Work RVU (10–17 versus <10)	2.299 (1.937–2.728)	+2
3	Work RVU (>17 versus <10)	4.445 (3.720–5.312)	+4
4	Preoperative albumin (≤3.5 versus >3.5)	1.485 (1.344–1.641)	+1
5	Integumentary versus hernia	1.144 (0.869–1.505)	+1
5	Respiratory and hemic versus hernia	3.116 (2.175–4.466)	+3
5	Heart versus hernia	2.310 (1.670–3.196)	+2
5	Aneurysm versus hernia	1.552 (1.203–2.002)	+2
5	Mouth, palate versus hernia	6.635 (4.782–9.206)	+7
5	Stomach, intestines versus hernia	2.126 (1.658–2.726)	+2
5	Endocrine versus hernia	1.537 (0.992–2.382)	+2
6	Preoperative sepsis	1.999 (1.707–2.341)	+2
7	Preoperative creatinine ≥1.5	1.651 (1.493–1.826)	+2
8	History of severe COPD	1.517 (1.362–1.689)	+2
9	Ascites	1.846 (1.496–2.278)	+2
10	Dyspnea (yes versus no)	1.318 (1.192–1.457)	+1
11	Impaired sensorium	1.498 (1.220–1.839)	+1
12	Preoperative bilirubin >1.0	1.205 (1.078–1.347)	+1
13	>2 alcoholic drinks/d in the 2 wk before admission	1.302 (1.135–1.494)	+1
14	Bleeding disorders	1.253 (1.074–1.462)	+1
15	Age (40–65 y versus <40 y)	1.704 (0.862–3.367)	+2
15	Age (>65 y versus <40 y)	2.062 (1.537–2.765)	+2
16	Preoperative white blood count (<2.5 versus 2.5–10)	1.480 (0.888–2.465)	+1
16	Preoperative white blood count (>10 versus 2.5–10)	1.204 (1.093–1.327)	+1
17	Preoperative serum sodium >145	1.564 (1.205–2.030)	+2
18	Weight loss >10%	1.255 (1.096–1.436)	+1
19	Preoperative acute renal failure	1.507 (1.171–1.939)	+2
20	Gender (male versus female)	1.193 (1.057–1.345)	+1
21	Congestive heart failure <30 d before operation	1.298 (1.089–1.547)	+1
22	Smoker	1.147 (1.049–1.255)	+1
23	Preoperative platelet count ≤150	1.211 (1.060–1.383)	+1
24	CVA/stroke with neurologic deficit	1.269 (1.095–1.471)	+1
25	Wound class (clean/contaminated versus clean)	1.156 (1.024–1.304)	+1
25	Wound class (contaminated versus clean)	1.361 (1.150–1.612)	+1
25	Wound class (infected versus clean)	1.249 (1.043–1.495)	+1
26	Preoperative SGOT >40	1.164 (1.041–1.301)	+1
27	Preoperative hematocrit ≤38	1.114 (1.014–1.225)	+1
28	CVA/stroke without neurologic deficit	1.228 (1.020–1.478)	+1

No. of records used = 90,055. The RRI score was divided into 3 discrete ranges based on the rate of RF: low (risk score<8; RF 0.1% to 0.2%), medium (risk score 8–12; RF 0.8% to 1.0%), and high (risk score >12; RF 6.5% to 6.8%). The scores accurately predicted the RF rate in each category. The c-indices (reflecting "discrimination," a measure of how well the scoring predicts the outcomes of RF) ranged from 0.8498 for the development set to 0.8594 for the validation data set, indicating good stability of the model.

Abbreviations: ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; RRI, respiratory risk index; RVU, relative value unit; SGOT, serum glutamic-oxalacetic transaminase.

From Johnson RG, Arozullah AM, Neumayer L, et al. Multivariable predictors of postoperative respiratory failure after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg 2007;204:1188–98; with permission.

to high-risk patients undergoing upper abdominal surgeries.[65] Lung expansion maneuvers including cough, deep breathing, incentive spirometry, positive end-expiratory pressure (PEEP), and CPAP reduce PPC rates. There does not seem to be a clear advantage for any particular modality. Preoperative inspiratory muscle training, a recently described modality that is an intensive multimodality intervention, reduces PPC rates in patients undergoing coronary bypass surgery.[14] Whether similar benefit exists for other high-risk surgeries is unknown, but this is an appealing and safe intervention that can be recommended pending further study.

SUMMARY

Evaluation of patients with pulmonary disease before surgery is a common activity for clinicians; this is an important undertaking as PPCs are as common and costly as cardiac complications. High-quality evidence from the literature has delineated those patient- and procedure-related factors that influence PPC rates. These risk factors are described in this article.

The evidence base for risk reduction strategies is not as robust. Further study will increase our understanding of which strategies reduce PPC risk to the greatest extent. Effective risk reduction strategies include maximizing airflow in obstructive disease, treating infections and CHF, and instituting preoperative pulmonary rehabilitation with deep breathing exercises or incentive spirometry. Clinicians should encourage patients to stop smoking at least 2 months before elective surgery, and lose weight if they have OSA. Communication among anesthesia, medical, and surgical colleagues is paramount to optimize perioperative care.

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