



Preoperative pulmonary evaluation:

Identifying and reducing risks for pulmonary complications

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Postoperative pulmonary complications are among the most common morbidities in patients undergoing major surgery. Yet despite the frequency and potential seriousness of these complications, preoperative patient evaluations often tend to focus more on cardiac, rather than pulmonary, risks.

This review discusses patient- and procedure-related risk factors that should be considered during preoperative pulmonary evaluation, as well as strategies for reducing the risk of pulmonary complications in surgical patients. In addition to this review, readers are referred to the upcoming American College of Physicians (ACP) guideline on preoperative pulmonary evaluation and its accompanying background papers, which are based on a systematic review of the literature. This will be the first set of evidence-based guidelines for preoperative pulmonary evaluation. As such, it is expected to help fill gaps in our current knowledge of perioperative pulmonary risks and management strategies.

■ THE STAKES: PULMONARY COMPLICATIONS ARE COMMON, SERIOUS, COSTLY

The major pulmonary complications that clinicians seek to prevent through proper preoperative evaluation and intervention include pneumonia, prolonged mechanical ventilation or respiratory failure, atelectasis, bronchospasm, and exacerbations of chronic obstructive pulmonary disease (COPD).

These complications are more widespread than is often perceived. Data from 3,970 patients in the

Revised Cardiac Risk Index cohort who underwent major noncardiac surgery found rates of respiratory failure (2%) and pneumonia (1%) to be comparable with or slightly higher than rates of the two most common cardiovascular complications, pulmonary edema (1%) and myocardial infarction (1%).¹

Additional studies^{2,3} have shown that patients who develop a postoperative pulmonary complication have longer hospital stays than do patients who develop a postoperative cardiovascular complication. For example, a patient in the intensive care unit who develops pneumonia may require prolonged ventilation and have a lengthy and costly hospital stay.

■ PATIENT-RELATED RISK FACTORS: WHAT IS THE EVIDENCE?

Studies have evaluated potential associations between various patient-related factors and postoperative pulmonary complications, as detailed below. Among these, COPD, general health status, and age are the factors most clearly associated with increased risk and should be considered during a preoperative assessment.

Chronic obstructive pulmonary disease

COPD doubles the risk of postoperative pulmonary complications.^{4,5} While clinical practice suggests that the severity of COPD influences postoperative pulmonary complication rates, the literature on this important point is limited. Physical examination findings can be helpful in assessing risk magnitude, as shown by Lawrence et al,⁶ who found that decreased breath sounds, prolonged expiration, rales, wheezes, and rhonchi were each associated with a sixfold increase in pulmonary complications compared with the absence of any of these findings. This study was conducted in patients undergoing elective abdominal surgery, which is associated with a relatively high risk of pulmonary complications.

General health status

General health status is an important predictor of the

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risk of pulmonary complications and has been evaluated using the American Society of Anesthesiologists (ASA) physical status classification to describe current health status.

The ASA classification was designed to estimate overall mortality risk in patients undergoing surgery, but a number of studies have shown that it also predicts cardiovascular and pulmonary complications.^{4,7,8} Patients who are graded higher than class 2 in the five-class ASA system (**Table 1**) have a twofold to threefold increased risk of postoperative pulmonary complications compared with those graded class 2 or lower.⁹ Thus, as an integrated risk index, the ASA classification not only provides the anesthesiologist's assessment of a patient's overall physical status, it also predicts the likelihood of postoperative pulmonary complications.

Two large studies^{10,11} that used multivariable analysis suggest that functional dependence (ie, inability to perform activities of daily living) is an independent risk factor for postoperative pulmonary complications. Although no statistically significant results have been reported, self-reported exercise capacity may also predict pulmonary complications.

Age

The role of patient age as a risk factor for postoperative pulmonary complications has been controversial. Although advanced age is associated with an increased risk of these complications, whether this increased risk is attributable to age or to the comorbidities associated with increased age is not clear. The pending ACP guideline and background papers are expected to better clarify the degree to which age may be a risk factor independent of comorbidities.

Obesity

Since decreased lung volume after surgery is one of the mechanisms that contributes to the development of postoperative pulmonary complications, obese patients who have a restrictive ventilatory pattern might be expected to have an increased risk for pulmonary complications. However, the literature has consistently found that no such association exists and that obesity is not a risk factor for postoperative pulmonary complications. Although distinguishing between obesity and other risk factors that are common among obese persons is difficult, studies that have used multivariable analysis have generally found no increase in pulmonary complications in obese surgical patients, even for morbidly obese patients or those undergoing bariatric surgery.^{12–14}

Nevertheless, a common complication of obesity, obstructive sleep apnea, may be associated with an

TABLE 1
ASA physical status classification
for surgical candidates

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

ASA = American Society of Anesthesiologists

increased risk of postoperative pulmonary complications. This suggestion comes from a single study from the Mayo Clinic¹⁵ that found unplanned intensive care unit transfers and length of hospital stay to be increased among patients with obstructive sleep apnea undergoing hip or knee replacement. However, pulmonary complications were not frequent enough in the overall study to allow detection of any potential association with obstructive sleep apnea. Further investigation is needed to determine whether such an association may exist.

Asthma

In contrast to COPD, well-controlled asthma is not a risk factor for pulmonary complications following surgery. A retrospective analysis from the Mayo Clinic found a low incidence of pulmonary complications among 706 patients with asthma undergoing various general surgeries.⁸ Pulmonary complications and their incidences were as follows:

- Bronchospasm, 1.7%
- Respiratory failure, 0.1%
- Laryngospasm, 0.3%.

There were no deaths and only one clinically important postoperative complication in the entire study sample. The subgroup of patients whose asthma was not well controlled (based on recent inhaler use or a recent emergency room visit) had significantly higher rates of pulmonary complications than their counterparts with well-controlled asthma.

Other patient factors of interest

Cigarette smoking confers a modest increase in pulmonary complication rates even among patients without COPD.^{16,17} The findings of the National Veterans Administration Surgical Quality Improvement Program also indicate that impaired sensorium, recent weight loss (more than 10% in the past 6

TABLE 2

Multivariable risk indices for postoperative pneumonia and respiratory failure (abbreviated)

Variable	Points for pneumonia	Points for respiratory failure
Surgery type/site		
AAA repair	15	27
Thoracic	14	21
Neurosurgery	8	14
Upper abdominal	10	14
Vascular	3	14
Neck	8	11
Emergency surgery	3	11
Weight loss	7	NA
Albumin < 3 g/dL	NA	9
BUN ≥ 30 mg/dL	3	8
Functional dependency	10	7
COPD	5	6
Age ≥ 70 yr	NA	6
Age ≥ 80 yr	17	NA
Risk class (point totals)	Risk for pneumonia*	Risk for respiratory failure*
Class 1 (10–15 points for pneumonia) (≤ 10 points for resp. failure)	0.24%	0.5%
Class 2 (16–25 points for pneumonia) (11–19 points for resp. failure)	1.19%	2.1%
Class 3 (26–40 points for pneumonia) (20–27 points for resp. failure)	4.0%	5.3%
Class 4 (41–55 points for pneumonia) (28–40 points for resp. failure)	9.4%	11.9%
Class 5 (> 55 points for pneumonia) (> 40 points for resp. failure)	15.8%	30.9%

AAA = abdominal aortic aneurysm; BUN = blood urea nitrogen; COPD = chronic obstructive pulmonary disease; NA = not assessed

* Development cohort.

Adapted from references 10 and 11.

planned will have a greater impact on risk than the risks inherent to the patient being sent to surgery. At the same time, most procedure-related risk factors are not modifiable, so identifying such a risk factor will not necessarily lead to a strategy to reduce risk. It does, however, allow physicians to stratify pulmonary risk for better planning and enhanced perioperative care.

Some of the best data to date on procedure-related risks for pulmonary complications have come from Arozullah et al, who developed and validated the first multivariable risk indices for postoperative pneumonia and respiratory failure.^{10,11} These indices, analogous to those used for cardiac complications, were based on the strength of predictors for pneumonia and respiratory failure as identified in prospective cohort studies of more than 160,000 veterans who underwent major noncardiac surgery.^{10,11} Table 2 summarizes these indices by listing the points these researchers assigned to various predictive factors for pneumonia and respiratory failure, as well as the rates for each complication according to patients' overall point totals. In this way, the indices can be used in clinical practice much as the Revised Cardiac Risk Index is used to assess risk for cardiac complications.

The cohort studies by Arozullah et al^{10,11} found surgical site to be the most important risk factor in predicting postoperative pulmonary complications, with aortic and thoracic surgeries carrying the highest risk, followed by upper abdominal procedures, neurosurgery, vascular procedures, and neck surgery. These findings are in keeping with other studies to date.

Other procedure-related risk factors for postoperative pulmonary complications include emergency surgery and prolonged surgery of greater than 3 hours' duration. The impact of general anesthesia as a risk factor (when compared with spinal or epidural anesthesia) remains controversial. A large meta-analysis reported that among patients randomly assigned to one anesthetic type or the other, those receiving spinal or epidural anesthesia (alone or combined with general anesthesia) experienced lower rates of pneumonia and respiratory failure,¹⁸ but sources of bias in this study have raised questions about the generalizability of its results.

■ ROLE OF PREOPERATIVE PULMONARY FUNCTION TESTING

Spirometry is indicated before surgery in all patients undergoing lung resection to estimate postoperative forced expiratory volume in 1 second (FEV₁) and suitability for resection.¹⁹ However, in patients undergoing other high-risk procedures, such as abdominal,

months), and a history of stroke are modest risk factors for postoperative pulmonary complications.^{10,11}

■ PROCEDURE-RELATED RISK FACTORS

Contrary to the case in cardiac risk assessment, procedure-related factors are more important than patient-related factors for predicting postoperative pulmonary complications. For this reason, the type of procedure

aortic, or nonresective thoracic surgeries, the role of pulmonary function tests (PFTs) has been more controversial, with the controversy centering on the following two questions.

Do PFTs predict risk more accurately than clinical evaluation alone?

The answer to this question appears to be *no*, according to one of the few studies that has directly compared clinical evaluation and spirometry for predicting pulmonary complications. In an analysis of more than 2,000 patients who underwent elective abdominal surgery, Lawrence et al⁶ compared adjusted odds ratios (ORs) for pulmonary complications among four variables:

- Abnormal physical examination, OR = 5.8
- Abnormal chest radiograph, OR = 3.2
- Goldman cardiac risk index (per point), OR = 2.0
- Charlson comorbidity index (per point), OR = 1.6.

In contrast, FEV₁, FVC, and FEV₁/FVC were nearly identical among patients with and without pulmonary complications, and no spirometric value was associated with postoperative pulmonary risk. Wong and colleagues⁷ similarly reported that an ASA physical status of class 4 or greater conferred higher ORs for pulmonary complications than did abnormal spirometry. These results and others suggest that clinicians can identify high-risk patients based on clinical criteria and that the results of spirometry are unlikely to modify the clinical risk estimate.

Are there spirometry values below which surgery should be denied?

At one time, a number of authorities argued that an FEV₁ less than 50% of predicted was a contraindication to surgery. This belief was called into question by a 1992 study by Kroenke et al²⁰ that evaluated 107 general surgical procedures (some high-risk) in 89 patients with severe COPD (ie, FEV₁ < 50% of predicted). Mortality was 6% overall and was clustered in the subset of patients undergoing coronary artery bypass graft (CABG) surgery (5 of 10 patients; 50%); mortality was 1% following the 92 noncardiac operations. Pulmonary complications occurred following 29% of operations; major pulmonary complications occurred after 7%. Although these complication rates are not trivial, they may be acceptable if the need for surgery is sufficiently compelling, even in high-risk patients.

The bottom line

Preoperative PFTs have a limited role in assessing a patient for surgery. PFTs should not be used to deny surgery if the reason for the surgery is compelling. PFTs

should be obtained, however, for all patients before lung resection. It is not necessary to routinely obtain PFTs before high-risk noncardiothoracic surgery.

PFTs can be helpful in cases when the history and physical examination leave the degree of risk uncertain—for example, if exercise intolerance or dyspnea remains unexplained after a clinical evaluation. PFTs also may occasionally be helpful if it is unclear whether a patient with COPD or asthma is at his or her best baseline function.

■ OTHER TESTING OPTIONS:

CONSIDER SERUM ALBUMIN AND BUN

The National Veterans Administration Surgical Quality Improvement Program found that levels of serum albumin and blood urea nitrogen (BUN) can be used to identify patients at risk for postoperative pulmonary complications.¹⁰ Both a low serum albumin (< 3 g/dL) and a BUN greater than 30 mg/dL were significant predictors of pulmonary complications.

■ STRATEGIES FOR REDUCING RISK

Preoperative strategies

Optimize management of chronic lung conditions.

The preoperative management of patients with COPD or asthma should be the same as it would be for patients not undergoing surgery. For instance, ipratropium or tiotropium is indicated for all symptomatic patients with COPD. Inhaled beta-agonists can be used as needed for symptoms. Theophylline should be continued if it is used chronically but should not be initiated shortly before surgery is planned. Liberal use of corticosteroids for a short period to “tune up” patients with COPD before surgery is safe and does not increase the risk of pneumonia or wound complications.

Airflow obstruction should be optimized to a goal peak flow that is at least 80% of the patient's personal best. Antibiotics should be used only if a change in the character of sputum suggests infection.

Advise carefully on smoking cessation. Notably, recent cessation of cigarette smoking (\leq 2 months before surgery) may pose a greater risk of postoperative pulmonary complications than smoking continuation. This finding, although not compatible with the notion that the preoperative setting provides a “teachable moment” for effective encouragement of smoking cessation, was suggested by a blinded prospective study of 200 unselected patients undergoing CABG surgery.²¹ When the researchers analyzed postoperative pulmonary complication rates by the patients' smoking status, they found the highest rate (57%) to be among those who had stopped smoking 1 to 8 weeks

before surgery. This rate was substantially higher than the 33% complication rate among current smokers. The complication rate among patients who had stopped smoking more than 8 weeks before surgery was the same as among nonsmokers (12%). Two other studies^{14,22} have yielded similar findings on high postoperative pulmonary complication rates following recent smoking cessation.

Although this finding may seem counterintuitive, its basis may be that many patients who quit smoking actually feel worse in the first 1 to 2 months and notice increased sputum production and cough.

Postoperative strategies

Lung expansion maneuvers and pain management are the two most important postoperative strategies for reducing the risk of pulmonary complications.

Lung expansion maneuvers work by reducing the expected drop in lung volumes after major surgery, particularly upper abdominal and thoracic surgeries. A meta-analysis of 14 randomized controlled trials of lung expansion maneuvers found that incentive spirometry and deep breathing exercises each reduced the risk of postoperative pulmonary complications by about 50%; no additional benefit was found from combining the two strategies.²³ Continuous positive airway pressure (CPAP) is an equally effective strategy, but it has disadvantages, including cost, its labor-intensive nature, and an association with small risks for barotrauma and aspiration. Nevertheless, CPAP may be preferred for patients who are unable to cooperate adequately with effort-dependent therapies.

Pain control. A meta-analysis of randomized controlled trials of postoperative pain control and pul-

monary complications demonstrated that epidural local anesthetics significantly reduce the risk of pneumonia and all postoperative pulmonary complications.²⁴

Selective nasogastric decompression in patients undergoing abdominal surgery is a lesser-known strategy for reducing the risk of pulmonary complications. A meta-analysis of 26 studies found that routine, as opposed to selective, use of nasogastric decompression might increase the risk of aspiration and pulmonary complications.²⁵ The ORs for pneumonia and atelectasis were 0.49 and 0.46, respectively, for patients who had selective nasogastric tube placement based on symptoms (nausea or abdominal distention) compared with routine tube placement.

SUMMARY

Postoperative pulmonary complications are among the most common sources of morbidity in patients undergoing major surgery. For this reason, the preoperative patient evaluation should emphasize risk factors for pulmonary complications as well as for traditional cardiac complications, as the former are comparably frequent and associated with longer hospital stays. Procedure-related risk factors are more important than patient-related risk factors for predicting pulmonary events, but clinicians should assess both types of factors. Pulmonary function testing has a limited role and should not be the basis for denying surgery if the surgical indication is compelling. Strategies to reduce the risk of postoperative pulmonary complications include optimizing management of chronic lung disease before surgery, lung expansion maneuvers, pain control, and selective placement of nasogastric tubes.

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