

Risk Assessment for and Strategies To Reduce Perioperative Pulmonary Complications for Patients Undergoing Noncardiothoracic Surgery: A Guideline from the American College of Physicians

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Postoperative pulmonary complications play an important role in the risk for patients undergoing noncardiothoracic surgery. Postoperative pulmonary complications are as prevalent as cardiac complications and contribute similarly to morbidity, mortality, and length of stay. Pulmonary complications may even be more likely than cardiac complications to predict long-term mortality after surgery. The purpose of this guideline is to provide guidance to clinicians on clinical and laboratory predictors of perioperative pulmonary risk before noncardiothoracic surgery. It also evaluates

strategies to reduce the perioperative pulmonary risk and focuses on atelectasis, pneumonia, and respiratory failure. The target audience for this guideline is general internists or other clinicians involved in perioperative management of surgical patients. The target patient population is all adult persons undergoing noncardiothoracic surgery.

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RECOMMENDATIONS

Recommendation 1: All patients undergoing noncardiothoracic surgery should be evaluated for the presence of the following significant risk factors for postoperative pulmonary complications in order to receive pre- and postoperative interventions to reduce pulmonary risk: chronic obstructive pulmonary disease, age older than 60 years, American Society of Anesthesiologists (ASA) class of II or greater, functionally dependent, and congestive heart failure.

The following are *not* significant risk factors for postoperative pulmonary complications: obesity and mild or moderate asthma.

Recommendation 2: Patients undergoing the following procedures are at higher risk for postoperative pulmonary complications and should be evaluated for other concomitant risk factors and receive pre- and postoperative interventions to reduce pulmonary complications: prolonged surgery (>3 hours), abdominal surgery, thoracic surgery, neurosurgery, head and neck surgery, vascular surgery, aortic aneurysm repair, emergency surgery, and general anesthesia.

Recommendation 3: A low serum albumin level (<35 g/L) is a powerful marker of increased risk for postoperative pulmonary complications and should be measured in all patients who are clinically suspected of having hypoalbuminemia; measurement should be considered in patients with 1 or more risk factors for perioperative pulmonary complications.

Recommendation 4: All patients who after preoperative

evaluation are found to be at higher risk for postoperative pulmonary complications should receive the following postoperative procedures in order to reduce postoperative pulmonary complications: 1) deep breathing exercises or incentive spirometry and 2) selective use of a nasogastric tube (as needed for postoperative nausea or vomiting, inability to tolerate oral intake, or symptomatic abdominal distention).

Recommendation 5: Preoperative spirometry and chest radiography should not be used routinely for predicting risk for postoperative pulmonary complications.

Preoperative pulmonary function testing or chest radiography may be appropriate in patients with a previous diagnosis of chronic obstructive pulmonary disease or asthma.

Recommendation 6: The following procedures should not be used solely for reducing postoperative pulmonary complication risk: 1) right-heart catheterization and 2) total parenteral

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nutrition or total enteral nutrition (for patients who are malnourished or have low serum albumin levels).

INTRODUCTION

Postoperative pulmonary complications play a significant role in the risk for surgery and anesthesia. The most important and morbid postoperative pulmonary complications are atelectasis, pneumonia, respiratory failure, and exacerbation of underlying chronic lung disease. While clinicians are very conscious of the importance of, and risk factors for, cardiac complications, clinicians who care for patients in the perioperative period may be surprised to learn that postoperative pulmonary complications are equally prevalent and contribute similarly to morbidity, mortality, and length of stay (1–5). Pulmonary complications may also be more likely than cardiac complications to predict long-term mortality after surgery, particularly among older patients (6).

This guideline is based on a 2-part systematic review prepared by Smetana and colleagues (7) and Lawrence and colleagues (8). The American College of Physicians (ACP) developed these guidelines to 1) guide clinicians on clinical and laboratory predictors of perioperative pulmonary risk before noncardiothoracic surgery and 2) evaluate the efficacy of strategies to reduce the risk for postoperative pulmonary complications. Studies of immunosuppressive states other than HIV infection (for example, organ transplantation) and of risk factors for postoperative venous thromboembolism were excluded from the review. The target audience is general internists or other clinicians involved in perioperative management of surgical patients. This guideline applies to adult patients undergoing noncardiopulmonary surgery. The perioperative period as defined in the studies ranged from 2 to 3 months before surgery and up to 3 months after surgery. A more in-depth discussion of the methods and the inclusion and exclusion criteria is available in the accompanying background papers in this issue (7, 8). In this paper, patient- and procedure-related risk factors are discussed separately.

PATIENT-RELATED RISK FACTORS

Potential patient-related risk factors fell into the following general categories: age; chronic lung disease; cigarette use; congestive heart failure; functional dependence; American Society of Anesthesiologists (ASA) classification; obesity; asthma; obstructive sleep apnea; impaired sensorium, abnormal findings on chest examination, alcohol use, and weight loss; and exercise capacity, diabetes, and HIV infection.

Age

The evidence review found that advanced age is an important predictor of postoperative pulmonary complications, even after adjustment for comorbid conditions. Ten multivariable studies showed that age was a significant risk

predictor and was the second most commonly identified risk factor. The odds ratio was 2.09 (95% CI, 1.70 to 2.58) for patients 60 to 69 years of age and 3.04 (CI, 2.11 to 4.39) for those 70 to 79 years of age compared with younger patients (those <60 years of age).

Chronic Lung Disease

Among studies reporting multivariable analyses, chronic obstructive pulmonary disease was the most commonly identified risk factor for postoperative pulmonary complications (odds ratio, 1.79 [CI, 1.44 to 2.22]). No eligible study determined the incremental risk for postoperative pulmonary complications in patients with chronic restrictive lung disease or restrictive physiologic characteristics due to neuromuscular disease or chest wall deformity, such as kyphoscoliosis. While clinicians may consider such patients with severe limitations to have an increased risk for postoperative pulmonary complications, the literature did not support an estimate of the magnitude of this risk in this group.

Cigarette Use

The available data are mixed but suggest a modest increase in risk for postoperative pulmonary complications among current smokers. The odds ratio for cigarette use was 1.26 (CI, 1.01 to 1.56). It is important to assess history of current smoking status and support for smoking cessation intervention very early in the preparation for nonemergency surgery.

Congestive Heart Failure

Good-quality evidence identified congestive heart failure as a significant risk factor for postoperative pulmonary complications (odds ratio, 2.93 [CI, 1.02 to 8.43]).

Functional Dependence

The evidence review showed that functional dependence is an important predictor of postoperative pulmonary complications. Total dependence was the inability to perform any activities of daily living, and partial dependence was the need for equipment or devices and assistance from another person for some activities of daily living. The odds ratio was 2.51 (CI, 1.99 to 3.15) for total dependence and 1.65 (CI, 1.36 to 2.01) for partial dependence.

ASA Classification

Several integrated measures of comorbidity have been evaluated as potential predictors of postoperative pulmonary complications. The ASA classification (Table) aims to predict perioperative mortality rates but has since been proven to predict both postoperative pulmonary and cardiac complications (9). Higher ASA class was associated with a substantial increase in risk when an ASA class of II or greater was compared with an ASA class of less than II (odds ratio, 4.87 [CI, 3.34 to 7.10]) and when an ASA class of III or greater was compared with an ASA class of less than III (odds ratio, 2.25 [CI, 1.73 to 3.76]).

Obesity

Studies evaluating clinically meaningful pulmonary complications after surgery have generally found no increased risk attributable to obesity, even for patients with morbid obesity (10, 11). Definitions of obesity varied from a body mass index of more than 25 kg/m² to “morbid obesity.” Postoperative pulmonary complication rates were 6.3% and 7.0% for obese and nonobese patients, respectively, in studies that reported only univariate data.

Asthma

Good evidence suggested that asthma is not a risk factor for postoperative pulmonary complications. Only 1 of 4 studies that examined the rate of postoperative pulmonary complications among patients with asthma included a control group; the rate in this study was 3%.

Obstructive Sleep Apnea

Obstructive sleep apnea increases the risk for airway management difficulties in the immediate postoperative period, but its influence on postoperative pulmonary complications has not been well studied. The evidence review identified a single univariate study that evaluated the risk due to obstructive sleep apnea among patients undergoing hip or knee replacement (12). In this case–control study, nonsignificant trends were seen toward higher rates of reintubation, hypercapnia, and hypoxemia for patients with obstructive sleep apnea. This finding suggests that postoperative pulmonary complication rates may have been higher among patients with obstructive sleep apnea, but this needs to be confirmed by more studies.

Impaired Sensorium, Abnormal Findings on Chest Examination, Alcohol Use, and Weight Loss

Fair evidence shows that impaired sensorium, abnormal findings on chest examination, alcohol use, and weight loss modestly increase the risk for postoperative pulmonary complications. Impaired sensorium is defined as 1) an acutely confused or delirious patient who is able to respond to verbal stimulation, mild tactile stimulation, or both, or 2) a patient with mental status changes, delirium, or both in the context of current illness. This definition excludes patients with stable chronic mental illness or dementia.

Exercise Capacity, Diabetes, and HIV Infection

Evidence was insufficient to support whether exercise capacity, diabetes, and HIV infection are independent risk factors for postoperative pulmonary complications.

PROCEDURE-RELATED RISK FACTORS

Procedure-related risk factors are as important as patient-related factors in estimating risk for postoperative pulmonary complications. These include surgical site, duration of surgery, anesthetic technique, and emergency surgery.

Table. American Society of Anesthesiologists Classification*

ASA Class	Class Definition	Rates of PPCs by Class, %
I	A normally healthy patient	1.2
II	A patient with mild systemic disease	5.4
III	A patient with systemic disease that is not incapacitating	11.4
IV	A patient with an incapacitating systemic disease that is a constant threat to life	10.9
V	A moribund patient who is not expected to survive for 24 hours with or without operation	NA

* Information is from reference 9. ASA = American Society of Anesthesiologists; NA = not applicable; PPC = postoperative pulmonary complication.

Surgical Site

Good evidence shows that the following procedures are related to increased risk for postoperative pulmonary complications: aortic aneurysm repair, thoracic surgery, abdominal surgery, upper abdominal surgery, neurosurgery, prolonged surgery, head and neck surgery, emergency surgery, and vascular surgery.

Duration of Surgery

Four studies that used multivariable analyses found prolonged surgery duration, ranging from 3 to 4 hours, to be an independent predictor of postoperative pulmonary complications (pooled odds ratio, 2.14 [CI, 1.33 to 3.46]).

Anesthetic Technique

Four studies provided estimates for risks related to general anesthesia; the odds ratio was 1.83 (CI, 1.35 to 2.46).

Emergency Surgery

Among studies reporting multivariable analyses, 6 reported emergency surgery as a significant predictor of postoperative pulmonary complications; the odds ratio was 2.21 (CI, 1.57 to 3.11).

LABORATORY TESTING TO ESTIMATE RISK

To determine the value of preoperative testing to estimate pulmonary risk, the authors of the evidence review assessed studies of spirometry, chest radiographs, blood urea nitrogen, oropharyngeal culture, and serum albumin measurement.

Spirometry

Although spirometry diagnoses obstructive lung disease, it does not translate into effective risk prediction for individual patients. Furthermore, the few studies that have compared spirometric data with clinical data have not consistently shown spirometry to be superior to history and physical examination in predicting postoperative pulmonary complications. Consensus exists regarding the value of spirometry before lung resection and in determining candidacy for coronary artery bypass; its value before extrathoracic surgery, however, remains unproven. Finally, the data

do not suggest a prohibitive spirometric threshold below which the risks of surgery are unacceptable. Therefore, spirometry should be reserved for patients who are thought to have undiagnosed chronic obstructive pulmonary disease.

Chest Radiographs

Clinicians frequently obtain chest radiographs as part of a routine preoperative evaluation. Most studies of the value of preoperative chest radiographs, however, have not studied postoperative pulmonary complications as the primary outcome measure but rather have evaluated the frequency with which an abnormal study changes perioperative management. In a recent review of this literature (13), it was found that 23.1% of preoperative chest radiographs were abnormal but only 3% had findings clinically important enough to influence management. An earlier review (14) found that 10% of preoperative chest radiographs were abnormal but only 1.3% showed unexpected abnormalities and only 0.1% influenced management.

Thus, the evidence suggests that clinicians may predict most abnormal preoperative chest radiographs by history and physical examination and that this test only rarely provides unexpected information that influences preoperative management. There is some evidence that this test is helpful for patients with known cardiopulmonary disease and those older than 50 years of age who are undergoing upper abdominal, thoracic, or abdominal aortic aneurysm surgery.

Blood Urea Nitrogen

Fair evidence supports serum blood urea nitrogen levels of 7.5 mmol/L or greater (≥ 21 mg/dL) as a risk factor. However, the magnitude of the risk seems to be lower than that for low levels of serum albumin.

Oropharyngeal Culture

The evidence review found only a single small study that evaluated the value of preoperative oropharyngeal culture to predict postoperative pulmonary complication risk (15). More studies are needed in this area.

Serum Albumin Measurement

Four studies that reported univariate analyses stratified postoperative pulmonary complication rates by serum albumin level and used a threshold of 36 g/L to define low levels (16–19). Unadjusted rates of postoperative pulmonary complications for patients with low and normal serum albumin levels were 27.6% and 7.0%, respectively. In the review of studies reporting multivariable analyses, a low serum albumin level was shown to be an important predictor of postoperative pulmonary complications (low values were defined variably from 30 to 39 g/L) (20–24). The National VA Surgical Risk Study reported that a low serum albumin level was also the most important predictor of 30-day perioperative morbidity and mortality (17). In this report, the relationship between serum albumin levels and mortality was continuous when levels were below approximately 35 g/L without a clear threshold value. On the

basis of the multivariate analysis, a serum albumin level less than 35 g/L is one of the most powerful patient-related risk factors and predictors of risk.

STRATEGIES TO REDUCE POSTOPERATIVE PULMONARY COMPLICATIONS

Opportunities to reduce risk for postoperative pulmonary complications occur throughout the perioperative period. Lawrence and colleagues' background review (8) discusses the evidence for lung-specific strategies, anesthetic and analgesic techniques, surgical techniques, and perioperative care. The review is limited to randomized, controlled trials; systematic reviews; or meta-analyses. Studies that used administrative data (for example, International Classification of Diseases, Ninth Revision, codes) to identify postoperative complications were excluded. A more detailed description of the methods is available in the paper by Lawrence and colleagues (8).

Lung-Specific Strategies

Preoperative Smoking Cessation

Studies evaluating the impact of smoking cessation on rates of postoperative pulmonary complications have generally included patients undergoing pulmonary or cardiac surgery, which were excluded from the review. The authors found only 1 randomized trial of a preoperative smoking cessation intervention that began approximately 6 to 8 weeks before hip or knee surgery and continued 10 days after surgery (25). Postoperative ventilatory support was the only measured pulmonary outcome and occurred in 1 patient in each group. However, several factors limited this study's ability to show decreased risk for pulmonary complications. The risk for postoperative pulmonary complications is low with hip and knee replacement, and only 1 potential postoperative pulmonary complication (ventilatory support) was evaluated. Future trials will need to stratify risk by the duration of preoperative smoking cessation. Another study showed that postoperative pulmonary complication rates did not decrease for smokers who stopped smoking or reduced smoking within 2 months of cardiothoracic surgery (26).

Lung Expansion Modalities

Lung expansion techniques include incentive spirometry; chest physical therapy, including deep breathing exercises; cough; postural drainage; percussion and vibration; suctioning and ambulation; intermittent positive-pressure breathing; and continuous positive-airway pressure.

The available evidence suggests that for patients undergoing abdominal surgery, any type of lung expansion intervention is better than no prophylaxis at all. However, no one modality is clearly superior, and the literature varies substantially regarding how clinicians actually administer the different methods. The available evidence does not suggest that combined methods provide additional risk reduc-

tion. Incentive spirometry may be the least labor-intensive and nasal continuous positive-airway pressure may be especially beneficial in patients who are unable to perform incentive spirometry or deep breathing exercises.

Anesthetic and Analgesic Techniques

Neuromuscular Blockade

The incidence of residual neuromuscular blockade was significantly higher among patients receiving pancuronium, and those patients were approximately 3 times more likely to develop postoperative pulmonary complications than patients without residual blockade. In contrast, among patients receiving an intermediate-acting agent (atracurium or vecuronium), there was no difference in the rates between those with and without prolonged blockade (4% vs. 5%). These data directly indicate that pancuronium use leads to higher rates of prolonged blockade and indirectly suggest an increased risk for postoperative pulmonary complications when compared with shorter-acting agents.

Anesthesia and Analgesia

A recent meta-analysis examined 141 randomized, controlled trials of general anesthesia versus neuraxial blockade in patients undergoing varied types of surgery (27). The comparison groups were patients receiving neuraxial blockade (44% with and 56% without concomitant general anesthesia) and those receiving general anesthesia alone. Complication rates with and without neuraxial blockade were, respectively, 3% and 5% for pneumonia (odds ratio, 0.61 [CI, 0.48 to 0.76]) and 0.5% and 0.8% for respiratory failure (odds ratio, 0.41 [CI, 0.23 to 0.73]). In a subgroup analysis of trials of neuraxial blockade alone versus general anesthesia alone, results were similar. This meta-analysis has been widely criticized, however, because of the very heterogeneous surgical populations and the use of older anesthetic techniques and older anesthetic agents. Overall, current evidence suggests that shorter-acting neuromuscular blocking drugs may prevent postoperative pulmonary complications.

Postoperative epidural pain management strategies seem superior to other routes of delivering opioids in preventing postoperative pulmonary complications. However, the risk for epidural hemorrhage in the setting of heparin for venous thromboembolism prophylaxis and postoperative epidural catheters may influence decisions regarding methods of pain control and venous thromboembolism prophylaxis.

Surgical Techniques

Overall, literature on laparoscopic versus open procedures did not systematically assess or report pulmonary complications, and most studies did not have sufficient statistical power to detect differences in rates of postoperative pulmonary complications. The evidence is not clear, and further studies are needed.

Perioperative Care

Nutritional Support

Malnutrition and hypoalbuminemia increase the risk for postoperative complications. Several studies have tried to determine if nutritional supplementation improves outcomes. Taken as a whole, the body of evidence, which includes a meta-analysis (28) and a multisite randomized trial (29), indicates no proven advantage to total parenteral nutrition over no supplementation or total enteral nutrition in reducing postoperative pulmonary complications. There is also a need for more research regarding “immunonutrition.”

Pulmonary Artery Catheterization

Only 1 randomized, controlled trial of pulmonary artery catheters in high-risk surgical patients has been published (30). Patients 60 years of age or older undergoing major abdominal, thoracic, vascular, or hip fracture surgery were randomly assigned to usual care or treatment guided by the use of a perioperative pulmonary artery catheter. All patients were in ASA class III or IV and were therefore at high risk for postoperative complications. The 2 groups did not differ in the primary outcome of in-hospital all-cause mortality, and postoperative pneumonia rates were also similar (6.7% and 7.3%, respectively; $P = 0.70$). This report shows no beneficial effect of pulmonary artery catheters as a strategy to reduce postoperative pulmonary complications.

Nasogastric Decompression after Abdominal Surgery

Selective use of nasogastric tubes refers to use only if postoperative nausea or vomiting, inability to tolerate oral intake, or symptomatic abdominal distention occur. *Routine use* of nasogastric tubes refers to standard use after surgery until gastrointestinal motility returns. A meta-analysis examined evidence from 26 studies (including case-control studies) of selective versus routine nasogastric decompression after elective laparotomy (31). Patients receiving selective nasogastric decompression had a significantly lower rate of pneumonia and atelectasis. There was no difference in aspiration rates. These results were confirmed in a more recent meta-analysis (32, 33).

SUMMARY

Clinicians should employ strategies to reduce postoperative pulmonary complications in patients who are at high risk after clinical risk stratification. Good evidence shows that patient-related risk factors, such as chronic obstructive pulmonary disease, age older than 60 years, ASA class of II or higher, functional dependence, and congestive heart failure, increase the risk for postoperative pulmonary complications. In addition, patients undergoing such procedures as prolonged surgery, abdominal surgery, thoracic surgery, neurosurgery, head and neck surgery, vascular surgery, aortic aneurysm repair, and emergency surgery are at

higher risk for postoperative pulmonary complications. General anesthesia and serum albumin levels below 35 g/L are also a strong marker of increased risk. Good evidence exists to support risk reduction strategies, including incentive spirometry and deep breathing exercises, and fair evidence exists to support selective nasogastric tube decompression after abdominal surgery. Fair evidence also suggests that short-acting neuroaxial blockade reduces postoperative pulmonary complications compared with long-acting neuroaxial blockade.

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Note: Clinical practice guidelines are “guides” only and may not apply to all patients and all clinical situations. Thus, they are not intended to override clinicians’ judgment. All ACP clinical practice guidelines are considered automatically withdrawn or invalid 5 years after publication, or once an update has been issued.

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