Preoperative Pulmonary Evaluation and Risk Mitigation

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KEYWORDS

• Postoperative pulmonary complications • Pulmonary evaluation
• Pulmonary risk indices • Risk mitigation

HOSPITAL MEDICINE CLINICS CHECKLIST

1. Postoperative pulmonary complications are common and can cause significant morbidity and mortality.
2. Multiple patient features are associated with increased risk of postoperative pulmonary complications (PPCs), specifically advanced age, comorbid status, congestive heart failure, chronic obstructive pulmonary disease, functional dependence, preoperative ascites, and preoperative sepsis.
3. Surgical site affects risk of PPCs, with closer proximity of incision to the diaphragm increasing the risk for PPCs.
4. Surgery lasting approximately 3 hours or longer doubles the risk of PPC.
5. In addition to a thorough history and physical examination, serum albumin, blood urea nitrogen (BUN), creatinine, and serum sodium levels may assist in preoperative evaluation.
6. Obtaining a routine preoperative chest radiograph is not recommended. If, however, clinical assessment in a high-risk patient raises concern, obtaining one may be supported.
7. Pulmonary risk indices are available but have historically been too cumbersome or specialized for everyday use. The Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) index by Canet and colleagues[40] shows promise.
8. Postoperative lung expansion maneuvers, preoperative intensive inspiratory muscle training, postoperative thoracic epidural analgesia, and selective (rather than routine) use of nasogastric tubes have been shown to reduce PPC.

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EPIDEMIOLOGY

1. What is the clinical significance of postoperative pulmonary complications?

Postoperative pulmonary complications (PPCs) are both common and clinically significant in the perioperative period. PPCs are involved in nearly one out of four postoperative deaths that occur within the first week.[1] Despite a substantial focus in the literature on perioperative cardiac complications, rates of PPCs have been shown to be as common as, or more common than, cardiac complications.[2] PPCs are also associated with a longer length of stay and overall increased hospital cost.[2,3]

2. What are the most important PPCs?

Although many studies evaluating PPCs have been done, no uniform definitions have been established, which may account for the heterogeneous incidence of PPCs in certain studies. General categories of PPCs exist, however, and most of the literature focusing on these complications includes the following:

Pneumonia or respiratory infection (suspected or confirmed by imaging)
Atelectasis
Bronchospasm
Prolonged mechanical ventilation or respiratory failure
Acute exacerbations of chronic obstructive pulmonary disease (COPD).

PATIENT-RELATED RISK FACTORS

1. How do patient-related factors affect risk for PPCs?

Age

Advanced age has been associated with increased PPCs,[4] although it was initially unclear if this finding was specifically related to age or due to comorbidities typical of those with advanced age (**Table 1**). Subsequent studies have identified that increasing age correlates with increased risk for PPCs even when adjusting for comorbidities. A 2006 systematic review by Smetana and colleagues[5] found an adjusted odds ratio (OR0) of 2.09 in patients ages 60 to 69 and 3.04 in patients ages 70 to 79.

Chronic Lung Disease

Studies evaluating the impact of chronic lung disease in the perioperative period have found that COPD nearly doubles the odds of PPCs.[5] On the other hand, asthma, when well controlled, was not associated with PPCs.[5] No studies have specifically evaluated restrictive lung disease and its impact on PPCs.

Congestive Heart Failure

There is a substantial body of evidence correlating congestive heart failure (CHF) with PPCs in noncardiac surgery. Among patients with a history of CHF going to surgery, the adjusted risk ratio was 2.93 for developing PPCs.[5]

Cigarette Smoking

Regardless of the diagnosis of lung disease, patients who smoke have a three times higher risk of PPCs.[6,7] In addition, a more recent evaluation found a dose-dependent increase in PPCs based on pack year exposure.[8]

Table 1
Strength of evidence for patient-related risk factors for PPCs

Strength of Evidence	Risk Factor
Supported by good evidence	Advanced age ASA class ≥II CHF Functional dependence Impaired sensorium COPD Preoperative sepsis Preoperative ascites
Supported by fair evidence	Weight loss History of stroke with residual deficits Cigarette use Alcohol use Abnormal findings on chest examination Pulmonary hypertension Obstructive sleep apnea[a] Obesity[a] Perioperative transfusion
Fair evidence this is *not* a risk factor	Diabetes
Good evidence this is *not* a risk factor	Asthma
Insufficient evidence	Corticosteroid use HIV infection Arrhythmia Poor exercise capacity

Within each column, risk factor is listed in order of strength of evidence.

Abbreviations: ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

[a] This is a change from the ACP guidelines due to recent evidence.[12–15]

Data from Smetana GW, Lawrence VA, Cornell JE. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144:581–95.

Comorbid Measures

Initially developed to determine perioperative mortality risk, the American Society of Anesthesiologists (ASA) classification has also been found to identify patients at increased risk for postoperative complications. Patients with ASA classification over class 2 are two to three times more likely to develop PPCs.[9]

Functional Dependence

Defined as "an inability to perform activities of daily living," increasing levels of preoperative dependence (partial vs full dependence) have been shown to correlate with increased risk for PPCs.[10,11]

Obesity

There are some early data to suggest that obesity is a risk factor for PPCs (adjusted OR 2.8) in abdominal surgery,[7] but other studies have not been able to find a significant difference related to body mass index (BMI).[5] More recent data suggest that elevated BMI may increase the risk of PPCs,[12] so this requires further evaluation.

Obstructive Sleep Apnea

An early study found obstructive sleep apnea (OSA) was associated with an increased risk for all complications, length of stay, and unplanned ICU transfers, but the study was not powered to further specify risk for PPCs.[13] Subsequently, Hwang and colleagues[14] conducted a study including 172 patients with clinical features suggestive of OSA. Patients with five or more desaturation episodes per hour had significantly higher rates of PPCs than did patients with fewer than five desaturations per hour. Although not conclusive of the role of diagnosed OSA, this study supported OSA as a risk factor for PPCs. Most recently, Memtsoudis and colleagues[15] retrospectively reviewed charts of patients who had had orthopedic or general surgical procedures. Those patients with a diagnosis of OSA had increased PPCs, again supporting OSA as a risk factor for PPCs.

Neurologic Impairment

Patients with impaired sensorium in the context of current illness or history of stroke with residual neurologic deficits were found to have a greater likelihood of PPCs (pneumonia and respiratory failure, OR 1.5 and 1.2, respectively) as compared with patients who did not have these neurologic impairments.[10,11] A second study by Johnson and colleagues[16] reported similar ORs. However, Johnson's study also included in the history of stroke those patients without a residual neurologic deficit.

Perioperative Transfusion

The impact of packed red blood cell transfusions has also been evaluated in PPCs, given the risks of increased volume and the known transfusion-associated inflammatory reactions that have been identified. Transfusion was found to be a risk factor when greater than 4 units were required,[10] with a pooled OR of 1.47 in the Smetana and colleagues[5] review. Furthermore, in 2009, Pedersen and colleagues[17] found an increased likelihood of PPCs (OR 2.1) with a minimum transfusion of 1 unit.

Preoperative Sepsis, Ascites, and Pulmonary Hypertension

In the past few years, since the American College of Physicians (ACP) guidelines were originally published, new clinical predictors for PPCs have been identified. The updated study of the National Surgical Quality Improvement Program (NSQIP) by Johnson and colleagues[16] found important risk factors, including preoperative sepsis (OR 1.99) and ascites (OR 1.85). In addition, pulmonary hypertension (PH) has also been shown as having a potential impact on PPCs. A case-control study conducted by Lai and colleagues[18] found PH to be an independent predictor (OR 1.1). Screening for PH before major noncardiac surgery is an area of ongoing research and not recommended at this time (see **Table 1**).

PROCEDURE-RELATED RISK FACTORS

1. How does surgical site influence risk for PPCs?

It is well known that surgical site plays a critical role in determining a patient's risk of PPCs (**Table 2**). In contrast to perioperative cardiac complications, procedure-related risk factors are actually more predictive of PPCs than are patient-related risk factors.[19] Indeed, surgical site is the most important risk factor for PPCs even in healthy patients. As the site of the incision moves closer to the diaphragm, the risk for PPCs increases. It is beyond the scope of this article to address every surgical procedure independently. Instead, the broad categories deemed most relevant by the current guidelines

Table 2
Strength of evidence for procedure-related risk factors for PPCs

Good evidence to support this risk factor	Aortic aneurysm repair Thoracic surgery Abdominal surgery Upper abdominal surgery Neurosurgery Prolonged surgery Head and neck surgery Emergency surgery Vascular surgery General anesthesia
At least fair evidence to support this risk factor	Perioperative transfusion
Good evidence that this is *not* a risk factor	Hip surgery Gynecologic or urologic surgery
Conflicting or poor evidence that this is a risk factor	Esophageal surgery

Within each column, risk factor is listed in order of strength of evidence.
Data from Smetana GW, Lawrence VA, Cornell JE. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144:581–95.

are addressed. It is important to keep in mind that each surgical procedure carries with it a unique risk and should be independently evaluated as such. Current guidelines conclude that the following procedures portend higher risk for PPCs.[20]

Aortic

Owing to the extraordinarily high risk of PPCs associated with aortic surgery, it is discussed separately from other vascular surgeries (see later discussion). A systematic review of PPCs by Smetana and colleagues[5] concluded that patients undergoing open aortic surgeries are at the highest risk for PPCs (OR 6.9). The review also revealed that among 16 studies of abdominal aortic aneurysm repair meeting inclusion criteria, the unadjusted PPCs rate was 25.5%. Endovascular repair of the aorta has a lower risk of pulmonary complications, with one cohort study finding that the pulmonary morbidity rate was 3% in the endovascular group, compared with 16% in the open repair group (relative risk reduction of 80%).[21]

Thoracic

Unsurprisingly, procedures that involve resection of lung tissue carry the greatest risk for PPCs among thoracic surgeries. However, even more commonly performed thoracic surgeries in which lung is not resected are high risk owing primarily to their disruption of the integrity of the thoracic cage.[22] In a systematic review of PPCs by Smetana and colleagues,[5] the pooled estimate OR for three studies of PPCs in thoracic surgery patients was 4.24. This was second only to aortic surgeries in respect to PPCs.

Abdominal (Any, Upper, and Lower)

A systematic review by Smetana and colleagues[5] evaluated 43 studies that assessed PPC rates in abdominal surgery. The studies were categorized as upper abdominal, any abdominal, and lower abdominal surgery. The studies that assessed any abdominal surgery were found to have an OR of 2.96 for PPCs. Those studies involving just the upper or just the lower abdomen were also found to have increased rates of PPCs.

Neurosurgery

Neurosurgical procedures are associated with PPCs because of their prolonged nature and the possibility of preoperative or intraoperative neurologic injury.[23] In a systematic review, the pooled estimate OR for PPCs in patients undergoing neurosurgical procedures was 2.53.[5]

Head and Neck

Patients undergoing major head and neck surgery often require tracheostomy, putting them at an especially high risk of PPCs. A study by Morton and colleagues[24] revealed that 45% of patients undergoing major head and neck surgery that involved a tracheostomy develop PPCs, most of which occur in the first 5 days after surgery. A systematic review by Smetana and colleagues[5] analyzed six studies and found that, overall, the unadjusted PPCs rate for head and neck surgeries was 10.3% (OR 2.21).

Vascular

Although most patients undergoing major vascular surgery have a smoking history, vascular surgery is high risk for PPCs independent of tobacco use. A cohort study by Kispert and colleagues[25] found an overall rate of PPCs to be 12.9%. Current guidelines report that vascular surgery (other than aortic), corresponds to an OR for PPCs of 2.1.[5]

2. How does duration of surgery influence risk for PPCs?

The current ACP guidelines reflect that prolonged surgery (defined as 2.5–4 hours) portends an increased risk for PPCs.[5] Theoretically, this may be due to the effects of prolonged exposure to anesthetic agents causing diaphragm relaxation, decreasing lung volume, and in turn promoting atelectasis. The pooled OR across the six studies included in the analysis was 2.26.

3. How does emergency surgery influence risk for PPCs?

Patients undergoing emergency surgery are at significantly increased risk for PPCs (OR 2.52).[5] This may be attributed to the inability to perform risk reduction strategies and the patient's underlying critical condition.

4. How does anesthetic technique influence risk for PPCs?

General Versus Regional Anesthesia

General anesthesia has several effects on the respiratory system. Most importantly, it decreases respiratory muscle tone and causes atelectasis by compression of lung tissue and suppression of surfactant function. A systematic review by Smetana and colleagues[5] reviewed four studies and concluded that general anesthesia is associated with an increased risk for PPCs (pooled OR 2.35).

Neuromuscular Blockade

When considering neuromuscular blockade, it is important to point out that patients receiving the long-acting agent pancuronium are much more likely to experience residual neuromuscular blockade. Resulting primarily from hypoventilation, this leads to a threefold higher rate of PPCs when compared with patients that do not experience residual neuromuscular blockade.[5] When possible, intermediate or shorter-acting agents such as atracurium or vecuronium are favored.

5. How does surgical technique influence risk for PPCs?

Intuitively, it makes sense that a laparoscopic surgery would cause less postoperative pain than open surgery. The next logical hypothesis is that lessened postoperative pain would facilitate deeper breathing and fewer PPCs. However, up until recently there was a paucity of evidence supporting this theory. A recent study by Weller and colleagues analyzed a database of 19,156 patients who underwent bariatric surgery and found that the rate of PPCs was almost double in patients who underwent an open surgery in comparison to laparoscopic surgery (OR 1.92) (see **Table 2**).[26]

INITIAL HISTORY AND PHYSICAL EXAMINATION

1. What are the most important components of the history in preoperative pulmonary evaluation?

Obtaining a thorough history can identify patient-related risk factors for PPCs and aid in stratifying risk. The clinician should seek a history of weight loss, exercise intolerance, chronic cough, or unexplained dyspnea.[27,28,29]

It is also essential to consider the patient's age, alcohol and smoking history, and comorbid conditions. Obviously, it is imperative to seek out a medical history of conditions deemed risk factors for PPCs (see previous discussion).

2. What are the most important components of physical examination in the preoperative pulmonary evaluation?

The physical examination should not be overlooked in the preoperative pulmonary evaluation. Clinicians should focus on identifying signs of unrecognized or decompensated cardiopulmonary disease. In patients with COPD or asthma, certain findings on chest examination will identify patients that do not have optimal reduction of airflow obstruction. In particular, prolonged expiratory phase, decreased breath sounds, dullness to percussion, wheezes, and rhonchi predict an increased risk for PPCs.[30,31] Clinical findings should guide diagnostic test ordering. In combination with the history, the lung examination has been shown to accurately predict an abnormal preoperative chest radiograph, lessening the need to order this diagnostic test.[5]

IMAGING AND ADDITIONAL TESTING TO STRATIFY RISK

1. What is the role of spirometry in preoperative pulmonary evaluation?

The role of spirometry in preoperative assessment has been debated for several years (**Table 3**). However, an increasing body of literature suggests that an abnormal preoperative spirometry does not predict risk of PPCs and is inferior to clinical assessment.[22,31]

2. What is the role of laboratory testing in preoperative pulmonary evaluation?

Serum Albumin Measurement

In early evaluations of serum albumin as a potential predictor of PPCs, a low albumin level (<3.5 g/dL) was associated with an increased risk.[32] For example, using the NSQIP database, which looks at a Veteran's Administration (VA)–based population, Arozullah and colleagues[10] found serum albumin to be a significant predictor of PPCs (OR 2.53). An updated assessment that also included non-VA hospitals found that it is still predictive but not as significantly (OR 1.5).[16]

Table 3
Strength of evidence for laboratory related risk factors for PPCs

Good evidence to support this risk factor	Albumin level <3.5 g/L
At least fair evidence to support this risk factor	Serum urea nitrogen level >7.5 mmol/L (>21 mg/dL) Serum sodium >145 mEq/L[a] Creatinine >1.5 mg/dL[a]
Conflicting or poor evidence that this is a risk factor	Abnormal chest radiography[b] Abnormal spirometry

[a] Serum sodium >145 mEq/L and creatinine >1.5 mg/dL were not graded in the 2006 American College of Physicians guidelines.[5]
[b] This is a change from the ACP guidelines due to conflicting or lack of adequate evidence. Limited evidence may support considering its use in patients older than 50 years undergoing upper abdominal, thoracic, or abdominal aortic aneurysm surgery, or in those with known cardiopulmonary disease.
Data from Smetana GW, Lawrence VA, Cornell JE. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144:581–95.

Serum Renal Function

Evaluation in early studies found that both an elevated blood urea nitrogen (BUN) (>30 mg/dL) and creatinine (>1.5 mg/dL) were associated with increased risk of PPCs (OR 2.3 and 1.5, respectively).[10] The updated assessment by Johnson and colleagues[16,33] found a less significant OR of 1.5 for elevated serum urea nitrogen, but a consistent OR for abnormal creatinine.

Serum Sodium

The updated NSQIP study included hypernatremia as a possible risk factor for PPCs. Preoperative levels of serum sodium greater than 145 mEq/L were found to predict development of PPCs (OR 1.56).

3. What is the role of chest radiography?

Chest radiography (CXR) is not an essential component of a routine preoperative assessment. In an earlier meta-analysis of studies assessing the value of CXR, only 1.3% of over 14,000 preoperative chest CXRs showed an unexpected abnormality and only 0.1% prompted a change in management.[34,35] This lack of diagnostic utility was supported in a more recent review that also found similar rates of PPCs between patients who had preoperative CXR and those who did not.[36] However, guidelines[5] do support its limited use based on studies using secondary multivariate analysis in a specialized patient population.[37] Other studies used to advocate for its use are limited by small sample size and an unusually high baseline PPCs rate (25% in patient with a normal CXR)[38] or by the study actually evaluating the utility of postoperative CXR.[39] Therefore, the authors do not recommend the use of routine, preoperative CXR. A CXR should be ordered if indicated by the history and physical examination, with a lower threshold to obtain one in patients at risk for PPCs (see **Table 3**).

4. What tools can be used to assess risk of PPCs (pulmonary risk indices)?

Although there are multiple risk factors that predict risk for PPCs, it may be difficult for the clinician to synthesize the cumulative risk for an individual patient. A risk index can be useful in this setting because it has been used in stratifying perioperative risk

for cardiac outcomes. There are similar pulmonary risk indices that have been developed in the literature.

Arozullah and colleagues[11] used the NSQIP database to develop and validate two sets of indices, each for specific PPCs (respiratory failure and pneumonia) in which 28 risk factors were identified among a VA population. These were then refined to an index including seven risk factors. These have been considered the "gold standard" for pulmonary risk index assessment.[35] However, sampling bias toward its specific population may affect its generalizability, limiting its use. Furthermore, using separate indices for specific PPCs is cumbersome. An updated index by Johnson and colleagues[16] refines the initial scoring system and improves its generalizability, but does so using 28 risk factors. The complexity, therefore, limits its use. In 2010, Canet and colleagues[40] published the Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) study, providing an index of seven independent, objective predictors developed and tested using a more generalizable sample. A subsequent international, multicenter study, the Prospective Evaluation of a Risk Score for Postoperative Pulmonary Complications in Europe (PERISCOPE) was recently performed to validate these predictors.[41] This pulmonary risk index (**Table 4**) would be more practical for everyday use.

RISK REDUCTION STRATEGIES

1. What are the most effective strategies to reduce risk of PPCs?

Smoking Cessation

The impact of smoking cessation on PPCs has long been debated (**Table 5**). There is data to suggest that smokers who quit shortly before surgery may actually have an

Table 4
ARISCAT risk score

Variables		Risk Score
Age	<50	0
	51–80	3
	>80	16
Preoperative saturation of peripheral oxygen (SpO_2)	>96	0
	91–95	8
	<90	24
Respiratory infection in the last month	No	0
	Yes	17
Preoperative anemia (<10 g/dL)	No	0
	Yes	11
Surgical incision	Peripheral	0
	Upper abdominal	15
	Intrathoracic	24
Duration of surgery (hours)	<2	0
	2–3	16
	>3	23
Emergency procedure	No	0
	Yes	8

Low risk <26, intermediate risk 26–44, high risk >45.

PPC rate: Low risk, 1.6%; intermediate risk, 13.3%; high risk, 42.1%.

Data from Canet J, Gallart L, Gomar C, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology 2010;113:1338–50.

Table 5
Summary of strategies to prevent PPCs and strength of evidence

Strength of Evidence	Preventive Strategy
Good evidence that the strategy reduces PPCs	Postoperative lung expansion modalities Postoperative epidural analgesia[a]
At least fair evidence that the strategy reduces PPCs	Selective postoperative nasogastric decompression Short-acting intraoperative neuromuscular blockade Laparoscopic (vs open) operation[b]
At least fair evidence that the strategy may reduce PPCs, but not to justify recommendation	Preoperative chest physical therapy[c]
At least fair evidence that the strategy does not reduce PPCs	Routine total parenteral or enteral nutrition Postoperative right-heart catheterization to guide therapy
Conflicting or poor evidence of effectiveness of the strategy to reduce PPCs	Smoking cessation Intraoperative neuraxial blockade Immunonutrition

Changes from the ACP guidelines.
[a] More recent data provide good evidence that this is a risk factor.[45]
[b] More recent data provide fair evidence to support this strategy to reduce PPCs.[26]
[c] More recent data provide fair evidence to support this strategy.
Data from Lawrence VA, Cornell JE, Smetana GW. Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144(8):596–608.

increased risk of PPCs due to increased secretions; however, experts believe that selection bias may have played a role in these findings.[19] At this time, evidence is insufficient to determine the potential benefit of preoperative smoking cessation. Although it may not reduce PPC risk, the overwhelmingly positive effect of smoking cessation on cardiovascular health, cancer risk, and lung function in general should prompt all physicians to use the preoperative pulmonary evaluation as an opportunity to counsel patients on smoking cessation. The possibility of benefit during and after their surgery may provide the motivation needed to quit permanently.

Lung Expansion Maneuvers

Postoperative lung expansion maneuvers, including incentive spirometry, deep breathing exercises, intermittent positive-pressure breathing, and continuous positive airway pressure (CPAP), are the only strategies to reduce PPCs supported by good evidence per the ACP guidelines. The use of CPAP is especially effective in patients unable to perform deep breathing exercises on their own. Recently, a systematic review and meta-analysis of nine trials comparing CPAP to standard therapy in patients undergoing abdominal surgery concluded that CPAP was associated with a significant reduction in overall PPCs (OR 0.66; 95% CI, 0.52–0.85).[42]

Preoperative Chest Physical Therapy

Preoperative chest physical therapy is a novel modality to reduce PPCs. In 2006, a randomized clinical trial was conducted to evaluate the benefit of preoperative chest physical therapy in patients at high risk for PPCs and undergoing coronary artery bypass graft surgery. Patients were randomized to preoperative inspiratory muscle training (20 minutes a day for 2 weeks before surgery) or usual care. Patients who

underwent inspiratory muscle training had a considerable reduction in PPCs (OR 0.52; 95% CI, 0.30–0.92).[43] The generalizability of these data to the noncardiothoracic surgery population is currently unknown and is an area that warrants investigation. When considering preoperative chest physical therapy, clinicians should consider this, as well as the cost and labor intensive nature of this strategy.

Selective Nasogastric Decompression

A recent meta-analysis by Nelson and colleagues[44] evaluated 24 studies comparing routine nasogastric tube use in abdominal surgery to selective nasogastric tube use in patients who have symptomatic nausea or abdominal distention. The study revealed that selective use significantly reduces PPCs, whereas routine use significantly increases PPCs.

Postoperative Thoracic Epidural Anesthesia

In 2007, a systematic review by Liu and Wu[45] revealed that postoperative thoracic epidural analgesia significantly decreases the risk of PPCs. In patients undergoing aortic aneurysm repair, coronary artery bypass surgery, and abdominal surgery, the use of postoperative thoracic epidural anesthesia reduced rates of pneumonia, respiratory failure, and pulmonary complications by one-third to more than one-half.[45] As these data were published after 2006, postoperative thoracic epidural anesthesia was not addressed as a risk reduction strategy in the ACP guidelines. Concern for epidural hemorrhage in the setting of heparin use for venous thromboembolism prophylaxis may influence decisions to use this risk reduction strategy.

Laparoscopic (vs Open) Operation

In 2008, a study by Weller and Rosati[26] analyzed a database of nearly 20,000 patients who underwent bariatric surgery and concluded that the rate of PPCs was almost double in patients who underwent an open surgery when compared with laparoscopic (OR 1.92). Choosing laparoscopic over open procedures in bariatric surgery patients is another strategy that could decrease PPCs. Because this study dealt with a strictly bariatric surgery population, the generalizability of these findings is questionable and more research is needed to further clarify this relationship in respect to other surgical sites (see **Table 5**).

CLINICAL GUIDELINES

1. *What are the best clinical guidelines for the preoperative pulmonary evaluation and for mechanisms of risk reduction?*

Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians.[20]

Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians.[5]

Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians.[41]

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