# Prevention of Postoperative Pulmonary Complications

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**KEYWORDS**

• Postoperative • Pulmonary complications • COPD • Respiratory failure

**KEY POINTS**

- Postoperative pulmonary complications (PPCs) are common and infer greater risk of morbidity and mortality to surgical patients.
- Careful preoperative evaluation can identify undiagnosed and undertreated illness and allow for preoperative intervention.
- Surgical, anesthetic, and patient factors contribute to developing PPCs.
- Certain high-risk groups may benefit from presurgical optimization of known disease as well as specific postoperative maneuvers.
- Comorbidities that greatly increase risk include chronic obstructive pulmonary disease (COPD), obesity, obstructive sleep apnea (OSA), obesity hypoventilation syndrome (OHS), pulmonary hypertension (PH), and smoking.

## INTRODUCTION

PPCs represent a significant burden of illness in surgical patients. The reported incidence is 5% for general surgical patients but as high as 20% in select groups undergoing high-risk procedures.[1–3] PPCs are as common as cardiac complications in general surgical patients.[4]

PPCs represent an important cause of mortality with rates as high as 25% depending on the operation and complication.[1] Abdominal surgical patients who develop postoperative pneumonia experience a 10-fold increase in mortality over those who do not, as well as longer length of stay.[5,6] In addition, PPCs increase 30-day readmission rates and may be a marker for decreased long-term survival in elderly hospitalized patients.[7] PPCs are more of a financial burden than cardiovascular or infectious complications after surgery, costing the United States $3.4 billion annually.[5,8]

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The spectrum of PPCs ranges from bronchospasm and atelectasis to pneumonia and respiratory failure. Atelectasis occurs in up to 90% of patients during an operation but is usually self-limited.[9] Pneumonia occurs in up to 15% of patients after surgery and has a high associated mortality rate.[5,10] Acute lung injury (ALI) is the most common cause of postoperative respiratory failure and is also associated with increased mortality.[11] The overall risk of acute respiratory distress syndrome (ARDS) among general surgical patients is approximately 0.2%; however, the risk is higher in subgroups with COPD and preexisting renal failure and those undergoing emergency surgery.[12]

A complex interplay of anesthetic factors, surgical factors, and patient factors contribute to the development PPCs. This review discusses the cause and prevention of PPCs in noncardiac surgical patients.

## RISK ASSESSMENT

Smetana and colleagues[4] conducted a systematic review of preoperative pulmonary risk stratification for the American College of Physicians, which remains the most widely cited clinical guideline (**Table 1**). Based on these findings, there is good evidence that patients with congestive heart failure, American Society of Anesthesiologists (ASA)

**Table 1**
**Risk factors for postoperative pulmonary complications**

| Patient-Related Factors[a] | Procedure-Related Factors[a] |
|---|---|
| **Supported by good evidence** | |
| Advanced age | Aortic aneurysm repair |
| ASA class ≥2 | Thoracic surgery |
| Congestive heart failure | Abdominal surgery |
| Functional dependency | Upper abdominal surgery |
| Chronic obstructive pulmonary disease | Neurosurgery<br>Prolonged surgery<br>Head and neck surgery<br>Emergency surgery<br>Vascular surgery<br>Use of general anesthesia |
| **Supported by fair evidence** | |
| Weight loss<br>Impaired sensorium<br>Cigarette use<br>Alcohol use<br>Abnormal results in chest examination | Perioperative transfusion |
| **Good evidence *against* being a risk factor** | |
| Well-controlled asthma | Hip surgery |
| Obesity | Genitourinary/gynecologic surgery |
| **Insufficient data** | |
| Obstructive sleep apnea[b]<br>Poor exercise capacity | Esophageal surgery |

*Abbreviation:* ASA, American Society of Anesthesiologists.

[a] Within each evidence category, risk factors are listed according to strength of evidence, with the first factor listed having the strongest evidence.

[b] Subsequent evidence indicates that this is a probable risk factor.

*Adapted from* Smetana GW. Postoperative pulmonary complications: an update on risk assessment and reduction. Cleve Clin J Med 2009;76(Suppl 4):S60–5.

class of 2 or greater, advanced age, COPD, and functional dependence have a higher risk of PPCs.[2,4,13,14]

A large, prospective multicenter trial by the ARISCAT (The Assess Respiratory Risk in Surgical Patients in Catalonia Group) group examined postoperative complications of general surgical patients in 59 hospitals in Spain. They identified 7 factors predictive of PCCs[3]:

1. Advanced age
2. Reduced preoperative peripheral capillary oxygen saturation ($Spo_2$)
3. Previous respiratory infection in the last month
4. Preoperative anemia (hemoglobin $\leq$10 g/dL)
5. Surgical incision close to the diaphragm
6. Longer duration of surgery
7. Emergency surgery

Other risk factors that have been linked to PPCs include decreased functional status, altered mental status, weight loss greater than 10% within the last 6 months, chronic kidney disease, diabetes mellitus, congestive heart failure, and significant alcohol use.[1,3,13,15–17]

Elderly patients have increased risk of PPCs even after adjusting for comorbidities.[4,18] Advanced age is accompanied by decreased elastic recoil of lung parenchyma, decreased chest wall compliance, decreased alveolar surface area, and decreased respiratory muscle strength.[18] Patients older than 70 years are at 3 times greater risk of experiencing a PPC.[19] Another article by Schlitzkus et al. in this issue addresses perioperative management of the elderly.

Gupta and colleagues[20] created a postoperative respiratory failure risk calculator based on National Surgical Quality Improvement Program (NSQIP) data, which considers ASA class, preoperative function, type of procedure, nature of surgery (emergent or elective), and presence of preoperative sepsis. This free calculator can be accessed at www.surgicalriskcalculator.com/.

## PREOPERATIVE EVALUATION

### *History and Physical Examination*

Prevention of PPCs begins with a thorough medical history. Special attention should be given to complaints related to underlying lung disease and smoking history. Exercise tolerance has been independently associated with improved survival after major abdominal operations.[21] Respiratory infection within 4 weeks and sputum production increase the risk of PPCs, as does alcohol use.[3,13,22,23]

Physical examination should pay careful attention to body habitus as well as cardiorespiratory signs. Severe obesity (body mass index >40 $kg/m^2$) increases the risk of unplanned tracheal intubation and complications in general.[24,25] A positive result in a cough test, whereby a patient attempts deep breathing and coughs involuntarily, is a predictor of PPCs.[3,26]

### *Laboratory Testing*

Routine preoperative laboratory testing may help identify patients at increased risk. Preoperative anemia was established as an independent risk factor for PPCs by the ARISCAT study, and elevated blood urea nitrogen levels (>30 mg/dL) may also confer increased risk.[3,15]

Several studies have demonstrated the association between low serum albumin levels and PPCs, and a large systematic review by Smetana and colleagues[13,27] found

good evidence to support serum albumin levels less than 30 g/L as a predictor for PPCs.[28] Patients with low serum albumin levels have significantly increased rates of reintubation, pneumonia, and failure to wean from mechanical ventilation.[28]

Routine arterial blood gas measurement is not indicated but may be useful to screen for OHS in at-risk patients to initiate positive airway pressure (PAP) therapy preoperatively, which can reduce morbidity and mortality (see later discussion).[29–31]

### *Other Investigations*

There is some evidence that an abnormal finding on chest radiograph (CXR) may correlate with an overall increased risk of PPCs.[32,33] Findings that indicate subclinical heart failure or infection should delay elective surgery.[29] The American College of Physicians guidelines currently recommend preoperative CXRs in patients 50 years or older with known cardiopulmonary disease who are undergoing high-risk surgery.[13]

Routine preoperative pulmonary function tests (PFTs) are useful in thoracic surgical patients, but their role in nonthoracic surgery is limited to at-risk groups.[34] A forced expiratory volume at one second ($FEV_1$) less than 60% of predicted has been identified as a risk factor for PPCs.[35] PFTs should be ordered selectively in at-risk populations.[19]

Other interventions can be considered in patients with known risk factors such as PH, which usually mandates a preoperative electrocardiogram and right heart catheterization if the diagnosis is suspected.[36]

## SURGICAL FACTORS

Postoperatively, inhibition of respiratory muscles contribute to pulmonary complications and are thought to be caused by the following[37,38]:

- Incisional pain
- Functional disruption from incisions
- Reflex inhibition of phrenic motor neuron output from traction of abdominal viscera

### *Surgical Site*

Surgical site is perhaps the most important risk factor in the development of PPCs.[4] In particular, aortic surgery, thoracic surgery, and upper abdominal surgery carry the highest risk of PPCs, although neck operations also carry increased risk.[13,39] Patients undergoing open abdominal aortic aneurysm have a risk of developing PPCs that approaches 25%.[13] In general, the risk of PPCs increases with increasing proximity to the diaphragm.[18] Transverse or oblique incisions may have a mildly decreased risk of associated PPCs compared with vertical midline incisions.[40]

The benefits of laparoscopy include smaller incisions, decreased systemic inflammatory response, reduced postoperative pain, and improved pulmonary function. When compared with open surgery, patients undergoing laparoscopy have a lower incidence of PPCs.[41,42]

Regardless of surgical site, emergency surgery confers a greater risk of PPCs than elective cases.[13,15,16]

### *Analgesia*

PPCs may occur less frequently in patients with either epidural or intravenous patient-controlled analgesia.[27,43] Segmental epidural blockade with local anesthetics can increase tidal volume and vital capacity and improve indices that reflect diaphragm activity after thoracic and upper abdominal surgery.[18,38,44] Several retrospective

studies have demonstrated a decrease in PPCs among patients with epidural analgesia, and a large meta-analysis found the rate of pneumonia decreased from 12.8% to 7.5% in patients who received a postoperative epidural versus systemic analgesia.[45–47] However, randomized trials have failed to reproduce this benefit.[48–50]

Although the evidence is not strong, epidurals may infer protection from PPCs, especially in high-risk patients.[51] Pain control has special importance in select patient groups with underlying cardiorespiratory comorbidity, such as PH, whereby increases in vascular resistance due to catecholamine release can have deleterious effects on cardiac function. Multimodal analgesia that minimizes narcotic use may also reduce PPCs.[52]

### *Anesthesia*

Several factors contribute to the harmful effects of general anesthesia on the lungs[38,53]:

- Instrumentation alters mucociliary function, promoting retention of secretions.
- Administered drugs release circulating mediators causing bronchoconstriction.
- There is decreased surfactant production.
- There is inhibition of alveolar macrophage activity.

General anesthesia causes an immediate and prolonged decrease in functional residual capacity (FRC) of up to 20% and is almost always associated with atelectasis.[54,55] Anesthesia causes immediate atelectasis in almost all patients as a result of chest wall deformation, decreased inspiratory muscle tone, and reduced FRC of the lung and may significantly impact gas exchange.[56–58] The physiologic response of the lungs and chest wall may be dose related, with higher doses causing uncoordinated respiratory function.[38,59] These effects can last into the postoperative period and contribute to overall complications.

### *Neuromuscular Blockade*

Neuromuscular blocking agents are necessary for procedures that require muscle relaxation. Their use increases the risk for postoperative desaturation, unplanned reintubation, and postoperative residual curarization (PORC).[60,61] PORC is an incomplete recovery from nondepolarizing neuromuscular blocking agents and is a known risk factor for PPCs.[62]

Long-acting blockade agents can have residual effects up to 7 days postoperatively and are associated with an increased rate of PPCs, particularly pneumonia.[63,64] These drugs should be avoided in any patient at increased risk of PPCs, whereas medium-acting compounds are the preferred agents for most general surgical patients.[27,61,64]

### *Ventilator Strategies*

There is strong evidence for the beneficial use of lower tidal volumes among patients with ALI, and all patients requiring mechanical ventilation may benefit from this strategy.[65,66] General surgical patients who undergo intraoperative mechanical ventilation with lower tidal volumes have lower levels of circulating inflammatory cytokines postoperatively[67] and may have a lower instance of pneumonia.[68] However, randomized studies to date fail to show major benefits of low intraoperative tidal volume strategies and a consensus is lacking.[11,66,69]

The use of positive end-expiratory pressure (PEEP) is generally a safe strategy that reduces the incidence and severity of atelectasis.[70–72] A Cochrane review of the use of intraoperative PEEP showed significant improvement in postoperative P/F ratios ($PaO_2/FiO_2$, the ratio of arterial oxygen concentration to the fraction of inspired oxygen) and reduced atelectasis.[58] Intraoperative recruitment maneuvers, such as the

vital capacity maneuver whereby lungs are inflated to 40 cm $H_2O$ for 15 seconds, can also reduce atelectasis.[73–75]

### *Fluids and Transfusion*

There is good evidence that patients with ARDS benefit from restrictive fluid management, and patients undergoing major abdominal surgery may also benefit from a similar strategy.[76,77] However, the role of restrictive fluid strategies in preventing PPCs is not well studied. In a recent, large retrospective database analysis, higher amounts of intraoperative crystalloid infusion were a risk factor for developing ARDS.[12] A volume of 1.5 L has been proposed as the threshold above which postoperative ALI is significantly increased.[78]

Emergency surgery is a known risk for PPCs, and although blood transfusions are frequently unavoidable in emergencies, they are also associated with adverse outcomes including increased PPCs.[79,80] Specifically, patients who receive more than 4 units before surgery are at increased risk of PCCs.[81]

### *Nutrition*

Low serum albumin level is an established risk factor for PPCs.[12,19,25,28] Preoperative protein depletion is associated with altered pulmonary dynamics and respiratory muscle function, which leads to a higher rate of pneumonia.[82] Weight loss of greater than 10% in the past 6 months is also an independent risk factor for PPCs.[81]

Despite the strong correlation between poor nutrition and an increased risk of PPCs, there is minimal evidence that routine total parenteral nutrition (TPN) modifies this risk; in fact, the use of TPN may increase complications.[27]

### *Deep Venous Thrombosis Prophylaxis*

Pulmonary embolism (PE) is a rare but potentially fatal complication of surgery. More than 95% of PEs arise from deep venous thrombosis (DVT) of leg veins[83]; thus, prevention of PE is primarily aimed at prevention of DVT. Another article in this issue focuses entirely on this topic; however, given the high morbidity associated with pulmonary emboli, a brief discussion of venous thromboembolism and preventative measures are included here.

Surgery predisposes patients to DVT by several mechanisms, including immobilization, proinflammatory states, and preexisting disease. Cancer increases the risk of venous thromboembolism 7-fold.[84]

The American College of Chest Physicians guidelines recommend the following[85,86]:

- Patients undergoing moderate- or high-risk surgery should receive low-molecular-weight heparin or low-dose unfractionated heparin.
- Patients at high risk for bleeding should receive mechanical prophylaxis with intermittent pneumatic compression.
- Aspirin alone is inadequate to prevent DVT.

Warfarin is effective for DVT prophylaxis; however, it is often contraindicated in surgical patients because of its long half-life and increased risk of bleeding.[87] Not enough data exist to comment on the use of newer anticoagulant agents. Inferior vena cava filters reduce the incidence of pulmonary emboli but do not necessarily reduce mortality and are not routinely recommended for primary prevention.[85,88]

### *Nursing Interventions, Physiotherapy, and Pulmonary Rehabilitation*

Deep breathing exercise, postural drainage, and pulmonary physiotherapy are simple exercises that pose minimal risk. However, there are limited data to suggest these

measures significantly prevent PPCs. Some studies suggest that preoperative physiotherapy and pulmonary rehabilitation may preserve pulmonary function postoperatively, particularly in patients with COPD.[89] Chest physiotherapy might reduce PPCs in obese patients undergoing abdominal surgery.[90]

Spirometry is a simple and inexpensive intervention; however, it has not been proven to effectively prevent PPCs. A 2014 Cochrane review found no significant benefit of spirometry in the prevention of PPCs.[91,92] There is a lack of randomized control trials addressing this topic.

### *Noninvasive Ventilation*

Minor reductions in PPCs have been observed with routine use of postoperative PAP. Several studies have demonstrated the role of continuous positive airway pressure (CPAP) in reducing atelectasis.[72,77] A recent meta-analysis of randomized control trials demonstrated that noninvasive ventilation reduces postoperative pneumonia and reintubation rates and may influence survival.[93]

Certain subgroups of patients benefit from PAP more than others. The severely obese and those with OSA have reduced rates of PPCs with the use of PAP therapy.[94,95] PAP should be continued postoperatively in anyone who used it before surgery and should be used as a rescue tactic in patients who experience postoperative respiratory distress.[29]

## HIGH-RISK POPULATIONS

Patient-related factors pose additional risks for development of PPCs. Certain groups should be given careful consideration before any operation. The following is a discussion of these groups and management strategies that may reduce risk.

### *Obesity*

Obesity is a disease of increasing prevalence worldwide and is associated with a spectrum of multisystem cormorbidities.[96,97] Particular to pulmonary physiology, obese patients have preexisting ventilation-perfusion mismatch due to underventilated and overperfused dependent lung tissue.[98] Increased lung blood volume and reduced chest wall compliance secondary to fat accumulation around the muscles of respiration reduces overall lung compliance.[98] On pulmonary function testing, obese patients have reduced FRC, forced vital capacity (FVC), and $FEV_1$ and are thus more prone to develop hypoxia in periods of apnea.[96,98]

Postoperatively, obese patients are more difficult to mobilize[98] and are at higher risk of venous thromboembolism.[96,99] Up to 30% of deaths in bariatric patients result from PE.[100] Although prevention of venous thromboembolism postoperatively is crucial, currently there is not enough evidence to recommend routine preoperative chemoprophylaxis.[101]

The mainstay of preoperative intervention for obesity is weight loss. Obese patients who decrease their weight by as little as 10% to 15% preoperatively can reduce the severity of sleep apnea by up to 50% and therefore reduce the risk of other PPCs.[102,103]

### *Obstructive Sleep Apnea*

Although OSA is often related to obesity, it is also an independent risk factor for PPCs and is associated with other conditions that may affect overall perioperative performance.[1,104,105] Specifically, OSA is associated with hypoxemia and ARDS.[104,106–108] In a large national inpatient analysis by Memtsoudis and colleagues,[104] general

surgical patients with OSA experienced significantly higher rates of ARDS as well as aspiration pneumonia, reintubation, and mechanical ventilation than matched controls. Preoperative optimization of OSA patients centers around 2 main components: disease identification and maximization of PAP therapy.

The true incidence of OSA is unknown; 3.2% of patients are diagnosed with the disease, but as many as 24% may be undiagnosed, and even those with known disease are often undertreated.[18,109,110] Patients who use CPAP preoperatively should be encouraged to continue it before surgery.[52]

Polysomnography remains the gold standard for diagnosis but may be difficult to obtain preoperatively. A thorough history can identify symptoms of daytime sleepiness, snoring, and partner-witnessed apnea episodes, all of which are associated with OSA. Physical examination findings might include a short, thick neck and obesity. In addition, questionnaires such as the Berlin, STOP (Snore-Tired-Obstruction-Pressure), and STOP-BANG (Snore-Tired-Obstruction-Pressure-BMI-Age-Neck-Gender) surveys can be useful for screening and diagnosis.[111,112]

Intraoperatively, several techniques have been shown to improve outcomes in patients with OSA. The pharyngeal dysfunction of OSA predisposes to higher rates of aspiration pneumonia; this can be partially countered by the use of short-acting neuromuscular blockers and acid-reducing medications.[104,113,114] General anesthesia should be avoided when possible, and shorter operative times lead to better outcomes.[115] In the setting of a general anesthetic, patients with OSA should be extubated fully awake and sitting upright to prevent airway obstruction.[115]

Postoperatively, OSA carries significant risk of hypoxemia and overall complications; this underscores the importance of immediate PAP therapy.[116,117] Opioids should be avoided when possible given the increased risk of respiratory depression. OSA patients may benefit from multimodal analgesia.[52]

### *Obesity Hypoventilation Syndrome (Pickwickian Syndrome)*

OHS is characterized by a triad of obesity, daytime hypoventilation ($Paco_2 \geq 45$ and $Pao_2 \leq 70$), and sleep-disordered breathing without alternate cause.[29,118] OHS is distinct from obesity and OSA. The estimated prevalence is 0.15% to 0.3% of the general adult population and 10% to 20% of obese patients with OSA; however, it is likely underdiagnosed.[29,119,120] The vast majority of patients with OHS also suffer from OSA.[29]

OHS poses a greater risk for several disease states including PH.[29] When compared with obese patients without hypercapnia, patients with OHS have greater morbidity from cardiac causes as well as a higher overall mortality.[29,121,122]

Although the evidence is not strong, there may be benefits of postoperative PAP therapy for OHS.[94,95] Treatment with PAP for a period as short as 5 days can improve hypoventilation and sleep-disordered breathing in patients with OHS and should be considered preoperatively.[123] PAP therapy may even lower mortality in OHS.[29]

### *Asthma*

Patients with well-controlled asthma tend to have normal levels in PFTs and arterial blood gas measurements and are not at risk for major PPCs.[19] However, patients with asthma with poor preoperative symptom control are at increased risk of minor complications, such as bronchospasm.[13,38,124]

Preoperative history should include medication review as well as the frequency and stimuli of attacks. An adjunct to preoperative examination is the forced expiratory time (FET), which is assessed by auscultation during expiration. FET values greater than 6 seconds correlate with abnormal $FEV_1/FVC$ ratios and should prompt further

investigations.[125] A patient's primary care physician can help optimize medications, and their involvement preoperatively is recommended. Patients should be advised to cease smoking at least 8 weeks before surgery, and certain patients may benefit from a brief course of corticosteroids.[126,127] Patients with asthma may also benefit from an increase in bronchodilator dosage preoperatively.[124]

Intraoperative measures to maximize management of patients with asthma include the following[125]:

- Careful intubation technique to prevent laryngeal spasm and edema
- Intubation and extubation in deep anesthesia
- Avoidance of drugs that may induce mast cell histamine release
- Use of volatile intravenous anesthetic drugs that promote bronchodilation
- Avoidance of anticholinesterase drugs

Postoperatively, adequate analgesia, bronchodilator administration, early mobilization, acid reflux prevention, and incentive spirometry are recommended.[19,27,128]

### *Chronic Obstructive Pulmonary Disease*

Patients with COPD have an unambiguously increased perioperative risk for complications, and COPD is perhaps the most frequently cited risk factor for PPCs.[3,13,18] The incidence of PPCs may be as high as 18% among patients with COPD undergoing general surgery operations, and the risk increases with disease severity.[13,18] If possible, surgery should be delayed in patients who present preoperatively with an acute exacerbation.

Empiric antibiotics are not indicated in COPD, but all patients should be screened for acute exacerbations and those with increased secretions should receive a short course of oral antibiotics.[18,129] In cases of persistent symptoms, corticosteroids should also be considered.[130] Preoperative pulmonary rehabilitation with muscle training improves muscle fiber remodeling as well as overall perioperative pulmonary function.[89,131]

Bronchodilator therapy should be maintained throughout the perioperative period in patients with COPD, as their daily use maintains postoperative respiratory function.[132,133] Other measures to reduce PPCs in patients with COPD are similar to those in patients with asthma; avoid airway trauma and medications that may induce bronchospasm.

### *Pulmonary Hypertension*

PH is defined by the World Health Organization as a mean pulmonary artery pressure greater than 25 mm Hg at rest or greater than 30 mm Hg during exercise. Patients with PH are unable to accommodate for physiologic alterations in preload and afterload that occur during surgery and are at greater risk for PPCs.[36] Patients with PH have an increased risk of overall morbidity and mortality when undergoing noncardiac surgery.[134,135] Specifically, the risk of respiratory failure is more common in patients with PH and is the most frequent complication.[24,135]

Perioperative management is focused on prevention of systemic hypotension and acute elevations in pulmonary artery pressure, both of which can be detrimental to the right ventricle.[36] Patients with PH require careful monitoring both during and after an operation.

### *Smoking*

Smokers who undergo noncardiac surgery experience up to a 4-fold increase in PPCs compared with nonsmokers.[32] The rate of PPCs in smokers varies somewhat related to the underlying condition of the lung. Smokers with normal spirometry have only a

4% risk of PPCs, whereas in heavy smokers this rate is as high as 43%.[136,137] Smokers are also more likely to develop pneumonia, fail to wean from a ventilator, require reintubation, and have a higher overall mortality after major surgery.[138]

Smoking impairs tracheobronchial clearance by damaging cilia and increasing mucous secretion and consistency.[139] It also increases the susceptibility to alveolar collapse, leading to increased rates of infection and prolonged mechanical ventilation.[140] Smokers are nearly twice as likely to develop specific respiratory complications such as reintubation, bronchospasm, laryngospasm, aspiration, and hypoxemia when compared with nonsmokers.[141]

Smoking cessation decreases the risk for PPCs by 20%[142] and is particularly important for patients with COPD.[53,132] The benefit of smoking cessation depends on the extent of life-time smoking, length of abstinence, and age at the time of cessation.[2] A review of smoking cessation found an overall postoperative complication risk reduction of 41%; this risk reduction was improved with each additional week of cessation.[142]

A transient increase in sputum production may actually increase risk for PPCs in the first several weeks after smoking cessation.[143–146] Therefore, abstinence should be recommended for a period of at least 4 weeks preoperatively to be beneficial.[147–150]

After smoking cessation, physiologic recovery is as follows[139]:

1 Week—ciliary activity recovers
2 Weeks—airway reactivity is reduced
6 Weeks—sputum volume returns to normal
3 Months—tracheobronchial clearance begins to return to normal
6 Months—marked improvement in small airway narrowing is noted

Smoking cessation 8 weeks before surgery may reduce the risk of PPCs to that of nonsmokers.[61,151]

## SUMMARY

PPCs occur frequently among general surgical patients. The spectrum of illness is broad and includes preventable causes of morbidity and death. Careful preoperative evaluation can identify undiagnosed and undertreated illness and allow for preoperative intervention. Optimization of patient, surgical, and anesthetic factors are crucial in the prevention of PPCs.

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