Perioperative Management of Patients at Risk for Postoperative Pulmonary Complications

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ABSTRACT

PURPOSE: To review the incidence and causes of postoperative pulmonary complications and outline perioperative measures to reduce the risk of these complications in selected populations.

EPIDEMIOLOGY: It is estimated that at a minimum 2.5% of patients undergoing surgery may experience a postoperative pulmonary complication. This translates to as many as a million postoperative pulmonary complications of the 40 million patients undergoing nonthoracic surgery annually in North America. This figure may be as high as 25% to 30% among high-risk patients undergoing major surgery.

REVIEW SUMMARY: Postoperative pulmonary complications contribute significantly to surgical morbidity and mortality. Causes of complications are multifactorial and include patient-related factors, surgery, and anesthesia type. Pulmonary function testing has a limited role in preoperative assessment and chest X ray and arterial blood gas measurement are rarely required. Despite the existence of postoperative pneumonia and respiratory failure indices, there is a need for research to further define risk factors and the development of improved and generalizable risk models.

TYPE OF AVAILABLE EVIDENCE: Prospective and retrospective cohort studies and nonsystematic reviews, randomized blinded clinical trials, and society guidelines.

GRADE OF AVAILABLE EVIDENCE: Fair

CONCLUSION: Postoperative pulmonary complications carry with them a significant burden in the form of morbidity, mortality, and increased hospitalization costs. Preoperative identification of patients at risk of complications allows for initiation of strategies to prevent complications and reduce their severity.

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Clinical postoperative pulmonary complications (PPCs) after nonthoracic surgery occur as frequently as perioperative cardiac complications and contribute significantly to morbidity and mortality.[1,2] Frequently reported clinical complications include atelectasis, pneumonia, bronchospasm, hypoxemia, and prolonged mechanical ventilation.[3] Identifying risk factors for PPCs is an important part of the preoperative evaluation, as is the initiation of appropriate perioperative interventions to prevent or reduce the severity of complications. The purpose of this review article is to provide primary care physicians with a brief overview of the epidemiology and definition of PPCs and evidence-based recommendations on how to identify at-risk patients and reduce the risk of these complications. This review draws on data from a variety of sources, including retrospective reviews, cohort studies, randomized clinical trials, and recent guidelines published by the American College of Physicians (ACP).

INCIDENCE AND PATTERN

Despite significant risks for morbidity, mortality, and increased medical costs, our knowledge of the incidence and pattern of PPCs is incomplete. The definition of PPCs varies across studies. Nearly 60% of published studies includ-

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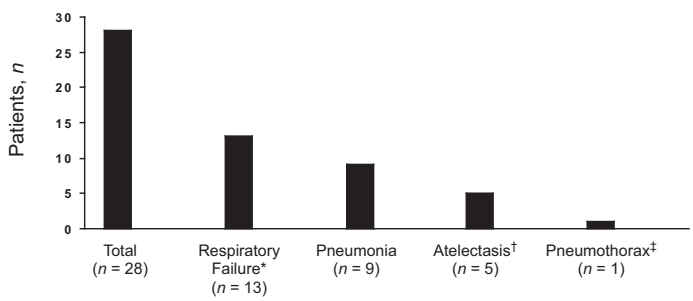
ed some combination of pneumonia or respiratory infection and respiratory insufficiency or failure; others include pulmonary edema and atelectasis.[4] For the purpose of this review article, PPCs are defined as: atelectasis severe enough to require bronchoscopy, pneumonia, bronchospasm, hypoxemia, and prolonged mechanical ventilation. However, it is important to understand that there does not exist a standard, common, definition of PPCs, unlike, for example, the definition of myocardial ischemia or infarction, which is defined by clinical signs and symptoms, electrocardiographic changes, and serum enzyme elevations. Therefore, it is difficult to compare studies in the literature because it is likely the definitions of a PPC are different between studies. Meta-analysis is particularly difficult in this situation. Prospective studies conducted among patients undergoing elective and emergency surgery in the 1990s reported an incidence of PPCs between 14% and 25%.[5,6]

A more recent study by McAlister et al suggested a somewhat lower incidence than earlier studies.[7] These authors conducted a prospective cohort study in low- to moderate-risk patients to determine risk factors for pulmonary complications following elective, nonthoracic surgery.[7] Of 1055 patients studied, 28 (2.7%) experienced complications within 7 days of surgery (Figure).[7] One of the patients who developed pneumonia subsequently died. Patients with complications had significantly longer lengths of stay compared to those without complications (27.9 days vs 4.5 days, respectively; $P = .006$).[7]

Of the 1055 patients studied, 11 had preoperative arterial blood gas (ABG) analysis ordered by their attending physician and chest X rays were ordered for 135 patients. None of the patients who had ABGs performed developed complications. Patients who had chest X rays were no more likely to develop complications. However, this should not be taken as evidence that preoperative ABG analysis prevents PPCs because it is unknown how the ABGs were used to manage the patients.

Based on the incidence of PPCs observed in this study, the authors concluded that of the 45 million patients in North America undergoing nonthoracic surgery annually, approximately 1 million will develop PPCs.[7] This figure may rise to 10% to 30% among high-risk patients undergoing major nonthoracic surgery.[2,8]

Figure. Incidence of Pulmonary Complications Within 7 Days of Elective Nonthoracic Surgery (n = 1055)



*Requiring ventilatory support.
†Requiring bronchoscopic intervention.
‡Requiring intervention.
Data from McAlister et al.[7]

Causes of Postoperative Pulmonary Complications

The effects of general anesthesia (GA), type of surgery, and patient factors all play a role in the development of PPCs. Surgery type and patient factors are the most important causes; however, the effects of GA should not be minimized. There are probably interactions or even synergies between these various factors to potentiate the development of PPCs.

Anesthesia

The administration of GA results in biological, mechanical, and functional changes to the respiratory system, all of which may contribute to the development of PPCs. GA has multiple biological effects on the respiratory system.[3] These include reductions in the number and activity of alveolar macrophages, inhibition of mucociliary clearance, elevated alveolar-capillary permeability, inhibition of surfactant release, increased pulmonary nitric oxide synthetase activity, and increased sensitivity of the pulmonary vasculature to neurohormonal mediators. These factors may set the stage for infection, lung edema, and hypoxia.

Following induction of GA, there is disruption of the normal activity of respiratory muscles. There is an immediate decrease in functional residual respiratory capacity (FRC). It was originally thought that FRC was reduced by changes in the position of the diaphragm. However, researchers now think that anesthesia also affects the rib cage and potentially the volume of intrathoracic blood.[9] These changes are accompanied by the formation of atelectatic plaques in dependent areas of the lungs.[10] Significant effects on diaphragmatic movement also occur, which may result in V/Q inequality, characterized by more ventilation in the superior portion of the lung (ie, where there is less gravity-related perfusion) compared to less ventilation in the dependent portions (ie, where there is more gravity-related perfusion).[3] This disturbance in V/Q matching results in shunt and dead space. In addition, there are changes in diaphragm position.[11] These functional and mechanical changes can result in hypoxia and atelectasis.

In some studies, duration of GA correlates with the development of PPCs, although this may merely be a surrogate for more complex surgery in sicker patients.[7,12] It has not been possible to distinguish between the effects

of a lengthy anesthetic and the effects of a lengthy surgery because they occur together. In a prospective study investigating anesthetic practice and the incidence of PPCs among patients undergoing various types of surgery, Pedersen et al found that GA of more than 3 hours duration was a risk factor.[12] Similarly, in a prospective cohort study of patients undergoing nonthoracic surgery, McAlister et al reported that duration of GA of at least 2.5 hours was a significant risk factor (P = .008).[7] In a prospective study of patients with PPCs following oncological surgery, Ozdilekcan et al found that longer duration of surgery was a risk factor.[13]

A meta-analysis examined 141 trials (n = 9559) comparing GA and neuraxial blockade in patients undergoing various types of operations.[14] Patients receiving neuroaxial blockade with or without concomitant GA were compared to those receiving GA alone. Compared to GA, neuroaxial blockade reduced the incidence of overall mortality (3% vs 2%, respectively; odds ratio [OR], 0.70; 95% confidence interval [CI], 0.54–0.90), pneumonia (5% vs 3%, respectively; OR, 0.61; 95% CI, 0.48–0.78), and respiratory failure (0.8% vs 0.5%, respectively; OR, 0.41; 95% CI, 0.23–0.73).[14] Subgroup analysis revealed that results were similar among patients undergoing neuroaxial blockade alone versus GA for pneumonia (OR, 0.63; 95% CI, 0.46–0.87) and for respiratory failure (OR, 0.37; 95% CI, 0.11–1.21). Sources of bias in this meta-analysis include clinically heterogeneous studies, unusually high mortality rates in several studies, older literature, small studies, and statistically significant benefit only for orthopedic surgery in subgroup analyses.[15-17] More recent randomized clinical trials have failed to establish a relationship between type of anesthesia and the development of pulmonary complications.[18-20]

Thus, the role of neuraxial anesthesia or analgesia in reducing or preventing PPCs is controversial. According to a recently published ACP review, postoperative epidural analgesia and patient-controlled intravenous analgesia "seem superior to on-demand delivery of opioids in preventing PPCs. Epidural analgesia may further reduce PPCs."[21] Because epidural approaches carry the risk of epidural hematoma and associated significant neurological complications, their risks and benefits should be weighed carefully.[21] The ACP systematic review of the literature and clinical guidelines also concluded:

- Intraoperative neuroaxial blockade, alone or in combination with GA, may prevent PPCs, although the evidence is conflicting.
- Several meta-analyses suggest that epidural anesthesia may reduce PPCs; however, large randomized clinical trials do not confirm benefit.
- Randomized clinical trials of combined intra- and postoperative anesthetic or analgesic regimens do not clearly indicate that a combined approach prevents PPCs.
- More good-quality efficacy trials with standardized optimal regimens for all groups and sufficient size to examine PPC rates are needed.[21]

Anesthetic interventions can also play a role in the development of PPCs. For example, postoperative residual block caused by pancuronium is a significant risk factor for PPCs.[1] These patients are 3 times more likely to develop PPCs than patients without residual block. This should not be taken to indicate that pancuronium is contraindicated but rather that anesthetic interventions have the potential to influence PPCs. However, overall, the available evidence suggests that drugs that offer a shorter duration of neuromuscular blockade are less likely to cause PPCs.[1]

It has been suggested that the effects of anesthesia on postoperative chest wall function may be lessened by regional anesthesia.[9] In a small cohort study of 14 patients, thoracic extradural block using 0.5% bupivacaine was shown to improve some pressure and motion indices of diaphragmatic function.[22] Whether this translates into fewer clinical pulmonary complications is unknown.

Surgery Type

Patients undergoing abdominal surgery are at increased risk for PPCs, with those undergoing upper abdominal procedures at higher risk.[23] Decreased postoperative vital capacity and FRC are common findings among these patients, with consequent V/Q inequality and hypoxemia. FRC can decrease significantly from baseline, returning to normal over 1 to 2 weeks. The diaphragmatic weakness seen in patients undergoing abdominal surgery may be the result of reflex inhibition of phrenic nerve output.[24,25] It has been suggested that surgical trauma may increase airway tone and reactivity.[26]

According to the ACP guidelines, other procedures that are related to an increased risk of PPCs are prolonged surgery, aortic aneurysm repair, thoracic surgery, head and neck, emergency, vascular, and neurosurgery.[1]

Compared to open procedures, laparoscopic surgery may offer some advantages in terms of pulmonary complications. In a cohort study of 55 patients who underwent cholecystectomy, compared to those undergoing open surgery, patients undergoing a laparoscopic procedure experienced less atelectasis (45% vs 15%).[27] Among laparoscopic patients, postoperative pulmonary functions tests were better than those undergoing open surgery.[27] Similar results have been found for patients undergoing laparoscopic versus open surgery for rectal cancer.[28] The ACP guidelines suggest that further studies are needed to clarify whether laparoscopic versus open procedures offer advantages in terms of the incidence of PPCs.[1]

Patient Factors

Several patient-related factors may contribute to the risk of PPCs. In the previously mentioned study by McAlister et al, although a number of continuous preoperative patient-related variables, including forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, and room air oxygen saturation, were significantly associated with PPCs, multivariate regression analysis revealed that only age 65 years or older (P <.001), presence of nasogastric tube (P <.001), and positive cough test (P = .01) were independently associated with complications.[7] Pedersen et al found that the elderly and patients with underlying chronic obstructive pulmonary disease (COPD) were at increased risk of PPCs.[12]

To date, there is no evidence that obesity is a significant risk factor for PPCs.[1] Studies suggest that there is a modest increase in the risk of complications among smokers.[1] According to the ACP guidelines, heart failure is a significant risk factor for the development of pulmonary complications.[1] In addition, functional dependence has been shown to be an important predictor of complications, with patients who are totally dependent at highest risk.[1] There is conflicting evidence regarding whether asthma is a risk factor for postoperative pulmonary complications. Exacerbation of bronchospasm in the perioperative period and severe bronchospasm during anesthesia and surgery is a significant concern for anesthesiologists. Warner et al, in a retrospective study, suggest that the incidence of perioperative bronchospasm in patients with known asthma is low but not insignificant.[29] Asthma does not appear in the risk indices developed by Arozullah et al.[30,31]

The ACP guidelines suggest that a low serum albumin level is an important predictor of PPCs.[4] In 4 of 5 eligible studies reviewed by the ACP, low serum albumin (defined variably from 30–39 g/L) was an independent risk factor.[4]

The American Society of Anesthesiologists (ASA) has a general risk classification system that was originally designed to predict perioperative mortality. The ASA system assigns patients to 1 of the following 5 classes: 1) a normally healthy patient, 2) a patient with mild systemic disease, 3) a patient with systemic disease that is not incapacitating, 4) a patient with an incapacitating systemic disease that is a constant threat to life, and 5) a moribund patient who is not expected to survive 24 hours with or without operation. Higher ASA class is associated with a significantly increased risk of PCPs.[4,32]

Preoperative Assessment

It has been suggested that risk factors for the development of PPCs are, on the whole, clinical in nature.[3] So then, what tests, if any, should be used in the preoperative evaluation of patients undergoing nonthoracic surgery? The ACP guidelines advise against the routine use of preoperative pulmonary function tests (PFTs), suggesting that a preoperative history and physical examination might be sufficient for identifying pulmonary risks.[1] This is primarily because available data do not suggest a prohibitive spirometric threshold below which the risks of surgery are unacceptable and because PFTs have not been demonstrated to better predict risks than the clinical identification of underlying lung disease.[1]

The ACP recommendations assume that the clinical assessment for the presence of airway obstruction is sensitive and specific. However, there are data to suggest that clinicians are not as accurate as we might prefer in determining whether airway obstruction is present. For example, patients with asthma may be unaware of significant changes in lung function.[33] In this situation, patient-reported symptoms may be unreliable for assessing asthma severity. PFTs can determine the degree of lung dysfunction and indicate whether preoperative interventions are effective. In a study of patients with an exacerbation of COPD, physicians' estimates of the degree of airway obstruction were inaccurate.[34] Prior to treatment, physicians were able to estimate the percent of predicted normal FEV_1 to within 10 points only 38% of the time and 46% of the time post-treatment. Of the patients whom the physicians thought had an improvement in pulmonary function with treatment, 49% actually did not improve, whereas 31% of the patients who the physicians thought did not improve actually did improve.[34] These results suggest that assessment of pulmonary function may require laboratory measurement. Finally, when internists, in a blinded fashion, were asked to assess patients (with spirometrically proven COPD) for the presence or absence of COPD, they were unable to diagnose COPD in a significant number of patients.[35]

In summary, PFTs have a role in preoperative pulmonary assessment. Without these measurements, there may be a tendency to underdiagnose (or overdiagnose) lung disease and consequently underestimate/overestimate the risk of PPCs. These tests are noninvasive, simple, and inexpensive. They should not be ordered indiscriminately. In the same way that we would not consider treating high blood pressure without measuring blood pressure, we should consider pulmonary function testing whenever the diagnosis of underlying lung disease, or its severity, is unclear.

Generally, it is unnecessary to obtain preoperative ABGs. Baseline ABGs add little to risk assessment nor do they aid in risk stratification and should be reserved for complex cases or for those in which there is some ambiguity.[3] They are usually not helpful postoperatively and are often of little use in weaning patients from mechanical ventilation. Patients that require postoper-

Table 1. Allocation of Points to Preoperative Risk Factors Used to Develop a Risk Index for the Development of Pneumonia Postoperatively

Preoperative Risk Factor	Point Value
Type of surgery	
Abdominal aortic aneurysm repair	15
Thoracic	14
Upper abdominal	10
Neck	8
Neurosurgery	8
Vascular	3
Age, *yrs*	
≥80	17
70–79	13
60–69	9
50–59	4
Functional status	
Totally dependent	10
Partially dependent	6
Weight loss >10% in past 6 months	7
History of COPD	5
General anesthesia	4
Impaired sensorium	4
History of stroke	4
Blood urea nitrogen level, *mg/dL*	
<8	4
22–30	2
≥30	3
Transfusion >4 units	3
Emergency surgery	3
Steroid use for chronic condition	3
Current smoker within 1 year	3
Alcohol intake ≥2 drinks/day in past 2 weeks	2

COPD = chronic obstructive pulmonary disease.
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ative mechanical ventilation are normally weaned from the ventilator not to a specific preoperative ABG target but rather are weaned to ventilator discontinuation if their blood gases are clinically acceptable.

To date, there are no data indicating that routine preoperative chest X ray predicts PPCs. The ACP guidelines suggest that physicians can predict most abnormal preoperative chest X rays by history and physical examination alone.[1]

Pulmonary Risk Index

Attempts are ongoing to develop and validate a general pulmonary risk index. One such effort has developed a pneumonia and respiratory failure index by assigning points to clinical and other factors on the basis of the significance of these factors as assessed by logistic regression. In both the Pneumonia Risk Index and the Respiratory Failure Index developed by Arozullah et al, the major risk factors are age, type of surgery, the presence of underlying lung disease, renal failure, poor nutritional status, and the amount of blood loss during surgery.[30,31]

Table 1 shows the points allocated to risk factors used to compile the Pneumonia Risk Index.[31] Patients used to develop and validate the index were assigned to 1 of 5 risk classes based on the predicted probability associated with various postoperative pneumonia risk index scores. Table 2 shows the classes and the actual incidence of postoperative pneumonia among patients used to validate the index.[31] To illustrate how the Pneumonia Risk Index is applied, consider a 75-year-old patient (13 points), still smoking (3 points), with COPD (5 points) and mild renal insufficiency (3 points), undergoing open emergency surgery (3 points) for an abdominal aortic aneurysm (15 points) who loses 5 units of blood (3 points). Looking at Table 2, this patient falls into Class 4 and thus has an 11% risk of developing pneumonia. Tables 3 and 4 show the point allocations and risk class categories for the Respiratory Failure Index.[30]

However, when considering these indices it is important keep in mind that they were developed retrospectively and that data were derived from a Veterans Affairs cohort that may not be representative of all patients, gender, and types of surgery. Also, cause and effect relations were not established by these studies and the risk factors are associations rather than pathophysiologic explanations for PPCs. Research is needed to further define the nature of risk factors and develop better predictive models of patients at risk of developing PPCs. However, these risk indices are useful to the extent that they focus attention on factors that are associated with PPCs and thus may help in preoperative evaluation and possibly in triaging patients to the ICU or other types of perioperative care.

Preoperative Management

There are several steps that can be taken preopera-

Table 2. Percent of Validation Cohort Patients Developing Pneumonia in Each Postoperative Pneumonia Risk Index Risk Class

Class	Points	Percent Developing Pneumonia
1	0–15	0.24
2	16–25	1.18
3	26–40	4.6
4	41–55	10.8
5	>55	15.9

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tively among patients at risk for PPCs to reduce the likelihood of their occurrence.

Smoking Cessation

Warner et al used a pulmonary function database to identify patients undergoing abdominal surgery who met the following criteria for airway obstruction ($n = 135$): an FEV_1 less than 40% of predicted normal value, a FEV_1/FVC ratio less than the lower limit of predicted normal, a smoking history of more than 20 pack-years, and an age older than 35 years.[36] A group of patients without airway obstruction ($n = 135$) was matched for gender, surgical site (upper vs lower abdominal), smoking history, and age. Medical records were reviewed by an abstractor to identify perioperative complications that occurred within 30 days after surgery.[36] The authors concluded that patients who have a history of more than 20 pack-years of smoking have an increased incidence of PPCs. It is recommended that smokers stop smoking at least 48 hours before surgery. This leads to reduced carboxyhemoglobin levels and abolishes the cardiovascular stimulant effects of nicotine.[3] Longer duration of cessation (1–2 weeks) is necessary for a decrease in sputum volume, whereas a period of 4 to 6 weeks is required to improve symptoms and lung function.[37] There is conflicting evidence regarding the value of smoking cessation within 2 months before surgery. There is some evidence that compared to patients who do not stop smoking, patients who stop smoking 8 or more weeks preoperatively have a lower rate of PPCs.[38,39] However, a cohort study suggested that pulmonary complication rates are higher for smokers who stopped or reduced smoking within 2 months before noncardiothoracic surgery.[40] The ACP guidelines suggest that smoking cessation may increase short-term risk because of transiently increased mucus production due to improved mucociliary activity and reduced coughing due to less bronchial irritation.[21] However, few, if any, clinicians encourage patients to continue smoking preoperatively. The overall health benefits of smoking cessation outweigh any theoretical risks associated with short-term preoperative smoking cessation.

Table 3. Allocation of Points to Preoperative Risk Factors Used to Develop a Risk Index for the Development of Respiratory Failure Postoperatively

Preoperative Risk Factor	Point Value
Type of surgery	
Abdominal aortic aneurysm repair	27
Thoracic	21
Upper abdominal	14
Neurosurgery	14
Peripheral vascular	14
Neck	11
Emergency	11
Blood urea nitrogen level >30 mg/dL	8
Partially or fully dependent	7
History of COPD	6
Albumin <30 g/L	6
Age, *yrs*	
>70	6
60–69	4

COPD = chronic obstructive pulmonary disease.
Reprinted with permission from Arozullah et al. *Ann Surg.* 2000;232:242-253.[30]

Table 4. Percent of Validation Cohort Patients Developing Respiratory Failure in Each Postoperative Respiratory Failure Risk Index Risk Class

Class	Points	Percent Developing Pneumonia
1	≤10	0.5
2	11–19	1.8
3	20–27	4.2
4	28–40	10.1
5	>40	26.6

Reprinted with permission from Arozullah et al. *Ann Surg.* 2000;232:242-253.[30]

Patients with Asthma

Fortunately, over the past 30 years there has been a reduction in the incidence of perioperative bronchospasm, pneumonia, respiratory failure, and death following surgery among patients with asthma.[23] However, these patients remain at increased risk of bronchospasm during anesthesia and surgery, although the risk is lower in patients with stable disease. Factors that may increase the risk of complications include recent asthma symptoms, recent use of antiasthma medications, and history of tracheal intubation for asthma.[29] There is no difference in complication rates between patients with asthma undergoing regional or GA.

Corticosteroids have been shown to be effective in preventing bronchospasm.[41-44] Among patients with asthma who are at high risk of PPCs, oral or, perhaps preferentially, inhaled steroids should be considered and, if used, initiated between 24 and 48 hours ahead of surgery.[23] In patients experiencing an exacerbation preoperatively and in whom surgery cannot be delayed, oral or intravenous administration (eg, hydrocortisone 100 mg every 8 hours) is recommended.[23] There does not appear to be an association between short courses of systemic steroids administered in the perioperative period and an increase in wound infection or poor wound healing.[45]

Inhaled β2 agonists are recommended for patients who experience wheezing preoperatively. If asthmatic symptoms do not improve, elective surgery should be postponed. It is important to be aware that improvement in asthma symptoms does not necessarily mean that a patient will not develop bronchospasm in response to stimuli in the intraoperative period. Airway hyper-reactivity persists for a period of weeks after an asthmatic flare.

Patients with Chronic Obstructive Pulmonary Disease

The most important step that these patients should take is to stop smoking. Respiratory infections in the preoperative period should be treated with an appropriate antibiotic. Because some patients with COPD experience bronchospasm in addition to their usual symptoms, inhaled β2 agonists or a course of steroids in the preoperative period may be useful.[23]

Efforts should be made to correct conditions that contribute to respiratory muscle weakness. These include malnutrition and electrolyte, metabolic, and endocrine disorders. In patients with cor pulmonale, heart failure should be treated. The presence of hypoxemia preoperatively calls for the initiation of continuous oxygen administration and postponement of elective surgery until there is some improvement in pulmonary hypertension and heart function.[23]

Incentive spirometry is thought to decrease rates of PPCs in patients with asthma and COPD in whom uncertainty exists as to the status of airflow obstruction when compared to baseline.[46] Incentive spirometry mimics natural sighing or yawning by encouraging the patient to take long, slow, deep breaths. A device is used that provides patients with positive feedback when they inhale at a predetermined flow rate or volume and sustain the inflation for a minimum of 3 seconds.

Lung Expansion Modalities

Lung expansion modalities 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.[1]

As described earlier in this article, incentive spirometry is valuable in patients with asthma and COPD, and other patients at increased risk of developing PPCs. According to the ACP guidelines, any lung expansion technique is better in reducing PPCs among patients undergoing abdominal surgery than no intervention at all.[1] However, it does not appear that combining methods further reduces the risk of complications, nor is it clear whether one modality is superior to another.[1] The guidelines suggest that incentive spirometry is probably the least labor-intensive technique and that nasal continuous positive airway pressure may be especially useful in patients unable to perform spirometry or deep breathing exercises.[1]

Postoperative Hypoxemia

Two important risk factors for the development of postoperative hypoxemia are obstructive sleep apnea and older age.[23]

Anesthesia and surgery may lead to worsening of sleep apnea and more severe hypoxemia.[23] Apnea can be further exacerbated by the administration of sedatives and analgesic agents. The fact that patients are frequently supine following surgery may also contribute to worsening sleep apnea. Because patients with this disorder might require a longer hospital stay and/or special monitoring, it would appear to be cost effective to diagnose sleep apnea preoperatively and implement risk reduction measures, such as administration of continuous positive airway pressure and bi-level positive airway pressure.[23] However, there are few data upon which to base such guidelines. Recently, the ASA published clinical care guidelines for the management of patients with obstructive sleep apnea (OSA).[47] The guidelines include:

- Appropriate preoperative assessment for the presence of OSA sufficiently in advance of surgery to allow for perioperative interventions.
- Severity of OSA, invasiveness of the planned procedure, and the requirement for postoperative analgesia all increase the risk of complications from OSA.
- Consideration of the use of continuous positive airway pressure or biphasic positive airway pressure perioperatively.
- Appropriate monitoring for postoperative airway obstruction and hypoxemia is indicated, as is careful selection of patients for outpatient surgery.

The elderly are more likely to develop severe hypoxemia than younger patients. In part, this relates to the normal increase in the A-a gradient that accompanies aging. Interactions between age, anesthesia, and narcotic analgesia can all contribute to hypoxemia in the elderly.[48] It is important to note that patients do not have to exhibit preoperative oxygen disturbances for postoperative hypoxemia to occur. In the elderly, hypoxemia can contribute to postoperative delirium, which can result in increased morbidity, delayed functional recovery, and prolonged hospital stay.[49] Administering low levels of supplemental oxygen is usually effective in maintaining normal arterial oxygen levels and should be administered routinely postoperatively to elderly patients, combined with a vigorous "wake-up" regimen.[50]

Conclusions

Awareness of the risk factors for the development of PPCs allows physicians to initiate interventions in the preoperative period aimed at reducing the frequency and

severity of complications. Patients at risk include the elderly and patients undergoing major abdominal, thoracic, and neurosurgical procedures. Cigarette smokers are at increased risk, as are those with low serum albumin levels. Anesthetic interventions, such as the use of shorter-acting muscle relaxants, may reduce risk. The role of regional anesthetic and analgesic techniques remain controversial with some evidence supporting their use in reducing PPCs, whereas other studies do not demonstrate a benefit. Lung expansion techniques are useful in preventing PPCs and there are few contraindications to their use. Additional research will help to further refine and define the nature of risk factors. The results of this research will contribute to the development of improved predictive models that will allow physicians to more accurately identify patients at risk and tailor interventions according to individual patient risk. Further research is also needed to define the role, if any, of neuraxial block and neuraxial analgesia in reducing the incidence of PPCs.

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