CME CREDIT

Postoperative pulmonary complications: risk assessment, prevention, and treatment

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SUMMARY Patients with pre-existing pulmonary disease and certain other conditions are at increased risk of postoperative pulmonary complications. This article surveys how internists can identify high-risk patients clinically, use pulmonary function studies, use specific therapy to reduce risk, and manage postoperative complications.

KEY POINTS Postoperative pulmonary complications occur more frequently in patients with chronic obstructive pulmonary disease, patients with higher American Society of Anesthesiologists (ASA) classification scores, and patients with upper abdominal and thoracic incisions. Postoperative pulmonary complications can be reduced by stopping smoking, alleviating airflow obstruction before surgery, preventing aspiration and venous thromboembolic disease, and, in the case of resectional surgery, by careful patient selection. Postoperative management of complications includes aggressively using lung-expansion techniques such as deep breathing, breath-holding, incentive spirometry, and, in selected cases, more complex respiratory therapies such as positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP).

INDEX TERMS: RESPIRATORY TRACT DISEASES; POSTOPERATIVE COMPLICATIONS
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PATIENTS WITH pre-existing pulmonary disease or certain other conditions, such as those that predispose to aspiration, are at increased risk of postoperative pulmonary complications, defined by O'Donohue[1] as a pulmonary abnormality that produces identifiable disease or dysfunction that is clinically significant and adversely affects the clinical course. This article summarizes current knowledge and provides a framework for internists caring for surgical patients at risk of pulmonary complications.

THE INTERNIST'S ROLE

When evaluating patients for surgery, the consulting internist has three main functions in assessing pulmonary risk: (1) to recognize patients at high risk for postoperative pulmonary complications, including those undergoing lung surgery; (2) to modify risk factors for postoperative pulmonary complications and optimize preoperative status through interventions such as smoking cessation, respiratory therapy, and treatment of preoperative bronchospasm; and (3) to manage the postoperative care, including prophylaxis against venous throm-

TABLE 1
RISK FACTORS FOR POSTOPERATIVE PULMONARY COMPLICATIONS

Definite risk factors
Site of operation, especially upper abdomen and thorax
General illness (eg, higher American Society of Anesthesiologists [ASA] class)
Chronic obstructive pulmonary disease
Probable risk factors
Obesity (eg, weight over 250 lb, body mass index more than 25 kg/m^2)
Advanced age (eg, more than 59 years)
History of cigarette smoking (ever)
Hypercapnia
Possible risk factors
Male gender
Lengthy surgery
Extended hospital stay before surgery
Hypoalbuminemia

TABLE 2
AMERICAN SOCIETY OF ANESTHESIOLOGISTS PHYSICAL STATUS SCALE*

Class†	Patient status
1	No organic, physiologic, biochemical, or psychiatric disturbance; localized operation
2	Mild to moderate systemic disease caused by condition to be treated or other process (hypertension, anemia, smoking, diabetes, obesity, asthma, chronic bronchitis, age < 1 or > 70, pregnant)
3	Severe systemic disturbance of whatever cause (angina, poorly controlled hypertension or diabetes, massive obesity, symptomatic chronic obstructive pulmonary disease, or prior myocardial infarction)
4	Severe systemic disorder already life-threatening and not correctable by operation (unstable angina pectoris, congestive heart failure, debilitating chronic obstructive pulmonary disease, hepatorenal failure)
5	Moribund with little chance of survival (ruptured aneurysm with shock, major cerebral trauma, massive pulmonary embolus)

*Adapted from Owens WD, Felts JA, Spitznagel EL Jr. ASA physical status classifications: a study of consistency of ratings. Anesthesiology 1978; 49:239–243.
†Add modifier "E" for emergency operation

boembolic disease, prevention of atelectasis, and appropriate use of respiratory therapy.

In keeping with the principles of consultation, the internist should provide information to the surgeon and anesthesiologist, but avoid dictating a specific treatment plan. If doubt exists as to the advisability of surgery, this should be discussed with the surgeon so that the risks and benefits can be assessed.

HOW SURGERY AFFECTS PULMONARY FUNCTION

Surgery and anesthesia combine to cause hypoxemia and changes in lung mechanics during the operation and for several days afterward. Recent studies have shown that in surgeries remote from the diaphragm, postoperative changes in pulmonary function are similar whether general anesthesia or spinal anesthesia is used.[2]

There are a number of mechanisms by which surgery and anesthesia affect pulmonary function. The supine posture during surgery decreases lung volume. Anesthetic agents impair respiratory muscle function, alter gas exchange, and impair mucociliary clearance mechanisms. Surgery exerts longer-lasting effects on pulmonary mechanics than anesthesia. Upper abdominal and thoracic operations are associated with a greater loss of pulmonary function than other operations. Reductions in functional residual capacity and vital capacity after upper abdominal surgery may persist for 5 to 7 days.

HOW COMMON ARE PULMONARY COMPLICATIONS?

The reported frequency of postoperative pulmonary complications varies greatly among series, depending on the definition used and the type of operation. Garibaldi et al[3] reported that 17.5% of 520 patients who had elective thoracic or abdominal surgery developed pneumonia. Poe et al[4] observed a 14.8% incidence of atelectasis, pneumonia, or purulent bronchitis among 209 patients who underwent elective cholecystectomy. Warner et al[5] found that 18.7% of 192 patients who underwent elective coronary artery bypass grafting suffered postoperative pulmonary complications. Svensson et al[6] noted a 60% incidence of postoperative pulmonary complications in 98 patients who underwent repair of aortic aneurysms. Hall et al[7] reported that 23.2% of 1000 patients who underwent laparotomy developed atelectasis or pneumonia. Calligaro et al[8] found major postoperative pulmonary complications in 16% of patients who underwent abdominal aortic surgery. Nine percent of patients contracted pneumonia, 5% had prolonged intubation (longer than 24 hours), and 2% were reintubated.

TABLE 3
AMERICAN COLLEGE OF PHYSICIANS RECOMMENDATIONS FOR PREOPERATIVE PULMONARY FUNCTION TESTING*

Type of surgery	Spirometry	Arterial blood gases	Split function test	Exercise test
Lung resection	All patients	All patients	Some patients	Some patients
Coronary artery bypass grafting	Smokers and patients with dyspnea	Smokers and patients with dyspnea	No	No
Upper abdominal	Smokers and patients with dyspnea	Smokers and patients with dyspnea	No	No
Lower abdominal, head and neck, orthopedic	Some patients with suspected lung disease or who need strenuous rehabilitation	No	No	No

*Adapted from reference 13

Operative risks, including those during lung resection, have declined over the last 20 years thanks to advances in surgical, anesthetic, and medical techniques. Nevertheless, postoperative pulmonary complications are associated with increased length of stay, and therefore increased cost. Stiller[9] found a mean length of stay of 15 days for patients with postoperative pulmonary complications, compared with 9 days for all patients. Celli et al[10] reported a 13-day length of stay in patients who developed a postoperative pulmonary complication after upper abdominal surgery, compared with 9.4 days in patients without postoperative pulmonary complications.

ASSESSING THE RISKS

Many of the available studies of risk factors for postoperative pulmonary complications have used univariate analysis. Several studies have also used multivariate analysis, which may provide a truer assessment of the factors associated with postoperative pulmonary complications.[3–7] Nevertheless, our ability to predict pulmonary complications preoperatively remains limited. Risk factors for postoperative pulmonary complications can be summarized according to the level of certainty in available studies (*Table 1*).

Clinical factors

Garibaldi et al[3] showed that patients were more likely to have postoperative pulmonary complications if they were in a higher ASA class (see *Table 2*), underwent thoracic or upper abdominal surgery, weighed more than 250 pounds, had low serum albumin concentrations, or had a prolonged hospital stay before surgery. Svensson et al[6] used multivariate analysis to review 22 risk factors and found that only two were significant: a history or examination suggesting chronic obstructive pulmonary disease (COPD) and a history of ever having smoked. Similarly, Hall et al[7] reviewed 13 factors for postoperative pulmonary complications after laparotomy and found seven to be significant in multivariate analysis: ASA scores greater than 2, upper abdominal incisions, residual intraperitoneal infection, age greater than 59 years, body mass index greater than 25 kg/m^2, preoperative stay exceeding 4 days, and gastroduodenal or colonic surgery. Williams-Russo[11] found that, among patients with a history of hypertension or diabetes, the risk after abdominal surgery was higher if they also had any history of asthma or chronic bronchitis.

Pulmonary function testing

In an extensive review, Zibrak et al[12] found that spirometry did not predict postoperative pulmonary complications in patients undergoing abdominal surgery. The rates of pulmonary complications varied among the studies reviewed, probably because the subjects underwent operations of different types and duration. The American College of Physicians[13] recommends spirometry only for cigarette smokers and for those being evaluated for respiratory complaints. *Table 3* presents recommendations for preoperative pulmonary function testing.

PREOPERATIVE MANAGEMENT

Overall, the goal of preoperative assessment is to detect (and modify) risk factors for postoperative

TABLE 4
TREATMENT STRATEGIES FOR REFRACTORY POSTOPERATIVE ATELECTASIS*

General techniques
Remove any obstruction to large airway (eg, mainstem or lobar bronchus)
Control pain
Provide therapy at least every 1–2 waking hours initially
Reduce frequency of therapy as improvement occurs
Ensure adequate supervision of therapy
Deep-breathing techniques
Voluntary deep breathing (with incentive spirometry)
Have patient repeat maximum lung inflations at least five times per session
Monitor volumes achieved
Have patient hold each breath for 5–6 seconds
Intermittent positive-pressure breathing
Use volume-oriented technique
Provide maximum inflations in series of at least five, repeated once or twice
Use only to treat clinically significant atelectasis, not as prophylaxis
Use if spontaneous inspiratory capacity is < 1 L (in adults)
Document that therapy increases inspiratory capacity by at least 25%
Measures to increase functional residual capacity
Intermittent continuous positive airway pressure (CPAP) or expiratory positive airway pressure by mask
Use adequate end-expiratory pressure (usually 10–15 cm H_2O) to increase functional residual capacity
Administer 25–35 breaths or for 5–10 minutes every 1–2 waking hours initially
Monitor constantly when an occlusive mask is used
Positive end-expiratory pressure (PEEP) or CPAP by tracheal tube (continuous)
Use adequate end-expiratory pressure (usually 10–15 cm H_2O) to increase functional residual capacity
Continue PEEP or CPAP for at least 24 hours after resolution of atelectasis on x-ray films

*From O'Donohue[1]

pulmonary complications. As considered below, interventions may include treatment of airflow obstruction, smoking cessation, prophylaxis against venous thromboembolism, weight reduction, prevention of aspiration, and appropriate use of lung-expansion techniques.

Treating airflow obstruction

COPD is associated with increased risk of postoperative atelectasis, bronchitis, pneumonia, ventilatory failure, and prolonged intensive care. Treating airflow obstruction before surgery probably lessens the risk. Tarhan et al[14] showed that men with COPD who received individualized preoperative treatment with oral or inhaled bronchodilators or both, systemic corticosteroids, or antibiotics had significantly fewer postoperative pulmonary complications than did untreated men (23.7% vs 43.1%, $P < .01$). Stein and Cassara[15] also found a significant reduction in pulmonary complications (21% vs 60%, $P < .01$) when COPD patients underwent a program that included bronchodilators, smoking cessation, antibiotics, or chest physiotherapy one to three times daily. Gracey et al[16] reported an observational series of 157 COPD patients undergoing surgery. Of 134 patients who underwent general anesthesia, 108 experienced no problems, but 26 had postoperative pulmonary complications without ventilatory failure, and seven required mechanical ventilation for longer than 48 hours. Those who required prolonged mechanical ventilation had not responded to intensive preoperative treatment.

Patients with asthma should be assessed for symptoms suggesting more severe airflow obstruction, such as nocturnal waking, frequent use of bronchodilators, recent use of inhaled and systemic corticosteroids, and previous surgical complications. The National Institutes of Health expert panel guidelines recommend that lung function be optimized, and that corticosteroid therapy be considered before and after surgery.[17] Pien et al[18] found no difference in the incidence of postoperative pulmonary complications among corticosteroid-treated asthma patients undergoing surgery compared with patients without asthma. However, pulmonary complications were significantly more frequent in patients who experienced wheezing before surgery than in those who developed wheezing afterward, suggesting that uncontrolled asthma increases the risk of pulmonary complications. There were no deaths, wound complications, or cases of adrenal insufficiency associated with corticosteroid use. These patients received hydrocortisone 100 mg every 8 hours before surgery, and, when indicated, oral corticosteroids as well.

A recent retrospective survey confirmed a low frequency of wound infections, pneumonia, and adrenocortical insufficiency among a group of 86 asthma patients.[19] Before surgery, patients received prednisone 1 mg/kg (up to 60 mg) daily for 3 to 7 days, together with hydrocortisone hemisuccinate

100 mg every 8 hours perioperatively. Overall, a brief perioperative course of glucocorticoids (eg, prednisone or an equivalent, 60 mg daily for 2 to 3 days before surgery and tapered off over 1 week after surgery) is recommended.

Smoking cessation

Stopping smoking before surgery has been shown to reduce the risk of postoperative pulmonary complications. However, Warner et al[5,20] showed that the frequency of pulmonary complications after coronary artery bypass grafting did not decrease significantly until at least 8 weeks after patients had quit smoking. In fact, patients who quit less than 8 weeks before surgery had a slightly *higher* incidence of pulmonary complications than did patients who continued to smoke. Nevertheless, most physicians recommend abstinence from cigarette smoking for as long as possible before surgery.

Weight reduction

Although several studies have demonstrated that obesity is a risk factor for postoperative pulmonary complications, few have assessed the benefits of preoperative weight loss, most likely because of the difficulties of losing weight and of organizing such a study. In spite of the paucity of data, weight loss is frequently recommended for obese patients facing elective surgery.

Prophylaxis of venous thromboembolic disease

As reviewed elsewhere in this issue,[21] prophylaxis against venous thromboembolism is widely advisable for patients undergoing surgery involving immobilization.

Prevention of aspiration

Gastroesophageal reflux, gastroparesis, emergency surgery, and pregnancy all increase the risk of aspiration. In high-risk patients, one should consider giving omeprazole or a histamine-2 receptor antagonist before surgery, because a low gastric pH poses a more important risk for serious aspiration pneumonia than does the volume of material aspirated. Aspirating particulate material also increases the risk of severe pneumonia. Patients should continue to receive nothing by mouth longer if the risk of aspiration appears high. Therapy for established aspiration is supportive, and antibiotics should be prescribed according to usual bacteriologic techniques.[22]

TABLE 5
PREDICTING FEV_1* AFTER PNEUMONECTOMY, USING PERFUSION LUNG SCANNING†

Predicted postoperative FEV_1 = (preoperative FEV_1) (percent perfusion to remaining lung)
Example: a patient with a planned left pneumonectomy
Preoperative FEV_1 = 1.30 L
Perfusion to right lung = 60% of total
Predicted postoperative FEV_1 = (1.30) (0.60) = 0.78 L

*Forced expiratory volume in 1 second
†Data from Cottrell and Ferson[26]

Lung-expansion techniques

Maneuvers that increase lung volume have reduced the incidence and severity of postoperative pulmonary complications in high-risk patients in prospective studies.[23] Chest physiotherapy is more effective if started before surgery rather than waiting until after surgery. The only beneficial expiratory maneuver is coughing. Intermittent positive-pressure breathing (IPPB) was initially thought to be beneficial, but subsequent studies failed to find it more effective than other treatments, and it costs more. Incentive spirometry has been shown to reduce the frequency of both radiological and clinical complications after abdominal surgery, but deep breathing may be equally effective in compliant patients. Patients should perform either maneuver as often as possible for 3 or 4 days after surgery.[24]

Continuous positive airway pressure delivered by mask (CPAP) has also received attention. The functional residual capacity appears to improve more with CPAP than with deep breathing or incentive spirometry, but the radiological and clinical frequency of postoperative pulmonary complications may be similar with either technique. Therefore, CPAP may be recommended for patients for whom the other techniques are unsuitable because of lack of cooperation or severity of illness.

TREATMENT OF PULMONARY COMPLICATIONS

Table 4 summarizes the treatment strategies for refractory postoperative atelectasis, a common complication.[1] About five deep breaths will improve lung function for about 1 hour. Breath-holding for 5.5 seconds is required to reduce intrasegmental differences by 60%; therefore, patients should take at least five sequential deep breaths once every waking hour, holding each breath for 5

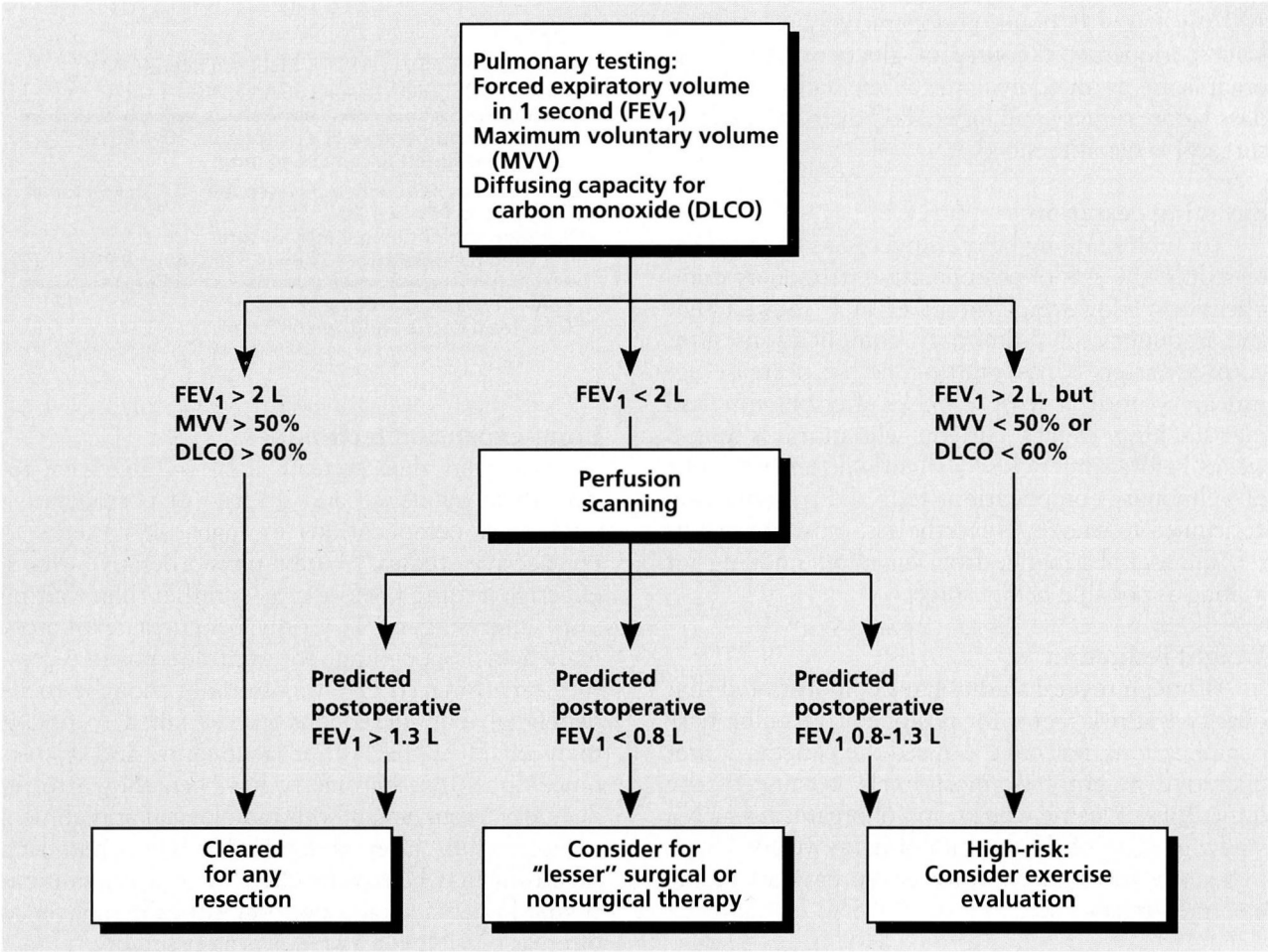

FIGURE. Flow diagram of preoperative patient evaluation for lung resection. Adapted from Cottrell and Ferson.[26]

to 6 seconds. The incentive spirometer helps with lung expansion, but it does not signal the patient to hold his or her breath. Thus, patient instructions should include reminders about the importance of breath-holding. Pain management may also be important in improving the ability to expand the lungs. If lobar atelectasis is radiographically refractory to chest physiotherapy after 24 hours, bronchoscopy should be considered.

EVALUATION BEFORE LUNG RESECTION

Evaluating cardiopulmonary status is especially important in patients undergoing lung resection, most of whom have diagnosed or suspected carcinoma of the lung. The operative mortality rate during lung resection has been reduced, from 10% to 15% to a recent rate of 2% to 7%.[25] An algorithm (*Figure*) can be used to guide the assessment of a patient before lung resection.[26] The tests most able to predict the ability to withstand lung resection include the forced expiratory volume in 1 second (FEV_1), the true maximal voluntary ventilation, and the diffusing capacity for carbon monoxide. In doubtful cases (if the FEV_1 is less than 2 L), split lung perfusion studies to estimate postoperative lung function are helpful (*Table 5*).[26] A predicted postoperative FEV_1 of more than 800 mL (in the remaining lung) indicates a greater likelihood of a favorable outcome. In high-risk patients (*Figure*), exercise evaluation may also be considered; a maximum oxygen consumption exceeding 15 mL/kg/minute favors resection.

Pulmonary artery pressure measurements have not achieved acceptance as a useful measure to determine surgical candidacy. Certain clinical features

such as hypercapnia, right-sided heart failure, left-sided heart failure, and age have all been considered. Despite concerns about referring hypercapnic patients for lung resection, no studies have shown that hypercapnia (ie, a $PaCO_2 > 45$ mm Hg) is an absolute contraindication to surgery, and there are anecdotal reports of such patients doing well afterward.

Similarly, mild left-sided heart failure and advanced age do not absolutely rule out lung resection. In contrast, right-sided heart failure probably is a contraindication, because further impairment of pulmonary flow is likely to increase the load on the right side of the heart. If pulmonary function studies, split lung perfusion studies, and exercise studies (if available) indicate that pneumonectomy seems very risky, nonanatomic resection or segmentectomy may offer greater hope of cancer cure than nonsurgical therapies. These smaller resections are more likely to preserve postoperative lung function.[27]

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