The goal of preoperative evaluation of the surgical patient is to identify patients at risk for complications during or following surgery. There are many potential types of complications that can impact outcome following surgery, but the identification of the patient at risk for postoperative pulmonary complications is particularly important given that this type of complication is the most frequent reported cause of morbidity and mortality in the postoperative period.1,2 Patients with preexisting lung disease have a particularly high risk of postoperative pulmonary complications,3,4 yet there are pathophysiologic changes that occur during and after surgery that can place patients without preexisting lung disease at risk for pulmonary complications, eg, bronchospasm, aspiration, atelectasis, pain, and pulmonary edema.5–7

Identifying patients at risk for pulmonary complications is the first step. The second, and perhaps more perplexing step, is figuring out how, or if, that risk once identified can be impacted. In the extreme, risk modification may involve canceling an operation, but clearly the type of operation planned, whether it is emergent or elective, the surgical site, and the fitness of the patient must influence this decision. Modifying the risk of postoperative pulmonary complications may involve anything from postponement of surgery and changes in the planned anesthetic technique to simple instructions to patients (ie, stop smoking, lose weight) and the educated use of simple interventions (eg, bronchodilators and incentive spirometry).

IDENTIFYING RISK FACTORS

Operative Characteristics

Understanding the risk of a surgical procedure infers a comprehension of the risk of not performing the procedure in a patient who requires it. Thus, when confronted by a patient who wants to know if the surgery is “too risky,” the medical consultant cannot respond intelligently or accurately without understanding the relative necessity and urgency of the proposed operation. Patients undergoing emergent surgery vs those undergoing elective surgery have a much higher risk of postoperative complications, including pulmonary complications such as pneumonia and prolonged mechanical ventilation.8 Even in the realm of elective procedures, however, it is clear that certain types of procedures are associated with an increased incidence of pulmonary complications. There is no uniform definition of what constitutes a postoperative pulmonary complication,9 but pneumonia (which itself is not uniformly defined), chest radiograph changes such as atelectasis or infiltrates, postoperative fever, prolonged mechanical ventilation, and respiratory failure are the ones most often cited in the literature. Length of stay in an ICU or in the hospital following surgery may provide a more definable but more indirect measure of postoperative pulmonary complications.10

The anatomic site of surgery is significant in the development of postoperative pulmonary complications.2,11 Abdominal surgery appears to pose a particularly high risk for pulmonary complications. Pulmonary complications have been reported in 20 to 70% of patients undergoing upper abdominal and thoracic operations3,12–14 compared with a 4% incidence of pulmonary complications after urologic or
orthopedic surgery. In one study, the pulmonary complication rate for all abdominal operations was 10.3% compared with a rate of 0.6% for nonabdominal and nonthoracic operations. One study showed the rate of postoperative pulmonary complications to be 25% for upper abdominal incisions vs 19% for thoracotomies. In thoracic resection, the complication rate relates to the amount of functional lung that has been resected. While risk based on site of operation might seem relatively immutable, newer operative techniques may change this. The use of laparoscopic techniques in particular may enhance recovery and reduce the risk of pulmonary complications by causing less pain and less disruption of abdominal and diaphragmatic muscle activity and allowing for more rapid recovery following an operation.

The duration of anesthesia also has been shown to be an independent predictor of postoperative pulmonary complications. Postoperative pneumonia is more common in operations lasting ≥ 4 h regardless of the site of operation. Improvements in anesthetic techniques, including the use of regional vs general anesthesia, better postoperative pain management, and the use anesthetic agents with shorter elimination half-lives may decrease the risk of many surgical procedures.

Patient Characteristics and Assessment of Pulmonary Function

Although age alone does not confer an independent risk of postoperative pulmonary complications, the fastest growing group of patients with cardiopulmonary disease is the elderly. The number of surgical procedures in elderly patients is on the rise and thus patient age may represent a recognizable if unalterable risk. Elderly patients have generally higher rates of treatment-related risks and also have a shorter life expectancy, thus the risk of surgery may compete more closely with the risk of not performing surgery in this group of patients.

Chronic lung disease poses the most significant patient-related risk for post-operative pulmonary complications. Distinguishing patients with lung disease from those without it is an important step in identifying the risk of postoperative pulmonary complications. Pulmonary function tests can assess the presence and the severity of lung disease, but the ability of different tests of pulmonary function to predict pulmonary complications has been variable. In terms of identifying patients with lung disease, minimal changes in pulmonary function test results alone may be no more sensitive as indicators of occult pulmonary disease than the information gathered from a careful history and physical examination. Thus, the wholesale use of pulmonary function tests as a preoperative screen for the presence of pulmonary disease in patients without a suggestive clinical history or examination is unwarranted. And in this circumstance, pulmonary function tests are of limited use in predicting individual outcomes. However, in patients undergoing lung resection, pulmonary function tests serve to establish a baseline from which to estimate the impact of surgery on respiratory function.

In patients with known underlying pulmonary disease such as COPD and asthma, pulmonary function tests can estimate disease severity and prompt interventions that may reduce risk. COPD patients have an overall increased rate of postsurgical complications that may range from 26 to 78%,

Persistently elevated $\text{PaCO}_2$ values of $> 45 \text{ mm Hg}$ predict a high risk for pulmonary complications or death. Arterial hypoxemia ($\text{PaO}_2 < 50 \text{ mm Hg}$) may also be a relative contraindication to surgery. While a high $\text{PaCO}_2$ or low $\text{PaO}_2$ may not absolutely contraindicate surgery, they can highlight the necessity of providing intense and careful preoperative support in high-risk patients. Nevertheless, the risk of an elective surgery in patients with severe lung disease, hypoxemia, and hypercapnia may in some instances prove to be unacceptable.

In high-risk patients undergoing pneumonectomy (those with an $\text{FEV}_1 < 2 \text{ L}$) in addition to full pulmonary function tests, postoperative lung function should be estimated by split-perfusion lung scanning. A predicted postoperative $\text{FEV}_1$ of $> 80 \text{ mL}$ has been associated with an operative mortality of approximately 15%, but it is believed to represent an acceptable cutoff for reasonable postoperative pulmonary function.

A chest radiograph is a type of preoperative assessment of pulmonary function. Just as pulmonary function tests are rarely abnormal in patients without risk factors for lung disease, chest radiographs rarely reveal anything that might change the decision to perform an operation in patients without other
risk factors. A chest radiograph is indicated in patients with evidence of new or changing lung disease or in patients believed to be at high risk for pulmonary complications.

**Reducing the Risk**

*History and Physical Examination*

A careful history that focuses on eliciting respiratory complaints such as breathlessness, cough, chest pain, exercise intolerance, and excessive sputum production may assist clinicians in identifying conditions that could increase the risk for postoperative pulmonary complications. Preoperative dyspnea scores, for instance, have been shown to correlate well with postoperative pulmonary complications in several studies.\(^2\),\(^3\),\(^4\) Although generally insensitive as a screening test, a thorough history and physical examination are relatively inexpensive and can set the stage for further workup. It provides an opportunity to consolidate information about the patient and the planned operation and to recommend a course of action for modifying risks in special populations of patients, especially those with preexisting lung disease. In addition, simple maneuvers that may promote lung health and decrease the risk of postoperative complications can be explained directly to the patient.

*Smoking Cessation*

The risk of developing postoperative pulmonary complications has been shown to decrease significantly after 8 weeks of smoking cessation,\(^5\) and it is increased in patients who continue to smoke.\(^6\),\(^7\),\(^8\),\(^9\) This time period correlates with the time it takes for improvements in tracheobronchial clearance and small airway function. Heavy smokers have a higher rate of pulmonary complications than patients who have smoked less, and heavy smokers tend to have significantly increased levels of carboxyhemoglobin that can cause decreases in arterial \(\text{PaO}_2\).\(^10\) The half-life for carboxyhemoglobin is approximately 6 h; therefore, there is a theoretical, if unproven, benefit to advising all patients, particularly heavy smokers, to stop smoking. As a 6-h half-life is known, smoking cessation should be advised at least 6 h before surgery.\(^11\),\(^12\) In one study, a loss of \(\geq 9\) kg even in a patient remaining 23% above ideal body weight was shown to lower the risk of pulmonary complications.\(^13\) In the case of the morbidly obese patient, delaying surgery until some weight loss can be achieved will likely reduce the risk of postoperative complications.

*Obesity*

Overall life expectancy is decreased in obese patients,\(^14\),\(^15\) but surgical mortality has not been shown to be increased.\(^16\) Obese patients, however, are at increased risk for postoperative pulmonary complications such as atelectasis.\(^17\) In one study, a loss of

**Chest Physiotherapy**

Several therapies that can be loosely classified as chest physiotherapy have been studied in relation to their ability to reduce postoperative pulmonary complications. These therapies have included deep breathing exercises in conjunction with chest percussion and postural drainage,\(^18\),\(^19\) peroperative intermittent positive pressure breathing,\(^20\),\(^21\) and incentive spirometry.\(^22\) As adjuncts to postoperative care, these therapies appear to be of some benefit in reducing pulmonary complications but are essentially of equivalent efficacy. Given the relatively low cost and simplicity of self-administered incentive spirometry, it is likely that incentive spirometry is the most reasonable intervention among these therapies for reducing the risk of pulmonary complications. It is important to note that preoperative instruction in the use of incentive spirometry is key to its effective use by the patient after surgery.

**Antibiotics, Bronchodilators, and Steroids**

Although 50% of the pneumonias diagnosed in hospital are in surgical patients,\(^23\) prophylactic antibiotic use in patients facing surgery should be reserved for patients with evidence of infected sputum.\(^24\) In patients with COPD and an increased cough with phlegm, a 10-day course of antibiotic therapy may reduce the risk of postoperative pneumonia.\(^25\) Elective surgical procedures should be delayed until a full course of antibiotic therapy is concluded in such patients.

In patients with symptomatic COPD and asthma, bronchodilators and steroids can prevent bronchospasm and reverse any reversible component of ongoing bronchospasm.\(^26\) \(\beta\)-Agonist medications are the first-line medications and can be administered via nebulizer or metered-dose inhaler. In one study of patients with COPD, those given a preoperative conditioning regimen, which included bronchodilators, had fewer postoperative pulmonary complications than historical control subjects.\(^27\) Another prospective study found that the use of bronchodilators and steroids decreased the risk of postoperative pneumonia in patients with COPD.\(^28\) In symptomatic asthmatic patients and patients with severe COPD, steroids may be beneficial,\(^29\) but they should be given at least 12 h before the operation because they can take > 6 h to take effect. If steroids are given,
they should be given in high doses for only a few days and then tapered gradually over the first postoperative week or longer. The pace of the taper will depend largely on the patients' history of lung disease and the role steroids have played in it, as well as on their postoperative course. In addition to being a good bronchodilator, theophylline has been shown to improve respiratory muscle function.43 Its use preoperatively as a bronchodilator should be limited to patients in whom it has been of proven benefit and/or those in whom severe bronchospasm persists despite the optimal use of inhaled bronchodilators and steroids.

CONCLUSION

The ability of history and physical examination, physiologic tests of pulmonary function, and radiographic studies to predict which patients undergoing an operation are at risk for pulmonary complications is limited and further research is still needed to determine the potential benefit of basing interventions to reduce risk on such information. Well-controlled prospective studies designed to answer such questions would be a welcome addition to the literature in this area.

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