Introduction

A variety of pulmonary complications occur in patients during and following nonthoracic surgery. These may include hypoxemia, atelectasis, bronchitis, pneumonia, and respiratory failure. The incidence of these complications is high and remains a major cause of morbidity and mortality in the postoperative state. Even so, this morbidity may be underestimated since hypoxemia, the most common pulmonary complication, exerts its influence throughout many organ systems through inadequate tissue oxygenation.

Physiologic Alterations Following Surgery

Predictable alterations occur in the pulmonary system in all patients undergoing surgery and general anesthesia regardless of age or underlying illness; the major impairment is a reduction in lung volume. Total lung capacity and all its subdivisions (vital capacity, residual volume, functional residual capacity, and other factors) are decreased; in addition, expiratory flows (FEV₁) are reduced to a similar degree. These changes occur during the operative procedure, are maximal within the first 24 hours and slowly resolve over five to ten days. The magnitude of decline is related to the location of the surgical procedure; operations on the upper abdomen generally result in reductions of 50% to 60%. Following lower abdominal procedures, lung volumes and flows decrease by 25%. There is no change in pulmonary function following operations on the extremities or the head and neck area.

With the change in volume, the lung becomes less distensible (reduced compliance), airways close and alveoli collapse, especially in dependent portions of the lung. Because of these abnormalities, there are areas in the lung in which ventilation is reduced but perfusion continues, resulting in hypoxemia. This decrease in arterial oxygen tension approximates 20 torr following upper abdominal surgery in normal persons.

Postoperatively, the respiratory rate increases and tidal volume decreases, although total minute ventilation is unchanged. Periodic deep inspirations, such as with sighs and yawns, are less frequent also. This unvarying pattern of respiration leads to alveolar collapse and a progressive decline in compliance and arterial oxygen tensions. These changes in respiratory pattern have been ascribed to postoperative pain and poor motion of the diaphragm. However, administration of narcotics to alleviate pain accentuates these changes as patients are reluctant to cough or take periodic deep breaths. This leads to retention of secretions, eventual atelectasis, and occasionally, pneumonia.

Because of tissue repair and healing, the metabolic rate is increased following operative procedures, resulting in an increase in respiratory demands approximating 15% to 25%. In addition, the work of breathing is increased because of the fall in lung compliance. Thus, in the postoperative state, the respiratory system...
TABLE 1
Characteristics of Patients at High Risk for Postoperative Complications

1. Advanced age (>65)
2. Obesity
3. Past or present smoker
4. Mucous hypersecretion
5. Abdominal operation
6. Postoperative FEV\textsubscript{1} < 1.02
7. CO\textsubscript{2} > 46 torr

is called upon to meet greater demands at a time when it is temporarily impaired. These pathophysiologic events result in a small risk of complication in normal patients and a much greater risk in patients with preexisting pulmonary disease.

Factors Predisposing to Postoperative Complications

Table 1 lists characteristics which predispose patients to postoperative complications.\textsuperscript{2} Elderly patients have smaller lung volumes and flow rates. Obesity decreases pulmonary compliance and reduces lung volumes and arterial oxygen tensions. Mucous hypersecretion (whether from smoking or other causes) reduces flow rates and predisposes to atelectasis and infection. Abdominal operations have significant effects on lung volumes as noted above. However, the most important factor contributing to postoperative complications is chronic obstructive lung disease. The vital capacities and flow rates are low in these patients, their work of breathing is increased and they are hypoxemic. In addition, a number of other features in the patient with chronic lung disease add to the excessive risks for postoperative complications. These include mucous hypersecretion, abnormal mucociliary clearance mechanisms, and a propensity toward bronchospasm. In addition, a small percentage of patients have an elevated arterial carbon dioxide tension indicative of far-advanced pulmonary dysfunction.

Preoperative Evaluation

Preoperative evaluation consists of the identification of those clinical features, functional abnormalities and operative considerations which are likely to lead to respiratory complications. Many predisposing factors can be identified by history and physical examination (age, weight, smoking, dyspnea, cough, and other findings). Similarly, operative factors such as the site of incision and the expected duration of anesthesia should be identified in consultation with the anesthesiologist and surgeon. Finally, an objective evaluation of lung volumes, air flow and gas exchange should be made. While many pulmonary function tests are available, simple spirometry and arterial blood gas evaluation are the most readily available and practical. The level of pulmonary dysfunction is best evaluated with the FEV\textsubscript{1}, although other spirometric tests have been used.\textsuperscript{3} An FEV\textsubscript{1} less than one liter per second may be associated with carbon dioxide retention; thus, a predicted postoperative FEV\textsubscript{1} greater than this is desirable. A reasonable estimate of the postoperative FEV\textsubscript{1} can be derived by multiplying the patient’s preoperative value by the decline expected based upon the location of the operation. As an example, if the patient’s preoperative FEV\textsubscript{1} were 2 liters and the contemplated operation were a gastrectomy, one might expect a 60% reduction in FEV\textsubscript{1}. Thus, the estimated postoperative FEV\textsubscript{1} would be 800 cc and the patient’s risk of respiratory failure high. Arterial blood gas analysis identifies patients with preexisting carbon dioxide retention and serves as a guide to oxygen supplementation.

Preventive Measures

Identification of patients at high risk is useful only if measures are available which may prevent complications. Fortunately, specific pre- and postoperative maneuvers in the high-risk patient have reduced the incidence of postoperative complications from 66% to 21%.\textsuperscript{4} A treatment program outline for preoperative, intraoperative, and postoperative care is presented in Table 2. For convenience, patients with COPD have been divided into four groups according to certain general characteristics; however, individual patients may fit into more than one category thus requiring more complex treatments as suggested in each specific category.

The first group includes patients with obstructive defects and also patients whose ventilatory capacities are reduced from other causes such as restrictive defects, advancing age, obesity, or other factors. Patient education is very important; a knowledgeable patient is more likely to cooperate with difficult or uncom-

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TABLE 2
Prevention of Postoperative Pulmonary Complications

<table>
<thead>
<tr>
<th>COPD</th>
<th>GROUP 1</th>
<th>GROUP 2</th>
<th>GROUP 3</th>
<th>GROUP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OBSTRUCTED HYPERSECRETION</td>
<td>HYPERSECRETION</td>
<td>BRONCHOSPASTIC</td>
<td>CO₂ RETENTION</td>
</tr>
<tr>
<td>PREOP</td>
<td>Instruction Stop smoking Percussion and drainage Hydration Antibiotics ?</td>
<td>Stop smoking Bronchodilators, aminophylline Beta agents, steroids</td>
<td>Maintain bronchodilators</td>
<td>Treat cor pulmonale Correct metabolic alkalosis</td>
</tr>
<tr>
<td>INTRAOP</td>
<td>PM operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTOP</td>
<td>Mobilize early Inspirometer Supplemental O₂ Care medication</td>
<td>Continue preop program Sputum smears</td>
<td>Maintain bronchodilators</td>
<td>Continue ventilator Maintain arterial blood gases ICU</td>
</tr>
</tbody>
</table>

Fortunate postoperative maneuvers aimed at protecting the respiratory system. Respiratory therapists can be employed to teach deep breathing maneuvers and coughing techniques. The patient can be instructed in the use of an inspirometer, a device to encourage maximum deep inspirations. Preoperative medications should be minimized; narcotics, benzodiazepams and other sedative drugs reduce respiratory drive and result in the unvarying respiratory pattern which may lead to alveolar and airway collapse, a fall in compliance and arterial hypoxemia. The patient should be encouraged to sit and walk as soon as possible postoperatively and the inspirometer should be used frequently. Supplemental oxygen should be administered until the patient has demonstrated the ability to maintain normal arterial oxygen tensions breathing room air. In addition, postoperative medications which could potentially suppress respiration should be given judiciously.

Those patients with mucous hypersecretion constitute group 2. The major postoperative respiratory complication in this group is atelectasis. Cessation of smoking will significantly reduce the amount of bronchial secretions. The duration of abstinence necessary for a significant change in the volume of secretions is highly variable; however, a period of five to seven days is usually sufficient. Every effort should be made to provide sufficient time prior to an operative procedure for clearing of the airways. Chest percussion and postural drainage accelerate the clearing process, and hydration aids in liquefying and mobilizing secretions from the tracheobronchial tree. Gram stains or culture of tracheobronchial secretions may reveal pathogenic organisms which should be treated with appropriate antibiotics. Operations should be scheduled for the afternoon; the morning is used in a vigorous attempt to remove any secretions which may have accumulated during the preceding night. In the postoperative period, good tracheobronchial toilet should be maintained. In addition, sputum smears should be evaluated on a regular basis to guide antibiotic usage.

Patients with bronchospasm (group 3) should also stop smoking, as cigarette smoke alone or in consort with other stimuli often induces bronchospasm. Bronchodilators should be administered preoperatively in therapeutic doses. Aminophylline and beta adrenergic agents are first-line drugs. Systemic steroids may be necessary in patients who have required their use in the past. Steroids must be given in those patients who require them on a routine basis for adequate bronchodilatation.

Patients in group 4 are those whose preoperative arterial carbon dioxide tensions are elevated and those who are likely to develop elevations because of the expected decline in their pulmonary function following surgery. Because the etiology of the respiratory failure is known (surgery) and improvement likely, the episodes should be managed with little difficulty. Preoperatively, cor pulmonale should be treated with diuretics and the administration of supplemental oxygen to correct pulmonary hypertension and relieve right heart failure. Diuretic and steroid administration may produce metabolic alkalosis which should be corrected since it depresses respiratory drive. During the
intraoperative period, an arterial line should be inserted for repeated measurements of arterial blood gases. The physician can then make appropriate changes in the ventilator settings to maintain adequate levels of arterial oxygen tension and baseline levels of arterial carbon dioxide. In particular, intraoperative hyperventilation should be avoided, as it leads to relative hyperventilation in the postoperative period as body tissue stores of carbon dioxide are replaced. In the postoperative period, ventilatory support should continue until the patient has demonstrated the ability to maintain his own ventilation. This type of care is given preferably in an intensive care unit where acute exacerbations of chronic respiratory failure are best managed.

Conclusions

The patient evaluation and respiratory care program outlined here provides a measure of protection for patients with preoperative pulmonary dysfunction. Such a program can be instituted with equipment now available and little added time, and if done routinely and diligently, leads to a reduction in postoperative complications. In addition, patients who in previous years might have been considered "too sick" for operation can now be managed through a postoperative period without significant morbidity and/or mortality. 

REFERENCES