Learning Objectives:
1) Review Functional Factors Contributing to Increased Respiratory Morbidity. 2) Examine Role and Efficacy of Measures to Improve Pulmonary Function. 3) Identify Benefits/Disadvantages of Various Anesthetic Drugs and Techniques.

Perioperative concerns in patients with respiratory disease have largely focused on risk assessment for development of postoperative pulmonary complications. The latter arise from two major causes. The first is the site of surgery such that upper abdominal procedures are associated with the greatest reduction in lung volumes with shallow breathing and abnormal gas exchange. These are intensified with thoracic surgery and its accompanying trauma to lung tissue. All of the surgical effects are multiplied in the presence of the other major factor, underlying lung dysfunction.

Although initial identification of patients with abnormal lung function is readily achievable with subjective information obtained from history and physical exam, objective estimation of disease severity requires some form of pulmonary function testing. The benefits from such evaluation are not confined to predicting and reducing postoperative complications. They also extend to reducing intraoperative morbidity by providing insight into choice of anesthetic drugs and techniques. This is particularly the case in patients with chronic obstructive disease (COPD).

CANDIDATES FOR PEROPERATIVE PULMONARY EVALUATION

For pulmonary function data to be of any value preoperative selection of patient for testing is of paramount importance. Essentially the prime candidates should be those in whom there is a reasonable expectation of abnormality and risk. A broad list was initially provided by Tisi 3 decades ago and included the following factors:

- Age > 70
- Morbid Obesity
- Thoracic Surgery
- Upper Abdominal Surgery
- History of Smoking, Cough
- Any Pulmonary Disease

This list was later refined by the American college of Chest Physicians. More recent adherence to the guidelines below have served to limit widespread costly and unnecessary testing.

- Lung Resection
- Smoking History, Dyspnea
- Cardiac Surgery
- Upper and Lower Abdominal Surgery
- Uncharacterized Respiratory Symptoms

PREDICTION OF PERIOPERATIVE RISK

Unfortunately no test result is an optimum predictor of perioperative respiratory morbidity because of limitations in identifying all of the important factors. A summary of pulmonary functional criteria suggestive of increased risk is outlined in TABLE 1.

One of the more valuable and easily obtained measurements is that of the peak expiratory flow (PEF). This is the maximal flow rate attained at the onset of a forced expiration. Although PEF can be estimated from the initial portion of the spirogram, it can be more conveniently measured with a host of inexpensive hand held flow meters. The PEF is highly dependent on effort and highly sensitive to the caliber of the large airways. The latter makes it useful for assessing bronchodilator therapy. Values less than 200L/min (3.3L/s) are indicative of impaired cough efficiency and a corresponding high risk of postoperative pulmonary difficulties. The PEF is also quite useful in differentiating between pulmonary and cardiac origins of dyspnea. Ailani, et al have devised the Dyspnea Differentiation Index (DDI) which is calculated as PEF x PaO2 / 1000. The DDI is superior to PEF reductions alone which themselves suggest a pulmonary cause of dyspnea. The latter group had DDI values less than one half those of patients with dyspnea due to cardiac causes (TABLE 2).

Of the indicators on Table 1 one of the more underappreciated factors is the chest x-ray. The presence of hyperaeration is a marker for clinically severe disease which has been associated with a significant (~33%) incidence of postoperative pulmonary problems. It usually identifies hyperinflation associated with airway obstruction and the loss of elastic recoil from destruction of lung parenchyma. This dynamic hyperinflation may also present problems intraoperatively with controlled ventilation.

The presence of resting hypercapnia (PaCO2 > 46 mmHg) in the absence of drug therapy (e.g. opioids) suggests some inadequacy of the respiratory apparatus due to advanced disease and portends the likelihood of problems regardless of the nature of the surgery. The chronic hypercapnia of of COPD is
associated with increased alveolar dead space (VD alv) which incurs the need for increased minute ventilation. Although simplistically attributed to respiratory muscle fatigue and diminished neural drive, the increased CO2 levels are actually a variant of “permissive hypercapnia” due to an economic breathing strategy of low tidal volumes (VT) and increased respiratory frequency (f). As such the respiratory muscles operate with a breathing pattern which offsets fatigue and lessens the sense of effort while producing less than optimal CO2 excretion because of the increased VD alv.

**PREOPERATIVE MEASURES TO IMPROVE LUNG FUNCTION AND RISK**

Identifying lung dysfunction is not devoted simply to assessing risk but also to alter morbidity by employing measures to improve lung function. Some of these modalities are listed in Table 3. Unfortunately today's custom of same day surgical admission limits their application. Nevertheless, 2 of the most important and effective maneuvers are cessation of smoking and bronchodilator therapy. There is roughly a 6 fold increase in peri operative complications (most notably bronchospasm) in smokers with spirometric evidence of airway obstruction. Smokers in general demonstrate an increase in adverse events especially during induction of anesthesia regardless of functional state. The obvious benefits of smoking cessation include a decrease in the volume of secretion and airway reactivity as well as improved mucociliary transport. Unfortunately, the benefits and the associated risk reduction are not achieved in less than a month of abstinence. Shorter periods (< 1 week) may actually be associated with increased secretions and heightened airway reactivity. The only benefit which accrues then is a reduction in carboxyhemoglobin content.

A common feature of patients with respiratory disease, especially those presenting for thoracic surgery, is a combination of airway hyper responsiveness and potentially reversible airway obstruction. Therefore, medications which establish and maintain patency of the airways are particularly valuable. Unfortunately, some clinicians assume that because a patient exhibits little or no response to bronchodilators during spirometric testing, the airway obstruction is not “reversible”. It is important, however, to realize that the response to bronchodilators tends to be bell shaped in that it is maximal with moderate disease and diminished in patients with both mild and severe disease. This is partly because usual reliance on FEV1 increase tends to underestimate therapeutic efficacy of bronchodilators. Spirometric inspiratory capacity (IC ) and derived measures such as the ratio of VT / IC or inspiratory reserve volume itself may provide a better estimate of reduced hyperinflation associated with the bronchodilating effect.

Long acting beta 2 sympathetic aerosols such as salbutamol or salmeterol are the mainstays for treatment and prevention of perioperative bronchospasm. Their use and efficacy is often limited by occurrence of tachycardia. The latter can be avoided by the use of quaternary anticholinergic compounds such as ipratropium and even more so tiotropium (SPIRIVA). The latter compound lacks the problematic inhibitory effects on M2 muscarinic receptors and has a very long (~24hr) duration of action. As such it can be conveniently administered preoperatively by means of a convenient aerosol-free inhaler.

**IMPLICATIONS FOR ANESTHETIC MANAGEMENT**

When possible regional anesthesia represents an ideal choice for patients with pulmonary disease because it obviates the need for airway instrumentation and possibility of adverse airway responses. This is not feasible if patients refuse or the site of surgery does not permit. Management of a general anesthetic in a patient with lung disease, in particular airway obstruction, revolves around prevention of airway constriction. The latter is best accomplished by avoiding airway stimulation in the presence of inadequate anesthetic depth. The choice of induction agents is vital in dealing with this potential problem. The limited clinical observations suggest that propofol may offer the best option for avoiding airway reactivity with induction and intubation. The advantages appear to be greatest in smokers.

The choice of inhalation anesthetics in such patients has historically placed emphasis on halothane largely because of its well recognized bronchodilating properties. The bronchodilating efficacy of sevoflurane, however, appears to be better in a population of VA patients, most of whom were smokers. Desflurane, on the other hand, is devoid of any bronchodilating actions and appears to have disadvantages related to its physical properties, most notably its high density and propensity for airway irritation.

Adequate anesthetic depth (>1 MAC) is obviously important to minimize likelihood of bronchospasm. When considering the mode of ventilation (i.e. spontaneous vs. controlled), it is important to consider the reduction in the ventilatory response to CO2 that accompanies inhalation anesthesia. With the mechanical impairment in patients with airway obstruction (e.g. decreased FEV1) one might expect CO2 removal to be further impaired. Indeed Pietak, et al reported alarming degrees of hypercapnia in such patients allowed to breathe spontaneously in the presence of 1% halothane. The low tidal volumes and high respiratory rates resulted in a high amount of “wasted” ventilation, more specifically increased alveolar dead space, despite the fact that overall minute ventilations were the same as normal patients. Although no data exist with newer agents...
such as sevoflurane in patients with obstructive lung disease, greater elevations of resting CO2 compared with halothane in normals would suggest that the effects in the presence of obstructive airway disease are also likely to be more severe.

**MANAGEMENT OF VENTILATION**

The need for positive pressure ventilation is unavoidable with general anesthesia in patients with variations of obstructive airway disease, but the approaches to mechanical ventilation are controversial. Traditional objectives have focused on the need to avoid excessive peak airway pressure (Ppk) based on the rather naïve perception that the latter is the major cause of lung parenchymal disruption usually referred to as “barotrauma” The limitation of Ppk is simplistically achieved by low rates of inspiratory flow(VI). The importance of reducing VI was long ago disputed by Tuxen and Lane who demonstrated that plateau pressure(Pplat) and not Ppk was related to lung hyperinflation, barotrauma, and circulatory depression. These are all the result of end expiratory and end inspiratory volume increases which can be reduced by the 3 following basic ventilatory strategies:

- Reduced Respiratory Frequency (f)
- Reduced Tidal Volume (VT)
- Shortened Inspiratory Time (Ti)

Reductions in f have the the greatest impact on reducing hyperinflation and are far more effective than reducing VT since the latter progressively increases the alveolar dead space fraction. Perhaps more benefits are derived from reductions in Ti to allow more time for passive exhalation. In order to maintain delivered VT, inspiratory flow rate must be increased. This is best accomplished with the square wave flow pattern of volume control ventilation. As surrogate markers of lung hyperinflation the plateau pressure during an inspiratory pause and “auto PEEP” are relatively easy to measure guides to adjusting ventilator settings. The former estimates the average end inspiratory alveolar pressure while the latter indicates that inspiration is beginning prior to the cessation of expiratory flow.

**MANAGEMENT IN THE IMMEDIATE POSTOPERATIVE PERIOD**

One major concern in these patients is the appropriate time to extubate. While the endotracheal tube may be removed early to minimize reactive bronchospasm, this is often not safe. Because of residual anesthetic effects, patients often require ventilatory support in the post anesthesia recovery unit. Reduced lung volumes and abnormal gas exchange persist for as long as 48 hours and patients whose respiratory dysfunction is obvious preoperatively require enhanced vigilance. However, it does seem reasonable to extubate some patients early on awakening and observe them closely for signs of deteriorating gas exchange before considering reintubation.

**POSTOPERATIVE ANALGESIA**

Analgesia, of course, is a vital component of postoperative therapy. In patients with lung disease there is a narrow therapeutic window because of respiratory depression associated with systemic opioids. Neuraxial blockade (e.g. epidural) with local anesthetics and opioids can avoid the problem somewhat. Although there are no objective data indicating improved spirometric performance, the benefits of mobility and deep breathing without discomfort render epidural analgesia an ideal choice. Much of its benefit accrues from a reduced need for systemic opioid analgesia.

**OXYGEN ADMINISTRATION.**

The need to administer supplemental oxygen to patients in the post anesthesia care unit is well recognized. There has been some unwarranted concern that oxygen administration will cause certain patients with obstructive lung disease and resting hypercapnia to stop breathing by eliminating their ventilatory response to hypoxia. While it may not be desirable to administer 100% oxygen to such patients, it is not appropriate to deny supplemental oxygen. The PaCO2 will increase and have long been recognized as due to a number of factors, the least of which is a major decrease in minute ventilation. These include the Haldane Effect and most notably an increase in V/Q mismatch because of the vasodilating actions of oxygen on the pulmonary vasculature.

**SUMMARY**

The peri-operative management of patients with lung disease begins with identifying such patients and determining the severity of their respiratory function. The latter may not require extensive spirometric evaluation and can be accomplished to a great extent by simple evaluations such as peak Flow, arterial blood gases, chest x-ray, etc. The evaluation serves to identify a group of patients at risk for postoperative pulmonary complications but also alerts to individuals who may experience a stormy anesthetic because of increased airway reactivity. In most instances therefore, the efforts are directed at minimizing airway responses during light anesthesia and periods of airway instrumentation. In other patients with lung dysfunction not associated with airway obstruction, the efforts must simply be directed at minimizing the further decrements in lung volume and deterioration of gas exchange so characteristic of the intra and post operative periods.

**REFERENCES**

IARS 2010 REVIEW COURSE LECTURES


---

<table>
<thead>
<tr>
<th>TABLE 1: INDICATORS OF INCREASED PERIOPERATIVE PULMONARY MORBIDITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 &lt; 2.0 L</td>
</tr>
<tr>
<td>FEF 25-75 &lt; 40 % of Predicted</td>
</tr>
<tr>
<td>Maximum Voluntary Ventilation &lt; 50% of Predicted</td>
</tr>
<tr>
<td>Peak Expiratory Flow &lt; 200 L/min</td>
</tr>
<tr>
<td>PaCO2 &gt; 46 mmHg</td>
</tr>
<tr>
<td>Chest X-ray Evidence of Hyperinflation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2: PULMONARY VS. CARDIAC CAUSES OF DYSPNEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac (n=24)</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
</tr>
<tr>
<td>Peak Flow (L/min)</td>
</tr>
<tr>
<td>DDI</td>
</tr>
</tbody>
</table>

Value are Mean +/- SD (Range)

<table>
<thead>
<tr>
<th>TABLE 3: PREOPERATIVE PULMONARY THERAPY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking Cessation</td>
</tr>
<tr>
<td>Bronchodilators</td>
</tr>
<tr>
<td>Incentive Spirometry (Sustained Deep Inspirations)</td>
</tr>
<tr>
<td>Chest Physiotherapy</td>
</tr>
<tr>
<td>Fluid Intake (&gt;3L/day)</td>
</tr>
<tr>
<td>Expectorants (Historically Glycerol Guaiacolate)</td>
</tr>
</tbody>
</table>