

Revista Mexicana de Anestesiología

Volumen **27**
Volume

Suplemento **1**
Supplement

2004

Artículo:

Preoperative assessment for pulmonary resection

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Preoperative assessment for pulmonary resection

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Preoperative anesthetic assessment prior to chest surgery is a continually evolving science and art. Recent advances in anesthetic management, surgical techniques and perioperative care have expanded the envelope of patients now considered to be “operable”⁽¹⁾. This seminar is an update on pre-anesthetic assessment for pulmonary resection surgery in cancer patients. The principles described will apply to all other types of non-malignant pulmonary resections and to other chest surgery. The major difference is that in patients with malignancy the risk/benefit ratio of canceling or delaying surgery pending other investigation/therapy is always complicated by the risk of further spread of cancer during any extended interval prior to resection. This is never completely “elective” surgery.

Several general points should be appreciated in the assessment of pulmonary resection patients:

- 1) Anesthesiologists are not gate-keepers. It is rarely the Anesthesiologist's function to assess these patients to decide who is or is not an operative candidate. In the majority of situations, the anesthesiologist will be seeing the patient at the end of a referral chain from chest or family physician to surgeon. At each stage there should have been a discussion of the risks and benefits of operation. It is the anesthesiologist's responsibility to use the preoperative assessment to identify those patients at elevated risk and then to use that risk assessment to stratify perioperative management and focus resources on the high-risk patients to improve their outcome. This is the primary function of the pre-anesthetic assessment.
- 2) Short term versus long term survival. Although there has been a large amount of research done on long term survival (6 months – 5 years) following pulmonary resection surgery there has been a comparatively small volume of research on the short term (< 6 weeks) outcome of these patients. However, this research area is currently very active and there are several studies which can be used to guide anesthetic management in the im-

mediate perioperative period where it has an influence on outcome.

- 3) Disjoint assessment. Until very recently, pre-anesthetic management was part of a continuum where a patient was admitted preoperatively for testing and the management plan evolved as test results returned. Currently, the reality of practice patterns in anesthesia has changed such that a patient is commonly assessed initially in an outpatient clinic and often not by the member of the anesthesia staff who will actually administer the anesthesia. The actual contact with the responsible anesthesiologist may be only 10 to 15 minutes prior to induction. It is necessary to organize and standardize the approach to preoperative evaluation for these patients into two temporally disjoint phases: the initial (clinic) assessment and the final (day-of-admission) assessment. There are elements vital to each assessment which will be described in this review.
- 4) “Lung-sparing” surgery. An increasing number of thoracic surgeons are now being trained to perform “lung-sparing” resections such as sleeve-lobectomies or segmentectomies. The postoperative preservation of respiratory function has been shown to be proportional to the amount of functioning lung parenchyma preserved⁽²⁾. To assess patients with limited pulmonary function the anesthesiologist must understand these newer surgical options in addition to the conventional lobectomy or pneumonectomy. Pre-thoracotomy assessment naturally involves all of the factors of a complete anesthetic assessment: past history, allergies, medications, upper airway, etc. This seminar will focus on the additional information beyond a standard anesthetic assessment that the anesthesiologist needs to manage a pulmonary resection patient.

Perioperative complications: To assess patients for thoracic anesthesia it is necessary to have an understanding of the risks specific to this type of surgery. The major cause of

perioperative morbidity and mortality in the thoracic surgical population is respiratory complications.

Major respiratory complications: atelectasis, pneumonia and respiratory failure occur in 15-20% of patients and account for the majority of the expected 3-4% mortality⁽³⁾. The thoracic surgical population differs from other adult surgical populations in this respect. For other types of surgery, cardiac and vascular complications are the leading cause of early perioperative morbidity and mortality. Cardiac complications: arrhythmia, ischemia, etc. occur in 10-15% of the thoracic population⁽⁴⁾.

ASSESSMENT OF RESPIRATORY FUNCTION

The best assessment of respiratory function comes from a detailed history of the patient's quality of life. A completely asymptomatic ASA class 1 or 2 patient with no limitation of activity and full exercise capacity probably does not need screening cardio-respiratory testing prior to pulmonary resection. Unfortunately, due to the biology of lung cancer these are a small minority of the patient population.

Because the anesthesiologist who will manage the case often has to assimilate a great deal of information about the patient in a short period of time it is very useful to have objective standardized measures of pulmonary function that can be used to guide anesthetic management and to have this information in a format that can be easily transmitted between members of the health care team. Much effort has been spent to try and find a single test of respiratory function that has sufficient sensitivity and specificity to predict outcome for all pulmonary resection patients. It is now clear that no single test will ever accomplish this. There are many factors that determine overall respiratory performance^(5,6). It is useful to think of the respiratory function in three related but somewhat independent areas: respiratory mechanics, gas exchange, and cardio-respiratory interaction.

- 1) *Respiratory Mechanics*: Many tests of respiratory mechanics and volumes show correlation with post-thoracotomy outcome: forced expiratory volume in one second (FEV1), forced vital capacity (FVC), maximal voluntary ventilation (MVV), residual volume/total lung capacity ratio (RV/TLC), etc. It is useful to express these as a percent of predicted volumes corrected for age, sex and height (e.g.: FEV1 %). Of these the most valid single test for post-thoracotomy respiratory complications is the predicted postoperative FEV1 (ppoFEV1 %) which is calculated as:

ppoFEV1 % = preoperative FEV1 % x (1 - % functional lung tissue removed/100).

One method of estimating the percent of functional lung tissue is based on a calculation of the number of functioning subsegments of the lung removed. Nakahara et al⁽⁴⁾ found that patients with a ppoFEV1 > 40% had no or minor post-resection respiratory complications. Major respiratory complications were only seen in the subgroup with ppoFEV1 < 40% (although not all patients in this subgroup developed respiratory complications) and 10/10 patients with ppoFEV1 < 30% required post-operative mechanical ventilatory support. These key threshold ppoFEV1 values: 30% and 40% are extremely useful to remember when managing these patients. The schema of may be overly complicated and it can be useful just to simply consider the right upper and middle lobes combined as being approximately equivalent to each of the other 3 lobes with the right lung 10% larger than the left. These data of Nakahara are from work done in the 1980's and recent advances, particularly the use of epidural analgesia has decreased the incidence of complications in the high-risk group⁽⁷⁾. However, ppoFEV1 values of 40% and 30% remain useful as reference points for the anesthesiologist. The ppoFEV1 is the most significant independent predictor of complications among a variety of historical, physical and laboratory tests for these patients⁽⁵⁾.

- 2) *Lung parenchymal function*: As important to the process of respiration as the mechanical delivery of air to the distal airways is the subsequent ability of the lung to exchange oxygen and carbon dioxide between the pulmonary vascular bed and the alveoli. Traditionally arterial blood gas data such as PaO₂ < 60 mmHg or PaCO₂ > 45 mmHg have been used as cut-off values for pulmonary resection. Cancer resections have now been successfully done⁽⁵⁾ or even combined with volume reduction in patients who do not meet these criteria⁽⁸⁾, although they remain useful as warning indicators of increased risk. The most useful test of the gas exchange capacity of the lung is the diffusing capacity for carbon monoxide (DLCO). Although the DLCO was initially thought just to reflect diffusion, it actually correlates with the total functioning surface area of alveolar-capillary interface. This simple non-invasive test which is included with spirometry and plethysmography by most pulmonary function laboratories is a useful predictor of post-thoracotomy complications. The corrected DLCO can be used to calculate a post-resection (ppo) value using the same calculation as for the FEV1. A ppoDLCO < 40% predicted correlates with both increased respiratory and cardiac complications and is to a large degree independent of the FEV1⁽⁹⁾.
- 3) *Cardio-pulmonary Interaction*: The final and perhaps most important assessment of respiratory function is an assess-

ment of the cardio-pulmonary interaction. All patients should have some assessment of their cardio-pulmonary reserves. The traditional, and still extremely useful, test in ambulatory patients is stair climbing⁽¹⁰⁾. Stair climbing is done at the patient's own pace but without stopping and is usually documented as a certain number of flights. There is no exact definition for a "flight" but 20 steps at 6 in/step is a frequent value. The ability to climb 3 flights or more is closely associated with decreased mortality and somewhat associated with morbidity. Less than 2 flights is very high risk.

Formal laboratory exercise testing has become more standardized and thus more valid and is currently the "gold standard" for assessment of cardio-pulmonary function. Among the many cardiac and respiratory factors which are tested, the maximal oxygen consumption (VO_2 max) is the most useful predictor of post-thoracotomy outcome. Walsh et al⁽¹¹⁾ have shown that in a high-risk group of patients (mean pre-operative FEV1 = 41% predicted) there was no perioperative mortality if the preoperative VO_2 max was > 15 ml/kg/min. This is a useful reference number for the anesthesiologist. Only 1/10 patients with a VO_2 max > 20 ml/kg/min had a respiratory complication. Exercise testing can be modified in patients who are not capable of stair climbing using bicycle or arm exercises. Complete laboratory exercise testing is labor intensive and expensive. Recently, several alternatives to exercise testing have been demonstrated to have potential as replacement tests for prethoracotomy assessment.

The six-minute walk test (6MWT) shows an excellent correlation with VO_2 max and requires little or no laboratory equipment⁽¹²⁾. A 6MWT distance of $< 2,000$ ft correlates to a VO_2 max < 15 ml/kg/min and also correlates with a fall in oximetry (SpO_2) during exercise. Patients with a decrease of $\text{SpO}_2 > 4\%$ during exercise (stair climbing 2 or 3 flights or equivalent)^(13,14) are at increased risk of morbidity and mortality. The six-minute walk test and exercise oximetry may replace VO_2 max for assessment of cardio-respiratory function in the future. Both of these tests are still evolving and for the present exercise testing will remain the gold standard. Post-resection exercise tolerance can be estimated based on the amount of functioning lung tissue removed. An estimated ppo VO_2 max < 10 ml/kg/min may be one of the few remaining absolute contra-indications to pulmonary resection. In a small series reported by Bollinger⁽¹⁵⁾ mortality was 100% (3/3) patients with a ppo VO_2 max < 10 ml/kg/min.

After pulmonary resection there is a degree of right ventricular dysfunction that seems to be in proportion to the amount of functioning pulmonary vascular bed re-

moved⁽¹⁶⁾. The exact etiology and duration of this dysfunction remains unknown. Clinical evidence of this hemodynamic problem is minimal when the patient is at rest but is dramatic when the patient exercises leading to elevation of pulmonary vascular pressures, limitation of cardiac output and absence of the normal decrease in pulmonary vascular resistance usually seen with exertion⁽¹⁷⁾.

- 4) *Ventilation perfusion (V/Q) scintigraphy*: Prediction of post-resection pulmonary function can be further refined by assessment of the pre-operative contribution of the lung or lobe to be resected using V/Q lung scanning⁽¹⁸⁾. If the lung region to be resected is non- or minimally functioning the prediction of post-operative function can be modified accordingly. This is particularly useful in pneumonectomy patients and should be considered for any patient who has a ppoFEV1 $< 40\%$.
- 5) *Split-lung function studies*: A variety of methods have been described to try and simulate the post-operative respiratory situation by unilateral exclusion of a lung or lobe with an endobronchial tube/blocker and/or by pulmonary artery balloon occlusion of a lung or lobe artery⁽¹⁹⁾. These and other varieties of split-lung function testing have also been combined with exercise to try and assess the tolerance of the cardio-respiratory system to a proposed resection. Although these tests are currently carried on and used to guide therapy in certain individual centers, they have not shown sufficient predictive validity for widespread universal adoption in potential lung resection patients. One possible explanation for some predictive failures in these patients may be that lack of a pulmonary hypertensive response to unilateral occlusion may represent a sign of a failing right ventricle misinterpreted as a good sign of pulmonary vascular reserve. Lewis et al⁽²⁰⁾ have shown that in a group of patients with COPD (ppo FEV1 $< 40\%$) undergoing pneumonectomy there were no significant changes in the pulmonary vascular pressures intraoperatively when the pulmonary artery was clamped but the right ventricular ejection fraction and cardiac output decreased. Echocardiography may offer more useful information than vascular pressure monitoring in these patients⁽²¹⁾. It is conceivable that the future combination of unilateral occlusion studies with echocardiography may be a useful addition to this type of pre-resection investigation.
- 6) *Flow-volume loops*: Flow volume loops can help identify the presence of a variable intra-thoracic airway obstruction by evidence of a positional change in an abnormal plateau of the expiratory limb of the loop⁽²²⁾. This can occur due to compression of a main conducting airway by a tumor mass. Such a problem may warrant induction airway management with awake intubation or mainte-

nance of spontaneous ventilation⁽²³⁾. However, in an adult patient capable of giving a complete history who does not describe supine exacerbation of cough or dyspnea, flow-volume loops are not required as a routine preoperative test.

- 7) *Combination of tests*: No single test of respiratory function has shown adequate validity as a sole pre-operative assessment⁽⁵⁾. Prior to surgery an estimate of respiratory function in all 3 areas: mechanics, parenchymal function and cardio-pulmonary interaction should be made for each patient. These three aspects of pulmonary function form the "Three-legged Stool" which is the foundation of pre-thoracotomy respiratory assessment. These data can then be used to plan intra- and post-operative management and also to alter these plans when intraoperative surgical factors necessitate that a resection becomes more extensive than foreseen. If a patient has a ppoFEV1 > 40% it should be possible for that patient to be extubated in the operating room at the conclusion of surgery assuming the patient is alert, warm and comfortable ("AWaC"). Patients with a ppoFEV1 < 40% will usually comprise about ¼ of an average thoracic surgical population. If the ppoFEV1 is > 30% and exercise tolerance and lung parenchymal function exceed the increased risk thresholds then extubation in the operating room should be possible depending on the status of associated diseases (see below). Those patients in this subgroup who do not meet the minimal criteria for cardio-pulmonary and parenchymal function should be considered for staged weaning from mechanical ventilation post-operatively so that the effect of the increased oxygen consumption of spontaneous ventilation can be assessed. Patients with a ppoFEV1 20-30% and favorable predicted cardio-respiratory and parenchymal function can be considered for early extubation if thoracic epidural analgesia if used. Otherwise, these patients should have a post-operative staged weaning from mechanical ventilation. In the borderline group (ppoFEV1 30-40%) the presence of several associated factors and diseases which should be documented during the pre-operative assessment will enter into the considerations for post-operative management.

INTERCURRENT MEDICAL CONDITIONS

- 1) *Age*. There does not appear to be any maximum age which is a cutoff to pulmonary resection. If a patient is 80 years of age and has a stage I lung cancer, their chances of survival to age 85 are better with the tumor resected than without. The operative mortality in a group of patients 80-92 years was 3%, a very respectable figure, in a series reported by Osaki⁽²⁴⁾. However, the rate of respiratory complications (40%) was double that expect-

ed in a younger population and the rate of cardiac complications (40%), particularly arrhythmias, was nearly triple that which should be seen in younger patients. Although the mortality from lobectomy in the elderly is acceptable, the mortality from pneumonectomy (22% in patients > 70 years)⁽²⁵⁾, particularly right pneumonectomy, is excessive. Presumably the reason for this is the increased strain on the right heart caused by resection of the proportionally larger vascular bed of the right lung.

- 2) *Cardiac disease*. Cardiac complications are the second most common cause of peri-operative morbidity and mortality in the thoracic surgical population.

- a) *Ischemia*. Because the majority of pulmonary resection patients have a smoking history, they already have one risk factor for coronary artery disease⁽²⁶⁾. However, elective pulmonary resection surgery is generally regarded as an "intermediate risk" procedure in terms of peri-operative cardiac ischemia, less than accepted "high-risk" procedures such as major emergency or vascular surgery⁽²⁷⁾. The overall documented incidence of post-thoracotomy ischemia is 5% and peaks on day 2-3 post-operatively⁽²⁸⁾. This is approximately the risk which would be expected from a similar patient population having major abdominal, orthopedic or other procedures. Beyond the standard history, physical and electrocardiogram, routine screening testing for cardiac disease does not appear to be cost-effective for all pre-thoracotomy patients⁽²⁹⁾. Non-invasive testing is indicated in patients with major (unstable ischemia, recent infarction, severe valvular disease, significant arrhythmia) or intermediate (stable angina, remote infarction, previous congestive failure, or diabetes) clinical predictors of myocardial risk and also in the elderly^(28,30). Therapeutic options to be considered in patients with significant coronary artery disease are optimization of medical therapy, coronary angioplasty or coronary artery bypass, either prior to or at the time of lung resection⁽³¹⁾. Timing of lung resection surgery following a myocardial infarction is always a difficult decision. Based on the data of Rao et al⁽³²⁾, and generally confirmed by recent clinical practice, limiting the delay to 4-6 weeks in a medically stable and fully investigated and optimized patient seems acceptable after myocardial infarction.
- b) *Arrhythmia*: Dysrhythmias, particularly atrial fibrillation, are a well recognized complication of all pulmonary resection surgery⁽³³⁾. Factors known to correlate with an increased incidence of arrhythmia are the amount of lung tissue resected, age, intraoperative

blood loss, and intra-pericardial dissection^(34,35). Prophylactic therapy with Digoxin has not been shown to prevent these arrhythmia's. However, Diltiazem has recently shown some promise⁽³⁶⁾.

3) *Renal Dysfunction*: Renal dysfunction following pulmonary resection surgery is associated with a very high incidence of mortality. Gollege & Goldstraw⁽³⁷⁾ reported a peri-operative mortality of 19% (6/31) in patients who developed any significant elevation of serum creatinine in the post-thoracotomy period, compared to 0% (0/99) in those who did not show any renal dysfunction. The factors which were highly associated ($p < .001$) with an elevated risk of renal impairment, are: previous history of renal impairment, diuretic therapy, pneumonectomy, postoperative infection and blood loss requiring transfusion. Other factors which were statistically significant but less strongly associated with renal impairment included preoperative hypertension, chemotherapy, ischemic heart disease and postoperative oliguria (< 33 ml/hr). Non-steroidal anti-inflammatory agents (NSAIDS) were not associated with renal impairment in this series but are clearly a concern in any thoracotomy patient with an increased risk of renal dysfunction. The high mortality in pneumonectomy patients from either renal failure or post-operative pulmonary edema emphasizes the importance of fluid management in these patients⁽³⁸⁾ and the need for close and intensive peri-operative monitoring, particularly in those patients on diuretics or with a history of renal dysfunction.

4) *Chronic obstructive pulmonary disease*: The most common concurrent illness in the thoracic surgical population is chronic obstructive pulmonary disease (COPD) which incorporates three disorders: emphysema, peripheral airways disease and chronic bronchitis. Any individual patient may have one or all of these conditions, but the dominant clinical feature is impairment of expiratory airflow⁽³⁹⁾. Assessment of the severity of COPD has traditionally been on the basis of the FEV1 % of predicted values. The American Thoracic Society currently categorizes Stage I $> 50\%$ predicted (this category previously included both "mild" and "moderate" COPD), Stage II: 35-50%, Stage III $< 35\%$. Stage I patients should not have significant dyspnea, hypoxemia or hypercarbia and other causes should be considered if these are present. Recent advances in the understanding of the COPD which are relevant to anesthetic management include:

a) *Respiratory drive*: Major changes have occurred in our understanding of the control of breathing in COPD patients. Many stage II or III COPD patients

have an elevated PaCO_2 at rest. It is not possible to differentiate these "CO₂-retainers" from non-retainers on the basis of history, physical examination or spirometric pulmonary function testing. This CO₂-retention seems to be more related to an inability to maintain the increased work of respiration (W_{resp}) required to keep the PaCO_2 normal in patients with mechanically inefficient pulmonary function and not primarily due to an alteration of respiratory control mechanisms. It was previously thought that chronically hypoxemic/hypercapnic patients relied on a hypoxic stimulus for ventilatory drive and became insensitive to PaCO_2 . This explained the clinical observation that COPD patients in incipient respiratory failure could be put into a hypercapnic coma by the administration of a high concentration of oxygen (FiO_2). Actually, only a minor fraction of the increase in PaCO_2 in such patients is due to a diminished respiratory drive, as minute ventilation is basically unchanged⁽⁴⁰⁾. The PaCO_2 rises because a high FiO_2 causes a relative decrease in alveolar ventilation and an increase in alveolar dead space by the redistribution of perfusion away from lung areas of relatively normal V/Q matching to areas of very low V/Q ratio because regional hypoxic pulmonary vasoconstriction (HPV) is decreased and due to the Haldane effect⁽⁴¹⁾. However, supplemental oxygen must be administered to these patients postoperatively to prevent the hypoxemia associated with the unavoidable fall in functional residual capacity (FRC). The attendant rise in CO₂ should be anticipated and monitored. To identify these patients preoperatively, all stage II or III COPD patients need an arterial blood gas.

b) *Nocturnal hypoxemia*: COPD patients desaturate more frequently and severely than normal patients during sleep⁽⁴²⁾. This is due to the rapid/shallow breathing pattern that occurs in all patients during REM sleep. In COPD patients breathing air, this causes a significant increase in the respiratory dead space/tidal volume (V_D/V_T) ratio and a fall in alveolar oxygen tension (PAO_2) and PaO_2 . This is not the sleep-apnea-hypoventilation syndrome (SAHS). There is no increased incidence of SAHS in COPD. In 8 of 10 COPD patients studied, the oxygen saturation fell to $< 50\%$ at some time during normal sleep and this was associated with an increase in pulmonary artery pressure⁽⁴³⁾. This tendency to desaturate, combined with the postoperative fall in FRC and opioid analgesia places these patients at high risk for severe hypoxemia postoperatively during sleep.

c) *Right ventricular (RV) dysfunction*: Right ventricular dysfunction occurs in up to 50% of COPD pa-

tients⁽⁴⁴⁾. The dysfunctional RV, even when hypertrophied, is poorly tolerant of sudden increases in afterload⁽⁴⁶⁾ such as the change from spontaneous to controlled ventilation⁽⁴⁵⁾. Right ventricular function becomes critical in maintaining cardiac output as the pulmonary artery pressure rises. The RV ejection fraction does not increase with exercise in COPD patients as it does in normal patients. Chronic recurrent hypoxemia is the cause of the RV dysfunction and the subsequent progression to cor pulmonale. Patients who have episodic hypoxemia in spite of normal lungs (e.g., Central Alveolar Hypoventilation, SAHS, etc.)⁽⁴⁸⁾ develop the same secondary cardiac problems as COPD patients. Cor Pulmonale occurs in 40% of adult COPD patients with an FEV₁ < 1 liter and in 70% with FEV₁ < 0.6 l⁽⁴⁵⁾. It is now clear that mortality in COPD patients is primarily related to chronic hypoxemia⁽⁴⁹⁾. The only therapy, which has been shown to improve long term survival and decrease right heart strain in COPD is oxygen. COPD patients who have resting PaO₂ < 55 mmHg should receive supplemental home oxygen and also those who desaturate to < 44 mmHg with usual exercise⁽⁴⁰⁾. The goal of supplemental oxygen and is to maintain a PaO₂ 60-65 mmHg. Compared to patients with chronic bronchitis, emphysematous COPD patients tend to have a decreased cardiac output and mixed venous oxygen tension while maintaining lower pulmonary artery pressures⁽⁴⁶⁾. Pneumonectomy candidates with a ppoFEV₁ < 40% should have trans-thoracic echocardiography to assess right-heart function. Elevation of right-heart pressures places these patients in a very high risk group^(47,48).

- d) Combined Cancer and Emphysema Surgery. The National Emphysema Treatment Trial has defined the minimal preoperative pulmonary function required for acceptable survival rates⁽⁴⁹⁾. The combination of volume reduction surgery or bullectomy in addition to lung cancer surgery has been reported in emphysematous patients who would previously not have met minimal criteria for pulmonary resection due to their concurrent lung disease⁽⁵⁰⁾. Although the numbers of patients reported are small, the expected improvements in post operative pulmonary function have been seen and the outcomes are encouraging. This offers an extension of the standard indications for surgery in a small, well selected, group of patients.

Preoperative therapy of COPD: There are four treatable complications of COPD that must be actively sought and therapy begun at the time of the initial pre-thoracotomy

assessment. These are: atelectasis, bronchospasm, chest infection and pulmonary edema. Atelectasis impairs local lung lymphocyte and macrophage function predisposing to infection⁽⁵¹⁾. Pulmonary edema can be very difficult to diagnose by auscultation in the presence of COPD and may present very abnormal radiological distributions (unilateral, upper lobes, etc.)⁽⁵²⁾. Bronchial hyperreactivity may be a symptom of congestive failure⁽⁵³⁾. All COPD patients should receive maximal bronchodilator therapy as guided by their symptoms. Only 20-25% of COPD patients will respond to corticosteroids. In a patient who is poorly controlled on sympathomimetic and anticholinergic bronchodilators a trial of corticosteroids may be beneficial⁽⁵⁴⁾. It is not clear if corticosteroids are as beneficial in COPD as they are in asthma.

Physiotherapy: Patients with COPD have fewer post-operative pulmonary complications when a perioperative program of intensive chest physiotherapy is initiated pre-operatively⁽⁵⁵⁾. It is uncertain if this benefit applies to other pulmonary resection patients. Among the different modalities available (cough and deep breathing, incentive spirometry, PEEP, CPAP, etc.) there is no clearly proven superior method⁽⁵⁶⁾. The important variable is the quantity of time spent with the patient and devoted to chest physiotherapy. Family members or non-physiotherapy hospital staff can easily be trained to perform effective preoperative chest physiotherapy and this should be arranged at the time of the initial preoperative assessment. Even in the most severe COPD patient, it is possible to improve exercise tolerance with a physiotherapy program⁽⁵⁷⁾. Little improvement is seen before one month. Among COPD patients, those with excessive sputum benefit the most from chest physiotherapy⁽⁵⁸⁾.

A comprehensive program of pulmonary rehabilitation involving physiotherapy, exercise, nutrition and education has been shown to consistently improve functional capacity for patients with severe COPD⁽⁵⁹⁾. These programs are usually of several months duration and are generally not an option in resections for malignancy although for non-malignant resections in severe COPD patients rehabilitation should be considered. The benefits of short duration rehabilitation programs prior to malignancy resection have not been fully assessed.

Smoking: Pulmonary complications are decreased in thoracic surgical patients who are not smoking *versus* those who continue to smoke up until the time of surgery⁽⁶⁰⁾. However, patients having cardiac surgery showed no decrease in the incidence of respiratory complications unless smoking was discontinued for more than eight weeks before surgery⁽⁶¹⁾. Carboxyhemoglobin concentrations decrease if smoking is stopped > 12 hr⁽⁶²⁾. It is extremely important for patients to avoid smoking postoperatively. Smoking leads to a prolonged

period of tissue hypoxemia. Wound tissue oxygen tension correlates with wound healing and resistance to infection⁽⁶³⁾.

Lung cancer: At the time of initial assessment cancer patients should be assessed for the “4-M’s” associated with malignancy: mass effects⁽⁶⁴⁾, metabolic abnormalities, metastases⁽⁶⁵⁾ and medications. The prior use of medications which can exacerbate oxygen induced pulmonary toxicity such as bleomycin should be considered⁽⁶⁶⁻⁶⁸⁾. Recently we have seen several lung cancer patients who received preoperative chemotherapy with cis-platinum and then developed an elevation of serum creatinine when they received non-steroidal anti-inflammatory analgesics (NSAIDS) post-operatively. For this reason we now do not routinely administer NSAIDS to patients who have been treated recently with cis-platinum.

Postoperative analgesia: If the patient is to receive prophylactic anticoagulants and it is elected to use epidural analgesia, appropriate timing of anticoagulant administration and neuraxial catheter placement need to be arranged. ASRA guidelines suggest prophylactic unfractionated heparin administration after catheter placement⁽⁶⁹⁾. Low molecular weight heparin (LMWH) precautions are less clear, an interval of 12-24 hours before and 24 hours after catheter placement are recommended.

Final preoperative assessment: The final preoperative anesthetic assessment for the majority of thoracic surgical patients is carried out immediately prior to admission of the patient to the operating room. At this time it is important to review the data from the initial pre-thoracotomy assessment and the results of tests ordered at that time. In addition, two other specific areas affecting thoracic anesthesia need to be assessed: the potential for difficult lung isolation and the risk of desaturation during one-lung ventilation.

CONCLUSION

Recent advances in anesthesia and surgery have made it so that almost any patient with a resectable lung malignancy is now an operative candidate given a full understanding of the risks and after appropriate investigation. This necessitates a change in the paradigm that we use for preoperative assessment. Understanding and stratifying the perioperative risks allows the anesthesiologist to develop a systematic focused approach to these patients both at the time of the initial contact and immediately prior to induction, which can be used to guide anesthetic management.

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