Preoperative Evaluation for Thoracic Surgery

Theofilos Matheos, MD[a,*], Lakshmi Ram, MD[b], Robert Canelli, MD[c]

KEYWORDS

• Thoracic preoperative evaluation • Cardiac risk stratification • Pulmonary function testing

KEY POINTS

- Readers will understand the physiologic effects of chest surgery and how intraoperative positioning can affect patient selection.
- This article discusses comorbid conditions that impact postoperative outcomes.
- Readers will review an algorithm based on pulmonary function testing that can identify surgical candidates.

INTRODUCTION

Patients presenting for thoracic surgery often have lung or bronchial carcinoma, a mediastinal mass, or esophageal disease. They typically are elderly, with a history of smoking and consequent comorbid conditions. The preoperative evaluation is an assessment of cardiac and pulmonary function with an aim to optimize these patients for a surgical procedure. Optimization may be limited, however, due to the underlying surgical disease. Ultimately, the decision to perform an operation or not depends on the risk of perioperative morbidity and also the predicted quality of life after surgery. Preoperative evaluation and testing aim to identify those patients who will tolerate a surgical intervention.

PHYSIOLOGIC EFFECTS OF CHEST SURGERY

The position on the operating room table effects a patient's underlying cardiopulmonary physiology. Thoracic surgery typically is performed in the lateral decubitus position with the operative side up. Additional physiologic changes occur when the chest cavity is opened. Likewise, optimal surgical exposure often requires collapse of the operative lung, creating further physiologic challenges. All these changes must be considered when making a decision on whether or not a patient will tolerate thoracic surgery.

Lateral Decubitus Position/Closed Chest

Perfusion (Q) of the nonoperative lung is greater than the operative lung because of the effects of gravity on the pulmonary circulation. The converse applies for the distribution of ventilation (V) between the lungs during invasive positive pressure ventilation. The resultant changes in ventilation and perfusion cause V/Q mismatch and shunt. The operative lung is well ventilated and poorly perfused, causing V/Q mismatch. Subsequently, the nonoperative lung is poorly ventilated and well perfused, leading to shunt. Additional challenges and further V/Q mismatch present when the operative lung is collapsed intraoperatively.

Lateral Decubitus Position/Open Chest

When the chest wall is open, compliance of the operative lung increases because it is less restricted by the chest wall. The increased compliance leads to further increases in the amount of ventilation directed to the operative lung and away from the nonoperative lung, which can lead

[a] Division of Critical Care Medicine, Department of Anesthesiology and Perioperative Medicine, University of Massachusetts Medical School, UMass Memorial Medical Center, 55 Lake Avenue North, Worcester, MA 01655, USA; [b] Department of Anesthesiology, Division of Critical Care, UMass Memorial Medical Center, Worcester, MA, USA; [c] Boston University School of Medicine, Boston, MA, USA
* Corresponding author.
E-mail addresses: Theofilos.matheos2@umassmemorial.org; Theofilos.matheos@gmail.com

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to worsening V/Q mismatch. Under normal circumstances, the distribution of perfusion is not greatly affected by the opening of the chest. If there is a large increase in the compliance and subsequent decrease in airway pressure of the operative lung, however, perfusion to the operative lung may increase, improving shunt.

One Lung Ventilation

When ventilation to the operative lung ceases, an obligatory shunt of 20% to 30% is created, because perfusion to the operative lung persists. This leads to a reduction in Pa_{O_2}. The major determinants of blood flow to the operative lung include gravity, underlying lung disease, surgical interference including clamping of the pulmonary artery, and hypoxic pulmonary vasoconstriction (HPV).

In the nonoperative lung, blood flow is determined by gravity, underlying lung disease, ventilation strategies, and HPV. The mode of ventilation is an important consideration; a reduction in tidal volume during 1 lung ventilation can result in atelectasis and increased shunt. Hyperventilation of the nonoperative lung may inhibit HPV, resulting in blood diversion to poorly oxygenated areas. Excessively high airway pressures result in an increase in pulmonary vascular resistance of the ventilated lung, leading to diversion of blood to the nonventilated lung.

Hypoxic Pulmonary Vasoconstriction

HPV maintains arterial oxygenation by diverting blood flow away from poorly ventilated areas of lung. Typically, this occurs in areas of atelectasis or low V/Q ratio. HPV may be inhibited by vasodilatory medications, such as nitroprusside, nitroglycerine, calcium channel blockers, and β_2-agonists. The HPV response is maximal at normal pulmonary artery pressures and decreases at both high and low pulmonary artery pressures. Both high and low Pv_{O_2} conditions inhibit HPV. A low Pv_{O_2} causes HPV to occur in normoxic alveoli, diverting flow away from those alveoli. This is why a reduction in cardiac output during 1 lung ventilation may result in severe hypoxemia. HPV also is inhibited by hypocapnia and enhanced by hypercapnia.

COMORBID CONDITIONS

Age

There is no upper age limit when considering lung resection surgery. Physiologic age is a better predictor of outcomes than chronologic age. Operative mortality rates related to surgical intervention in patients aged 80 years to 90 years are approximately 1.4% and long-term outcomes appear satisfactory; however, patient comorbidities and mediastinal lymph node dissection have been identified as factors that increase the risk of postoperative complications in this population.[1]

Cough

Cough can be suggestive of pulmonary or cardiac disease. Elevated pulmonary artery pressures leading to interstitial and alveolar edema indicate cardiac etiology. Cough with expectoration for months and years commonly occurs in chronic obstructive pulmonary disease (COPD) or bronchitis. Initial assessment must be tailored to recognize triggers, such as medications, environmental factors, smoking, and COPD. Infectious etiology must be considered.

Dyspnea

Dyspnea also is a common symptom of lung and cardiac disease. When dyspnea is combined with cough or sputum, it most often is due to pulmonary disease. Inspiratory dyspnea suggests obstruction of the upper airway whereas expiratory dyspnea is more indicative of lower airway obstruction. Paroxysmal nocturnal dyspnea develops due to interstitial and interalveolar edema.[2] If a cough develops before paroxysmal nocturnal dyspnea, it most likely is related to chronic pulmonary disease; however, if cough develops after symptoms of dyspnea, it likely is due to left ventricular failure.

Tobacco Use

Smoking status is a risk factor for developing several postoperative complications, including respiratory failure, intensive care unit admission, pneumonia, and wound infection, among others. Abstinence from cigarette smoking can improve perioperative outcomes and decrease the risk of cardiovascular and respiratory complications, although the necessary duration of abstinence to achieve this risk reduction is debated. Smoking cessation 12 hours to 48 hours prior to surgery reduces carboxyhemoglobin levels in the blood and shifts the oxyhemoglobin dissociation curve to increase oxygen-carrying capacity. Smoking cessation for approximately 2 weeks improves ciliary function and reduces bronchial secretions. Cessation for 4 weeks to 8 weeks before surgery decreases postoperative pulmonary complications considerably. The benefits of nicotine replacement therapies in abstaining smokers seem to outweigh the risks of continued smoking.[3]

Chronic Obstructive Pulmonary Disease

COPD is the most common comorbid condition in patients presenting for thoracic surgery. It is characterized by a reduction in airflow that is not fully reversible. The severity of COPD is classified based on spirometry findings and correlates with an increasing risk of postoperative pulmonary complications as airflow limitation increases.[4] Patients with severe COPD often have concomitant right ventricular dysfunction and cor pulmonale. These patients pose unique challenges during intraoperative management, particularly during 1 lung ventilation for both surgeons and anesthesiologists.

Lung Cancer

Lung cancer is the leading cause of cancer death for both men and women in the United States.[5] Resectability of the cancer refers to whether or not a tumor can be resected completely based on anatomic location. Operability takes into account the functional status of the patient and characterizes a patient's ability to tolerate the procedure.

Hypertension

Systemic hypertension is a known risk factor for postoperative cardiovascular complications. Preoperative evaluation should aim to rule out secondary causes for hypertension, such as renal artery stenosis and pheochromocytoma. It should evaluate the severity of the disease, which requires multiple blood pressure readings on separate occasions. It also should identify evidence of target organ involvement. Examples of target organ involvement may include coronary disease, cerebrovascular disease, impaired renal function, and signs of left ventricular hypertrophy or heart failure. Patients who have severe hypertension or moderate hypertension with target organ involvement should have their blood pressure controlled before surgery. Surgery should not be deferred, however, on the basis of a single elevated blood pressure reading in the preoperative period, except for grade 3 hypertension. A patient's antihypertensive medications should be continued during the perioperative period, with the exception of angiotensin-converting enzyme inhibitors and angiotensin receptor blockers, which can cause profound and prolonged systemic hypotension during general anesthesia.[6,7]

Diabetes Mellitus

Diabetes mellitus has an impact on multiple organ systems. The disease presents increased risks for perioperative complications including myocardial infarction, stroke, limb ischemia, pressure sores, wound infection, and more. Preoperative evaluation should assess compliance with medications and symptoms of autonomic dysfunction. Blood glucose levels should be within normal limits before surgery. It is typical to discontinue long-acting oral hypoglycemic agents on the day of surgery yet continue insulin regimens the evening before. Type 1 diabetics mellitus should have basal insulin pumps continued to prevent diabetic ketoacidosis.[8]

PREOPERATIVE ASSESSMENT

Airway Assessment

Airway assessment is an essential part of the preoperative evaluation of any surgical patient. The aim is to predict potential difficulties with mask ventilation and endotracheal intubation based on a patient's physical features and to develop a management plan accordingly. This is important especially for placement of double-lumen endotracheal tubes, which technically can be more challenging than single-lumen tubes. Anatomic features with airway implications include Mallampati score, ability to open the mouth, thyromental distance, neck mobility, and neck circumference.

Lung Examination

Respiratory rate, regularity, and depth and effort of breathing should be observed. Restrictive lung disease is characterized by rapid shallow respirations, whereas obstructive disease features slow deep respirations. Asymmetric chest movement can occur due to phrenic nerve pathology, pneumothorax, or pleural effusion. On percussion, hyperresonance is indicative of emphysema or pneumothorax. Dullness suggests pleural effusion, atelectasis, or pneumonia. On auscultation of the lungs, prolonged expiration, expiratory wheezes, and rhonchi are indicative of obstructive lung disease. Absent breath sounds may indicate pleural effusion or atelectasis. Bronchial breath sounds are suggestive of pneumonia.

CARDIAC RISK STRATIFICATION

The revised cardiac risk index (RCRI) is used to predict the chances of a patient developing major cardiac complications after noncardiac surgery. A modified RCRI has been developed and validated to predict this risk in patients specifically after lung resection. The 4 items included in the recalibrated RCRI are cerebrovascular disease, cardiac ischemia, renal disease, and pneumonectomy. The screening tool can be used for cardiac risk stratification prior to thoracic surgery and for selecting those patients who may benefit from preoperative cardiology consultation and further cardiac testing.[9,10]

LABORATORY AND IMAGING STUDIES

Complete Blood Cell Count and Metabolic Studies

Complete blood cell count may reveal polycythemia caused by chronic tobacco use. Liver function tests may be abnormal due to metastatic lung cancer. Elevations in calcium may be due to bone metastasis or a paraneoplastic syndrome associated with tumor. Syndrome of inappropriate antidiuretic hormone may occur in squamous cell lung cancer and may cause hyponatremia. Elevated alkaline phosphatase may be a result of liver or bone metastasis.

Chest Radiography

A baseline chest radiograph often is included in the assessment of patients presenting for thoracic surgery. Important radiographic findings with perioperative implications include tracheal deviation or obstruction, pleural effusion implying diminished vital capacity and functional residual capacity, bullous lung disease at risk of rupture from positive pressure ventilation, cavitation with air fluid levels suggesting infectious process, and alveolar or interstitial infiltrates that contribute to V/Q mismatch and shunt.

Chest Computed Tomography

It is routine for lung cancer patients to have a computed tomography (CT) scan of the chest to determine anatomy of the tumor, nodal involvement, and metastatic spread. Thus, CT scan has a role in evaluation and staging of lung cancer, helping to decide on management strategy and operative approach. The limitation of CT scan is the reduced precision for recognizing mediastinal lymph node metastasis compared with PET-CT scan.[11]

Electrocardiogram

The simplicity of electrocardiogram and its capability to provide details of the electrical functions of the heart makes it important in assessment of patients with cardiothoracic pathology. New-onset arrhythmias, such as atrial fibrillation or left bundle branch block, should be investigated further prior to surgery. Evidence of left ventricular hypertrophy in a patient with systemic hypertension may indicate target organ involvement and necessitate preoperative blood pressure optimization.

Arterial Blood Gas

Arterial blood gas analysis can be performed on patients who are considered for lung resection, although this test is not required preoperatively.[12] Baseline oxygenation and ventilation values can aid in intraoperative ventilator management and postoperative care of the thoracic surgery patient; however, arterial P_{O_2} and P_{CO_2} have not been shown to predict postoperative complication rates accurately.

PULMONARY FUNCTION TESTING

Surgical resection often is the only curative option for non–small cell lung cancer; however, many of these patients have limited pulmonary reserve. Resection of functional lung tissue may result in an unacceptably poor quality of life after recovery from surgery. The underlying purpose of preoperative pulmonary function testing is to predict the functional status and quality of life of these patients after surgery as well as the risk of postoperative morbidity.

Spirometry

Measured forced expiratory volume in 1 second (FEV_1) is an essential assessment tool when evaluating a patient for thoracic surgery. FEV_1 predicts the degree of respiratory impairment in patients with COPD. Patients with a preoperative FEV_1 greater than 80% predicted often can tolerate pneumonectomy and with greater than 70% predicted can tolerate lobectomy. A preoperative FEV_1 less than 60% predicted is a strong indicator of postoperative respiratory complications and 30-day mortality.[13]

Diffusing capacity of carbon monoxide (DLCO) can determine the presence of emphysematous changes in lung tissue. Preoperative DLCO has been shown to significantly predict mortality and postoperative pulmonary complications after lung resection. DLCO values less than 60% are considered inappropriate for major lung resections whereas DLCO greater than 70% is associated with decreased postoperative complication rates.[14]

Predicted Postoperative Lung Function

Predicted postoperative (PPO) lung function studies determine the contribution of the segment of the lung to be resected to a patient's overall lung function, thereby allowing for a prediction of the patient's postoperative pulmonary function status.

These studies were first described in the 1970s and are used routinely today.[15] Quantitative radionuclide perfusion lung scanning is recommended to determine PPO FEV_1 and PPO DLCO for patients requiring pneumonectomy. In patients undergoing lobectomy, however, the anatomic method of segmental counting can be used.[16]

PPO FEV_1 and PPO DLCO should be calculated in all patients whose baseline FEV_1 and DLCO are less than 80% predicted. PPO FEV_1 and PPO DLCO values greater than 60% indicate low risk of postoperative morbidity after major anatomic lung resection. PPO FEV_1 and PPO DLCO values between 30% and 60% warrant a low-technology exercise test, such as stair climbing or 6-minute walk tests.[17] The stair climbing test has been shown an adequate predictor of postoperative pulmonary and cardiac complications and is both safe and economical; however, standardizing the test has been challenging.[18]

Cardiopulmonary Exercise Testing

Cardiopulmonary exercise testing (CPET) is used to evaluate for abnormalities in oxygen transport that may be masked at rest. CPET calculates maximal oxygen consumption ($\dot{V}O_{2max}$), an indicator of cardiorespiratory fitness, which can be used to predict a patient's ability to tolerate certain thoracic surgical procedures. CPET is indicated when either the calculated PPO FEV_1 or PPO DLCO is less than 30% predicted. A $\dot{V}O_{2max}$ greater than 20 mL/kg/min is preferred for patients undergoing pneumonectomy whereas $\dot{V}O_2$max greater than 15 mL/kg/min may be acceptable for lobectomy. $\dot{V}O_{2max}$ less than 10 mL/kg/min indicates a high risk of mortality after major anatomic lung resection and necessitates the calculation of PPO $\dot{V}O_{2max}$.[17]

THE PREOPERATIVE VISIT

The stress of surgery induces a catabolic state that leads to increased cardiac demand, relative tissue hypoxia, increased insulin resistance, impaired coagulation profiles, and altered pulmonary and gastrointestinal function. This response can lead to organ dysfunction, increased morbidity, and delayed surgical recovery.[19] Colorectal surgery was the first surgical subspecialty to conceptualize the idea of enhanced recovery after surgery (ERAS). Some of the benefits of ERAS programs include reductions in hospital length of stay, decreased postoperative complication rates without changes in readmission rates,[20] and improved patient satisfaction.[21] Enhanced recovery after thoracic surgery (ERATS) programs have since been created with similar principles in mind.[22]

The term, ERATS, implies an emphasis on care after surgery; however, the process begins in the preoperative period, well before a patient's surgery. This is the time to engage patients, educate them on the steps of their journey, and manage their expectations. It is the time to task patients with taking an active part in their care, from preparation to recovery. This also is the time to optimize patients, both physically and mentally. Prescribed fitness regimens,[23] nutritional support, and smoking cessation counseling[24] all can improve baseline functional status and contribute to better postoperative outcomes.

Optimized medication regimens, especially for patients with known or newly diagnosed COPD, is a key component to improving postoperative outcomes. Pulmonary status optimization requires close review of prescribed medications, symptoms, and pulmonary function so that medications can be adjusted to be consistent with the current guidelines.[25] Even marginal gains in preoperative FEV_1 can have perioperative benefits. When COPD is a new diagnosis, there is evidence to suggest that short-term benefits can be made on FEV_1 and COPD severity within 1 week of initiating new therapies.[26]

Traditional fasting requirements the night before surgery deplete liver glycogen and are associated with impaired glucose metabolism and increased insulin resistance. Data from the anesthesia literature have demonstrated that intake of clear fluids up until 2 hours before surgery does not increase gastric content volume, reduce gastric fluid pH, or increase complication rates. Thus, in contrast to traditional nil per os strategies, clear liquids, including oral carbohydrate drinks, should be allowed up to 2 hours before induction of anesthesia and light meals up to 6 hours prior.[27] This can avoid dehydration, reduce preoperative thirst and anxiety, and reduce postoperative interleukin-6 levels and insulin resistance, all of which have a positive impact on hospital length of stay and patient satisfaction.[28,29]

SUMMARY

Preoperative assessment is the critical first step for all patients considered for thoracic surgery. It is the time when surgeons decide if a patient is a surgical candidate or not. For those individuals deemed surgical candidates, it is the time for them to become educated on their perioperative course so that realistic expectations can be set. Most critically, it is the time for surgical candidates to improve their chances at survival and reduce their risk of morbidity with a prescribed optimization regimen. Successful outcomes and mitigated surgical risk start with the preoperative evaluation.

DISCLOSURE

The authors have nothing to disclose.

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