Lesson 281: PreAnesthetic Assessment of the Patient for Lung Resection

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TARGET AUDIENCE: Anesthesiologists

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Needs statement

Lung cancer continues to be the leading cause of cancer mortalities in men and women. Improvements in the surgical treatment of this deadly disease have increased the number of patients admitted for lung resection surgery, including both lobectomy and complete pneumonectomy. Cardiothoracic anesthesiologists as well as general anesthesiologists should be familiar with the often complicated management of these cases.
**Learning Objectives**

At the end of this activity, the participant should be able to:

1. Identify findings of concern from preoperative chest x-rays and electrocardiograms.
2. Outline the stepwise process of a preoperative evaluation to determine a patient’s ability to tolerate lung resection.
3. Cite pulmonary testing parameters that indicate a high risk of lung resection.
4. Describe different methods and equipment available for lung isolation.
5. Select the proper type and size of device for lung separation.
6. Review the special considerations for use of a right-sided double-lumen endotracheal tube.
7. Explain how to verify that lung isolation has been achieved.
8. Discuss optimal ventilator settings during lung isolation.
9. List the differential diagnosis for oxygen desaturation during lung isolation.
10. Describe techniques for treating oxygen desaturation during lung isolation.

**Case History**

A 60-year-old obese man with a history of significant tobacco abuse (more than 50 pack-years), chronic obstructive pulmonary disease, pulmonary hypertension, systemic hypertension, type 2 diabetes, and chronic renal insufficiency was evaluated for dyspnea on exertion; a right lower-lobe lung mass was discovered. The patient was admitted for a video-assisted thoracoscopic surgical biopsy of the lung mass, and possible thoracotomy and lobectomy. A preoperative evaluation was significant for the following: The patient was 78 inches tall and weighed 133 kg. His vital signs were as follow: heart rate, 75 beats/min; blood pressure, 120/72 mm Hg; temperature, 98.4°F; respiratory rate, 18 breaths/min; SpO2, 96% on 2 L through a nasal cannula. Physical examination findings included a Mallampati class I airway with an oral opening of 5 cm and a temporomandibular distance greater than 5 cm. Lung auscultation revealed decreased breath sounds especially at the right base, retractions, and a prolonged expiratory phase. Computed tomography (CT) of the chest revealed a spiculated nodule 15-mm wide in the right lower lobe. Pulmonary function test results were forced expiratory volume in 1 sec (FEV1), 2.04 L (42% of predicted); forced expiratory flow 25%-75%, 0.54 L per second (11% of predicted); diffusion capacity of the lung for carbon monoxide (DLCO), 61% of predicted. Echocardiography revealed moderate right atrial and ventricular dilation, preserved left ventricular end diastolic function, and no significant valvular abnormalities. Catheterization of the right side of the heart determined that pulmonary artery pressure was 60/26 mm Hg. A thallium stress test found mild apical ischemia and ejection fraction of 70%. Electrocardiography (ECG) revealed sinus bradycardia (54 beats/min). Laboratory test results were blood urea nitrogen, 52 mg/dL; creatinine, 2.4 mg/dL; urinalysis, 3+ protein; all other results were within normal limits.

In the patient undergoing lung resection, the pertinent issues of a preanesthetic evaluation are to 1) determine whether the patient can tolerate the pulmonary consequences of the planned procedure, 2) develop the best strategy to achieve and manage lung isolation, and 3) plan strategies to minimize and treat perioperative complications associated with lung resection.

In addition to obtaining a medical history and conducting a physical examination, minimal preoperative testing for lung resection should include a complete blood count, basic metabolic profile, coagulation profile, arterial blood gas analysis, ECG, chest x-ray, and pulmonary function testing. For example, ECG findings that include low-voltage QRS complex caused by lung hyperinflation and poor R-wave
progression across the precordial leads indicate chronic obstructive pulmonary disease. An enlarged P-wave in lead II indicates right atrial hypertrophy. An R/S ratio greater than 1 in lead V1 denotes right ventricular hypertrophy and likely pulmonary hypertension.\(^1\)

In the review of preoperative chest x-rays, the presence of certain lesions are of particular importance to the anesthesiologist. Tracheal deviation or obstruction can predict difficulties with intubation or ventilation. A mediastinal mass can cause difficulty with ventilation, superior vena cava syndrome, or compression of the pulmonary artery. Pleural effusions result in decreased vital capacity and functional residual capacity. Cardiac enlargement can indicate heart failure. Bullous cysts can rupture or possibly compress the adjacent lung. Air-fluid levels can signify an abscess — hazardous for the spread of infection. Parenchymal reticulation, consolidation, atelectasis, or edema indicate increased ventilator inequality and transpulmonary shunt.\(^2\)

Numerous articles — sometimes conflicting — have been published over the years on the topic of preoperative pulmonary function and predictability for tolerating lung resection. Figure 1 illustrates the algorithm established by the American College of Chest Physicians (ACCP) in 2007 for assessing perioperative risk.\(^3\) Total pneumonectomy and lobectomy are differentiated with regard to acceptable values. The medical history should reveal whether the patient experiences undue dyspnea on exertion. Examination of radiographic images (either plain film or CT) determines whether interstitial lung disease is present. Spirometric measurements should then be obtained. If the patient has an FEV\(_1\) greater than 80% or greater than 2 L (>1.5 L for lobectomy), and no dyspnea on exertion or interstitial lung disease, then no further testing is required. If the patient meets the FEV\(_1\) criteria, but has dyspnea on exertion or interstitial lung disease, then diffusion capacity of the lung for carbon monoxide (DLCO) should be measured. If DLCO is greater than 80% predicted, no further testing is indicated.

If the FEV\(_1\) or DLCO measurements fail the criteria, the predicted postoperative (PPO) FEV\(_1\) and DLCO should be determined. Multiple methods are available, but all are based on determining the fraction of preoperative pulmonary function that will remain postoperatively, and multiplying the preoperative spirometric measurements by the predicted fraction. The simplest and most sensitive method is anatomic estimation, based on the number of lung segments to be removed.\(^4\) The fraction of function remaining postoperatively is estimated as \((1–0.0526 \times S)\), where S is the number of segments to be removed. The equation was developed by Juhl and Frost.\(^5\) Each lung segment represents one-nineteenth of total pulmonary function and assumes typical anatomy in which each lower lobe contains 5 segments, the right upper lobe contains 3, the right middle lobe 2, and the left upper lobe 4. This method has been shown to consistently underestimate postoperative FEV\(_1\) for lobectomy by an average of 250 mL, and for pneumonectomy by nearly 500 mL. Thus, if an unadjusted measurement by the Juhl and Frost method indicated adequate PPO lung function, no further testing is required. Some have advocated increasing the lung volume thus calculated, but caution is warranted if no further testing is indicated based on an adjusted calculation.

If additional testing is indicated, radiography can be used to assess postoperative lung function. Either ventilation/perfusion scanning or quantitative CT scanning is recommended. The functionality of the lung segments to be removed, as well as that of remaining lung tissue, can be determined with such studies. The PPO FEV\(_1\) using these methods equals preoperative FEV\(_1\) \(\times (1–\gamma/z)\), where \(\gamma\) is the number of functional lung segments to be removed, and \(z\) is the total number of functional lung segments. For instance, if a patient scheduled for a right lower lobectomy had a preoperative FEV\(_1\) of 1.4 L, and quantitative CT scanning revealed that the right lower lobe contained 3 functional segments and 2 nonfunctional segments, PPO FEV\(_1\) would equal 1.4 L \(\times (1–3/17)\), or 1.15 L.
Figure 1. Preoperative physiologic assessment of perioperative risk.3

CXR, chest radiograph; CPET, cardiopulmonary exercise testing; CT, computed tomography; DLCO, carbon monoxide diffusion in the lung; FEV₁, forced expiratory volume in 1 sec; PPO, predicted postoperative; VO₂ max, maximum volume of oxygen consumption

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There is an increased risk for morbidity and mortality of patients in whom the PPO FEV₁ or PPO DLCO is less than 40% predicted. The ACCP recommends exercise testing of these patients. For patients in whom PPO FEV₁ is less than 30% predicted, or in whom the product of %PPO FEV₁ and %PPO DLCO is less than 1,650, the ACCP recommends nonoperative or nonstandard surgical management.

Analysis of arterial blood gas (room-air sample) can sometimes provide useful information. The ACCP regards an oxygen saturation of less than 90% as an independent risk factor for perioperative complications, and an indication for further physiologic testing (eg, exercise testing). A PaCO₂ greater than 45 mm Hg has not been proven to independently increase perioperative complications. However, the ACCP recommends further physiologic evaluation of such patients.

Formal cardiopulmonary exercise testing is used to measure the patient’s maximum oxygen consumption (VO₂max). A VO₂max less than 15 mL/kg per minute in a patient in whom PPO FEV₁ or PPO DLCO is less than 40% predicted, or a VO₂max less than 10 mL/kg per minute in any patient, is a relative contraindication for standard surgical management. VO₂max can be estimated through less formal means. The ability to climb 5 flights of stairs indicates a VO₂max greater than 20 mL/kg per minute. The inability to climb a single flight of stairs denotes a VO₂max less than 10 mL/kg per minute. However, caution is necessary when relying on a patient’s history regarding stair climbing because of the possibility of inaccurate recall or reporting of current ability, and confounding factors including speed of ascent and coexisting musculoskeletal problems.

**Considerations for Lung Isolation**

Once the decision to proceed with lung resection has been made, further evaluation is directed toward determining the best intraoperative management. Single-lung ventilation is used for most lung resection procedures; however, it is not an absolute requirement. Table 1 lists the absolute and relative indications for lung isolation. Video-assisted thoracoscopic surgery is an absolute indication for lung isolation. For thoracotomy, lung isolation is relatively indicated to improve surgical exposure, particularly during upper lobectomies.

The 2 major classes of devices available for achieving lung isolation are endobronchial tubes (EBTs) and endobronchial blockers (EBBs). Several devices can be used as EBBs. EBTs can be further divided into double-lumen endotracheal tubes (DLTs) and single-lumen tubes (SLTs) placed into the mainstem bronchus of the ventilated lung. In pediatric patients in whom bronchi are too small to accommodate a DLT, an EBB or endobronchial SLT must be used. In many adult patients, any

<table>
<thead>
<tr>
<th>Table 1. Indications for Lung Isolation</th>
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<tr>
<td><strong>Absolute</strong></td>
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<tr>
<td>1. Isolation of each lung to prevent contamination of a healthy lung</td>
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<tr>
<td>a. Infection (abscess, infected cyst)</td>
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<td>b. Massive hemorrhage</td>
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<td>2. Control of distribution of ventilation to only 1 lung</td>
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<tr>
<td>a. Bronchopleural fistula</td>
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<td>b. Bronchopleural cutaneous fistula</td>
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<tr>
<td>c. Unilateral cyst or bullae</td>
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<tr>
<td>d. Major bronchial disruption or trauma</td>
</tr>
<tr>
<td>3. Unilateral lung lavage</td>
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<tr>
<td>4. Video-assisted thoracoscopic surgery</td>
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<tr>
<td><strong>Relative</strong></td>
</tr>
<tr>
<td>1. Surgical exposure (high priority)</td>
</tr>
<tr>
<td>a. Thoracic aortic aneurysm</td>
</tr>
<tr>
<td>b. Pneumonectomy</td>
</tr>
<tr>
<td>c. Upper lobectomy</td>
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<tr>
<td>2. Surgical exposure (low priority)</td>
</tr>
<tr>
<td>a. Esophageal surgery</td>
</tr>
<tr>
<td>b. Middle and lower lobectomy</td>
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<td>c. Thoracoscopic under general anesthesia</td>
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The indications for use of an EBT include procedures in which positioning obstructs the mainstem bronchus of the ventilated lung. In this scenario, one should place either an endobronchial SLT or a DLT with the bronchial lumen supplying the ventilated lung. The DLT provides the most rapid selective lung inflation and deflation, oxygen insufflation, or continuous positive airway pressure (CPAP), and access to either bronchus for intraoperative suctioning of secretions. If postoperative intubation is required, it is preferable at the end of the procedure to replace the DLT with an SLT in which the tip is above the carina. An endobronchial SLT can be retracted to a supracarinal position after cuff deflation.

If the patient has been intubated preoperatively, it is often preferable to place an EBB rather than assume the risks inherent with reintubation or tube exchange. Furthermore, if postoperative intubation and ventilation is anticipated, EBBs can be removed at the end of the procedure with relative ease. An EBB is most commonly used for lung isolation in a patient with a tracheostomy. Another advantage of an EBB is the ability to selectively isolate individual lobes or segments to improve oxygenation and ventilation. An EBB is best for the patient in whom the right upper lobe bronchus is abnormally placed or the left main bronchus is severely angulated, and in which a DLT cannot be positioned appropriately. If a preoperative bronchoscopic evaluation has been performed, it should be reviewed to determine whether an EBB is indicated.

EBBs should be placed using direct bronchoscopic visualization. In adults, the devices are typically placed coaxially with both the bronchoscope and EBB positioned inside the endotracheal tube (ETT), tracheostomy tube, or rigid ventilating bronchoscope. A multi-port adapter allows simultaneous ventilation and coaxial EBB placement. An EBB can also be placed parallel to (outside) the airway or ventilating bronchoscope if it would significantly obstruct the inside of the airway. Parallel placement is more commonly used in pediatric patients or adults requiring narrow ETTs or tracheostomy tubes. Ventilation and parallel EBB placement can proceed simultaneously without the use of a special adapter. Figure 2 illustrates the correct placement of an EBB in the left mainstem bronchus.

**Table 2. Indications for an Endobronchial Blocker or a Double-Lumen Tube**

<table>
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<tr>
<th>Endobronchial Blocker</th>
<th>Double-Lumen Tube</th>
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<tr>
<td>Infant or small child</td>
<td>Risk for obstruction of ventilated mainstem bronchus</td>
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<tr>
<td>Tracheostomy</td>
<td>Frequent suctioning required</td>
</tr>
<tr>
<td>Selective isolation of individual lobe or segment</td>
<td>Repeated deflation and reinflation of operative lung</td>
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<tr>
<td>Aberrant anatomy</td>
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<tr>
<td>Intubation prior to procedure</td>
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<tr>
<td>Difficult airway</td>
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Figure 2. Endobronchial blocker in left mainstem bronchus.

There are several devices that can be used as EBBs; all contain a cuff at the distal end that can be inflated to ensure tight endobronchial blockade. Originally, Foley urinary and Fogarty vascular catheters were used. A 7F Fogarty catheter is ideal for adult bronchial blockade; a 3F or 5F catheter is best suited for mainstem bronchial blockade in pediatric patients, and lobar or segmental blockade in adults.

Foley and Fogarty catheters are still used as EBBs; there also are products specifically designed for this purpose. For example, a wire-guided EBB designed for coaxial placement with a flexible fiber-optic bronchoscope is available. The wire-guided EBB contains a coaxial wire with a distal loop that encircles the end of the flexible fiber-optic bronchoscope to facilitate simultaneous visualization and placement of the EBB. The wire is removed after confirmation that EBB placement is satisfactory. The wire-guided EBB also contains a hollow lumen that can be used for oxygen insufflation or endobronchial suctioning. There is also available an SLT equipped with a coaxial EBB that can be advanced into the desired mainstem bronchus. The retractable rigid EBB also serves as a stylet during endotracheal intubation. An SLT with coaxial EBB should be placed with the cuff just below the larynx to allow maximal manipulation of the EBB. Because of the rigidity of the coaxial EBB, it is not well suited for guidance into a segmental bronchus.⁶

Lung isolation in the patient with a difficult airway can be managed in a variety of ways. Unless a DLT is particularly indicated, it often is most convenient to place an SLT by conventional means and subsequently advance it into the mainstem bronchus, or place an EBB. If a DLT is particularly indicated, fiber-optic intubation can be used. However, the bulky construction and extra length of the DLT causes fiber-optic placement to be more difficult. Another option is the placement of an airway exchange device over which the DLT can be inserted while using a laryngoscope to facilitate tube passage.¹

DLTs are designated as left- or right-sided in accordance with the side of the bronchial lumen. Because the right upper lobe bronchus takeoff is barely distal to the primary carina, the right-sided DLT contains an orifice designed to permit ventilation of the right upper lobe. Figure 3 illustrates a bronchoscopic view of the correct placement of a right-sided DLT as seen through the bronchial lumen.

If the orifice in the right-sided DLT is not properly positioned around the opening of the right upper lobe bronchus, that lobe will be hypoventilated or nonventilated—worsening the already suboptimal pulmonary status during single-lung ventilation. Therefore, many anesthesiologists prefer left-sided DLTs for all lung isolation procedures because either lung can be selectively ventilated regardless of the side of the DLT. However, certain left-lung procedures (eg, those involving resection of the left mainstem bronchus) are not amenable to a left-sided DLT. In these cases, an EBB or right mainstem SLT is an option for avoiding use of the right-sided DLT. Anesthesiologists who have maintained their skills with right-sided DLTs can use them successfully, however.¹¹

There are no firm guidelines for selecting an appropriately sized DLT. Factors such as sex, height, and tracheal diameter commonly are used. However, a prospective pilot study by Amar et al¹² found no difference in hypoxemia or clinical outcome among patients for whom DLT size was chosen based on clinical measurements and patients in whom a 35F DLT was used regardless of the sex or size of the
patient. Advocates for the use of smaller DLTs believe the insertions are less difficult and less traumatic. Men, on average, have larger tracheal diameters and glottic openings than women. At the author’s institution, one practitioner favors using a 35F DLT in women and a 37F DLT in men.

**Preparation of the Patient**

Lung isolation procedures present a variety of stresses to the pulmonary and cardiac systems, including reduced ventilatory capacity, physiologic shunting and compromised oxygenation, increased airway pressures, pneumothorax, pulmonary hypertension, and right ventricular failure. Atrial fibrillation after noncardiac thoracic surgery is more likely in men older than 55 years with a resting heart rate greater than 72 beats/min. Appropriate therapy with a perioperative calcium-channel blocker or β-blocker significantly reduces the risk for atrial tachyarrhythmia.

Before lung resection, reasonable measures should be taken to optimize pulmonary function. Patients should be encouraged to quit smoking before the procedure. Smoking cessation at least 4 to 6 weeks before surgery is associated with fewer postoperative complications. Whereas the benefits diminish with shorter periods of abstinence, there is no advantage from continuing to smoke during the preoperative period. Pulmonary infections must be treated aggressively preoperatively. Euvolemia and electrolyte balance should be attained to decrease the viscosity and facilitate removal of bronchial secretions. Chest physiotherapy and mucolytics such as acetylcysteine can be beneficial in clearing the bronchial tree. If pulmonary function testing indicates a response to bronchodilators, these agents should be administered immediately preoperatively.

When a thoracotomy is planned, epidural analgesia—unless contraindicated—should be offered to patients. Effective analgesia without respiratory depression is intuitively advantageous after lung resection. Also, epidural analgesia may be associated with a decrease in perioperative mortality after lung resection.

**Intraoperative Monitoring**

In addition to standard American Society of Anesthesiologists (ASA) monitoring, an arterial cannula is essential for the continuous monitoring of blood pressure and serial analysis of blood gases. For a thoracotomy in the lateral position, the cannula is best placed in the dependent arm to warn in case of axillary artery compression, and allow for readjustment of position if necessary. Indications for the placement and monitoring of central venous access are similar to those for other surgical procedures—namely, a likelihood of massive fluid or blood product resuscitation, severe underlying cardiac disease, or the need to administer agents centrally. Pulmonary artery catheterization is indicated in patients with moderate to severe pulmonary hypertension or heart failure. The indications for transesophageal echocardiography are similar to those for pulmonary artery catheterization; the advisability of using either monitor (or both) largely depends on the anesthesiologist’s experience and proficiency.

**Intraoperative Management**

In a recent study, 0.2 mg/kg of IV dexamethasone administered at the time of induction was found to effectively lower the incidence of postoperative hoarseness and sore throat in patients intubated with a DLT. A left-sided DLT is passed through the larynx with the endobronchial lumen facing anteriorly. It is important to then rotate the tube 90 degrees to the left immediately to avoid passing the endobronchial lumen into the right mainstem. When using a right-sided DLT, the tube is likewise
rotated 90 degrees to the right after tracheal intubation. Particular care must be taken to bronchoscopically confirm that the orifice of the endobronchial lumen is positioned to allow ventilation of the right upper lobe.

If using an EBB, one should allow 15 to 20 minutes after blockade to ensure adequate pulmonary deflation. An EBB in the left mainstem bronchus should be placed distal enough to prevent dislodgment, but proximal enough to ensure blockade of the left upper lobe orifice. In the right mainstem bronchus, the proximal positioning of the right upper lobe orifice necessitates that the EBB be placed more superficially, increasing the likelihood of dislodgment.

Regardless of the method selected for lung isolation, proper placement of the device should be confirmed bronchoscopically and clinically—after the initial placement, as well as after the patient has been placed in a lateral position. There are 2 readily identifiable landmarks worthy of mention. Orientation within the trachea can be established by the anterior position of the tracheal rings (Figure 4). And the right mainstem bronchus can be identified by the trifurcation of the right upper lobe bronchus, which is typically the most proximal branch (Figure 5).

In Figure 6, aberrant anatomy is shown with the right upper lobe bronchus branching proximal to the carina. Note that the tracheal rings help to confirm the anatomic variant. Figure 7 shows a bronchoscopic view through the tracheal lumen of a correctly positioned left-sided DLT, with the bronchial cuff barely visible in the left mainstem bronchus. Figure 8 shows a left-sided DLT with the bronchial cuff positioned too proximally.
Unless the pulmonary artery supplying the collapsed lung has been clamped, a degree of transpulmonary shunt is inevitable. However, 2 factors serve to mitigate this shunt. First, placing the patient in a lateral decubitus position with the ventilated lung in the dependent position utilizes gravity to draw perfusion away from the collapsed lung. Furthermore, hypoxic pulmonary vasoconstriction (HPV) of the collapsed lung further reduces shunt flow. In a typical patient, under these conditions 80% of pulmonary blood flow is directed through the ventilated dependent lung and 20% through the operative collapsed lung.

In vivo studies have shown that volatile anesthetic agents inhibit HPV in a dose-dependent manner. Nitrous oxide is a less significant inhibitor of HPV, but its use necessarily reduces the oxygen concentration that can be delivered. IV anesthetics have the least effect on HPV.

The optimal tidal volume during single-lung ventilation is controversial. Some have recommended higher tidal volumes of 10 to 12 mL/kg, whereas others have advocated lower tidal volumes of 5 to 6 mL/kg.

In the event of oxygen desaturation during single-lung ventilation, one should consider causes common to any desaturation—including circuit disconnection or kink, endotracheal extubation, mucous plug, pulmonary edema, or a decrease in cardiac output—and treat appropriately. Inadvertent clamping or lesion of the pulmonary vasculature or bronchi supplying the ventilated lung should be considered. Complications unique to single-lung ventilation are high on the differential, and a bronchoscopic examination should be undertaken to ascertain malpositioning of the EBB or EBT.

During a search for an underlying cause of desaturation, strategies should be implemented to improve oxygenation. First, the FiO₂ can be maximized to 100%. Second, CPAP should be applied to the operative (nonventilated) lung at a pressure of 10 cm H₂O or less. Third, positive end-expiratory pressure can be applied or increased to the nonoperative (ventilated) lung. If desaturation continues, consider clamping the pulmonary artery supplying the operative lung. It sometimes is necessary to reinflate the operative lung after communication with the surgeon.
At the conclusion of the surgical procedure following re-expansion of the collapsed lung (except in the case of pneumonectomy), the decision must be made whether to extubate the patient or maintain postoperative ventilatory support. Extubation criteria common to any procedure should be applied: adequate reversal of neuromuscular blockade, appropriate spontaneous tidal volumes, sufficient oxygenation and ventilation as assessed by blood gases, \( \text{SpO}_2 \), and \( \text{ETCO}_2 \), ability to follow commands, hemodynamic stability, and absence of pulmonary edema. As with any procedure, the administration of massive amounts of fluid or blood products is a relative contraindication to extubation.

If postoperative ventilation is required in a patient in whom a DLT was used, it should be replaced with a SLT over an airway exchange catheter. Possible indications for leaving a DLT in place postoperatively include a particularly difficult airway or significant airway edema. For such patients, the intensive care unit must be familiar with the management of DLTs.

**Management of the Case Presented**

Before the induction of general anesthesia, an IV was placed for peripheral access, and the patient given nebulized albuterol and 3 mg of midazolam; a left radial peripheral arterial cannula was placed. Preoxygenation was administered, and ASA monitors were applied. General anesthesia was induced intravenously with 100 mg of lidocaine, 150 mcg of fentanyl, and 150 mg of propofol. For muscle relaxation, 20 mg of cisatracurium was administered intravenously.

Direct laryngoscopy with a Macintosh 3 blade provided a view classified as Cormack-Lehane grade 1; a 41F left DLT was placed without incident. In combination with 100% oxygen, desflurane was administered with an end-tidal concentration of 4.5% to 7.2% for intraoperative anesthesia. (Based on preoperative pulmonary function testing, the patient was considered to have a particularly high risk for desaturation, so a maximal FIO2 was deemed optimal.) DLT placement was confirmed bronchoscopically.

A central venous catheter was inserted in the right internal jugular vein, and a pulmonary artery catheter placed through its introducer port. An epidural catheter was placed for postoperative pain control. The patient was repositioned in the left lateral decubitus position and proper DLT placement was reconfirmed.

The right lung was deflated. The patient tolerated single-lung ventilation moderately well; however, he had an episode of desaturation (\( \text{SpO}_2, 86\% \)). Because the surgeon had requested suctioning of the operative lung to ensure full collapse, CPAP to that lung was not considered an option. Therefore, a modest increase in positive end-expiratory pressure to the nonoperative lung from 5 to 7 cm H\(_2\)O was applied. Subsequently, an \( \text{SpO}_2 \) greater than 92% was maintained.

A biopsy of the mass in the right lower lobe was performed with video-assisted thoracoscopy and determined to be of concern for malignancy. The procedure was converted to an open thoracotomy and the right lower lobe was resected. The remaining right lung was re-expanded and oxygen saturation improved to 100%. Neuromuscular blockade was reversed with 6 mg of neostigmine and 0.8 mg of glycopyrrrolate.

The patient was returned to the supine position, and regained spontaneous ventilation with tidal volumes greater than 800 mL. He was able to follow commands appropriately and lift his head for longer than 5 seconds, and was extubated successfully. Oxygen was administered to the patient at 10 L
per minute via the modified Bain circuit during his transport to the intensive care unit for postoperative care.

Dr. Elizabeth A.M. Frost, who is the editor of this continuing medical education series, is clinical professor of anesthesiology at The Mount Sinai School of Medicine in New York City. She is the author of Clinical Anesthesia in Neurosurgery (Butterworth-Heinemann, Boston) and numerous articles. Dr. Frost is past president of the Anesthesia History Association and former editor of the journal of the New York State Society of Anesthesiologists, Sphere. She is also editor of the book series based on this CME program, Preanesthetic Assessment, Volumes 1 through 3 (Birkhäuser, Boston) and 4 through 6 (McMahon Publishing, New York City).

REFERENCES


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Post-test

1. Which of the following findings is most likely to indicate pulmonary hypertension?
   a. Lung hyperexpansion on chest radiography
   b. Tracheal obstruction on chest radiography
   c. R/S ratio greater than 1 in lead V1 on electrocardiography
   d. Low-voltage QRS complex on electrocardiography

2. A 46-year-old man, scheduled for a right middle lobectomy, has a forced expiratory volume in 1 sec (FEV1) of 2.5 L on spirometry. His predicted value is 3.6 L. According to the American College of Chest Physicians (ACCP) guidelines, what is the next appropriate step in evaluating this patient?
   a. Proceed to surgery without further workup.
   b. Measure the diffusion capacity of the lung for carbon monoxide (DLCO).
   c. Obtain sample of room-air blood gases.
   d. Perform cardiopulmonary exercise testing.

3. According to current ACCP guidelines and the original anatomic estimation method of Juhl and Frost, which of the following sets of values indicates a patient in whom a left lower lobectomy is high risk?
   a. FEV1 is 45% of predicted; DLCO is 68%; maximum oxygen consumption (VO2max) is 18 mL/kg per minute.
   b. FEV1 is 45% of predicted; DLCO is 75% of predicted; VO2max is 14 mL/kg per minute.
   c. FEV1 is 55% of predicted; DLCO is 60% of predicted.
   d. FEV1 is 65% of predicted; DLCO is 50% of predicted; VO2max is 17 mL/kg per minute.

4. A 67-year-old man with a VO2max of 11 mL/kg per minute is scheduled to undergo a resection of the anterior segment of the right upper lobe. You are concerned that the patient will not tolerate single-lung ventilation. Which airway device would be the best for deflating only the operative pulmonary segment?
   a. Wire-guided endobronchial blocker
   b. Laryngeal mask airway
   c. Single-lumen tube with coaxial endobronchial blocker
   d. Robertshaw left-sided double-lumen tube (DLT)
5. A 53-year-old woman is scheduled to undergo a resection of the right middle lobe. The surgeons request lung isolation. Without any additional information, which of the following would be the best airway device?

a. 39F right-sided DLT  
b. 35F right-sided DLT  
c. 39F left-sided DLT  
d. 35F left-sided DLT

6. Which of the following is the most accurate statement regarding right-sided DLTs?

a. Avoid using them if at all possible, regardless of which is the operative lung.  
b. There is no significant difference in insertion technique, compared with a left-sided DLT.  
c. Care must be taken to avoid occluding the orifice of the right upper lobe bronchus.  
d. Anesthesiologists report that frequent use of them is associated with higher morbidity and mortality compared with avoiding their use.

7. During bronchoscopic verification of DLT placement, a bronchus is visualized in which the carina further branches into 3 divisions instead of 2; which lobe does the bronchus most likely supply?

a. Right upper lobe  
b. Right middle lobe  
c. Right lower lobe  
d. Left upper lobe

8. Which statement best describes optimal ventilator settings during single-lung ventilation?

a. A tidal volume of 6 mL/kg has proved to be the safest.  
b. A tidal volume of 12 mL/kg has proved to be the safest.  
d. The parameters for acceptable airway pressures are the same as for double-lung ventilation.

9. Which scenario is most likely to contribute to poor oxygenation during single-lung ventilation?

a. Use of a total IV anesthetic technique  
b. Transpulmonary shunting in the nonventilated lung  
c. Positioning of the ventilated lung in the dependent position  
d. Hypoxic pulmonary vasoconstriction in the nonventilated lung
10. A 58-year-old woman, weighing close to her ideal body weight (60 kg), is undergoing resection of a tumor in the left lower lobe. Her left lung is isolated; her right lung is being selectively ventilated with a tidal volume of 480 mL at a frequency of 12 breaths/min with an FiO₂ of 80%. Her SpO₂ measured 99% during one-lung ventilation, but decreased to 88% within the previous 5 minutes. Which of the following maneuvers is least likely to increase her oxygen saturation?

a. Retracting an endobronchial tube that has migrated deep into the mainstem bronchus  
b. Increasing FiO₂ to 98%  
c. Applying continuous positive airway pressure to the left lung  
d. Increasing her ventilatory rate to 16 breaths/min