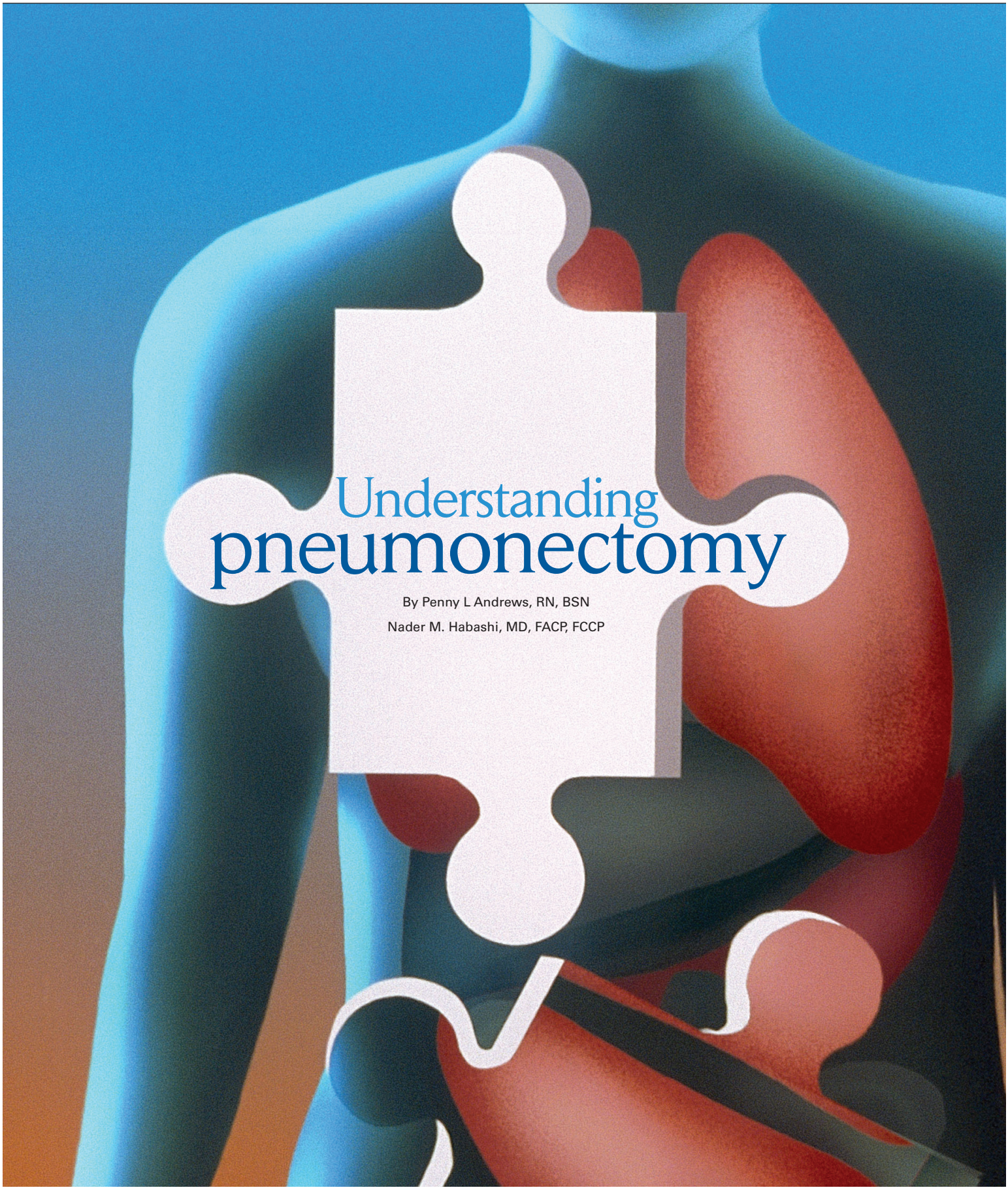

Understanding pneumonectomy

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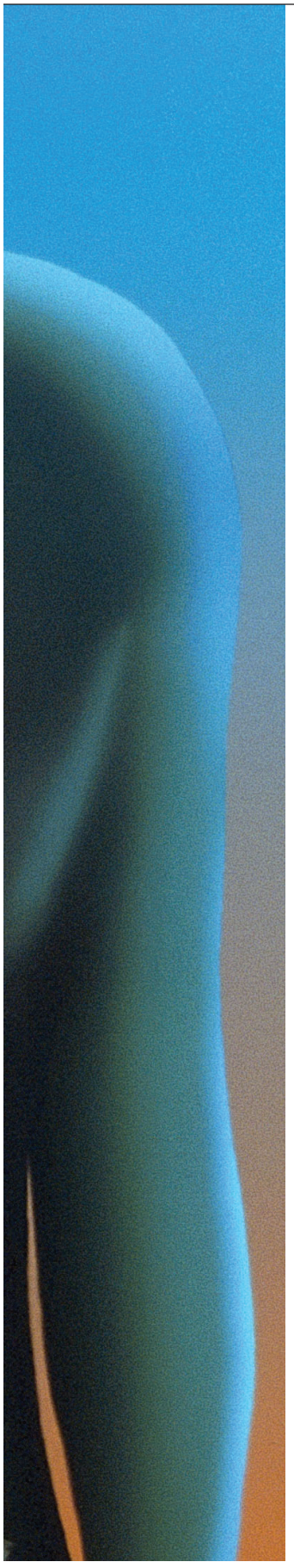

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Various diseases or traumatic injury may require the surgical removal of a single lobe of the lung (lobectomy) or the entire lung (pneumonectomy) (See *Types of thoracotomy*). The most common reason for a pneumonectomy is lung cancer. Other reasons may include traumatic chest injury with irreparable damage to the bronchus/major blood vessels or severe forms of chronic obstructive pulmonary disease (COPD) where lung tissue is severely damaged with impaired gas exchange. Maintaining lung function during and after a pneumonectomy is essential for adequate gas exchange. This article will discuss the intraoperative concerns and management of patients undergoing a pneumonectomy.

Background

In 1931, the first successful pneumonectomy was completed in two stages by Rudolph Nissen on a young patient with a thoracic crush injury.[1] In 1933, the first single-stage pneumonectomy was successfully completed on a patient with lung cancer by Graham and Singer.

Currently, there are two types of pneumonectomy: simple pneumonectomy, or the removal of the affected lung, and extrapleural pneumonectomy where not only the affected lung is removed, but also part of the diaphragm, parietal pleura, and pericardium linings may be removed and replaced by a synthetic patch. An extrapleural pneumonectomy is an extensive surgery primarily for the treatment of pleural malignant mesothelioma. Malignant mesothelioma is a rare form of cancer affecting mesothelial cells of the body's serous membranes. The most common form of malignant mesothelioma affects the pleura (lining of the lung cavity) but other forms can also affect the lining of the abdomen (peritoneum) or heart (pericardium).

Physiology

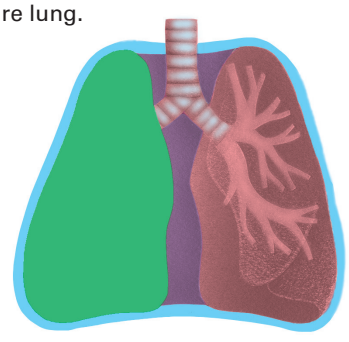
Although it is possible to live with only one lung, the remaining lung must assume the full workload for gas exchange and perfusion where it was previously

Types of thoracotomy

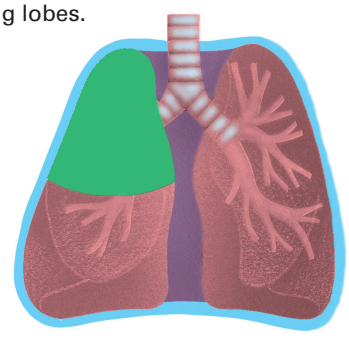
Thoracotomy, a surgical incision into the thoracic cavity, is performed to locate and examine abnormalities (such as tumors, bleeding sites, or thoracic injuries), to take a biopsy, or to surgically remove diseased lung tissue.

The types of procedures include pneumonectomy, lobectomy, segmental resection, and wedge resection.

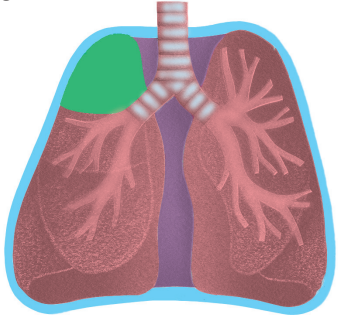
Pneumonectomy
Pneumonectomy is the surgical removal of the entire lung.



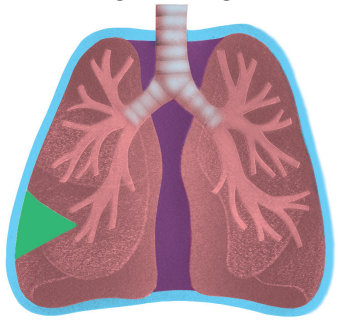
Lobectomy
Lobectomy is the surgical removal of one of the five lung lobes.



Segmental resection
Segmental resection is removal of one or more lung segments.



Wedge resection
Wedge resection is the removal of a small lung portion without regard to segments.



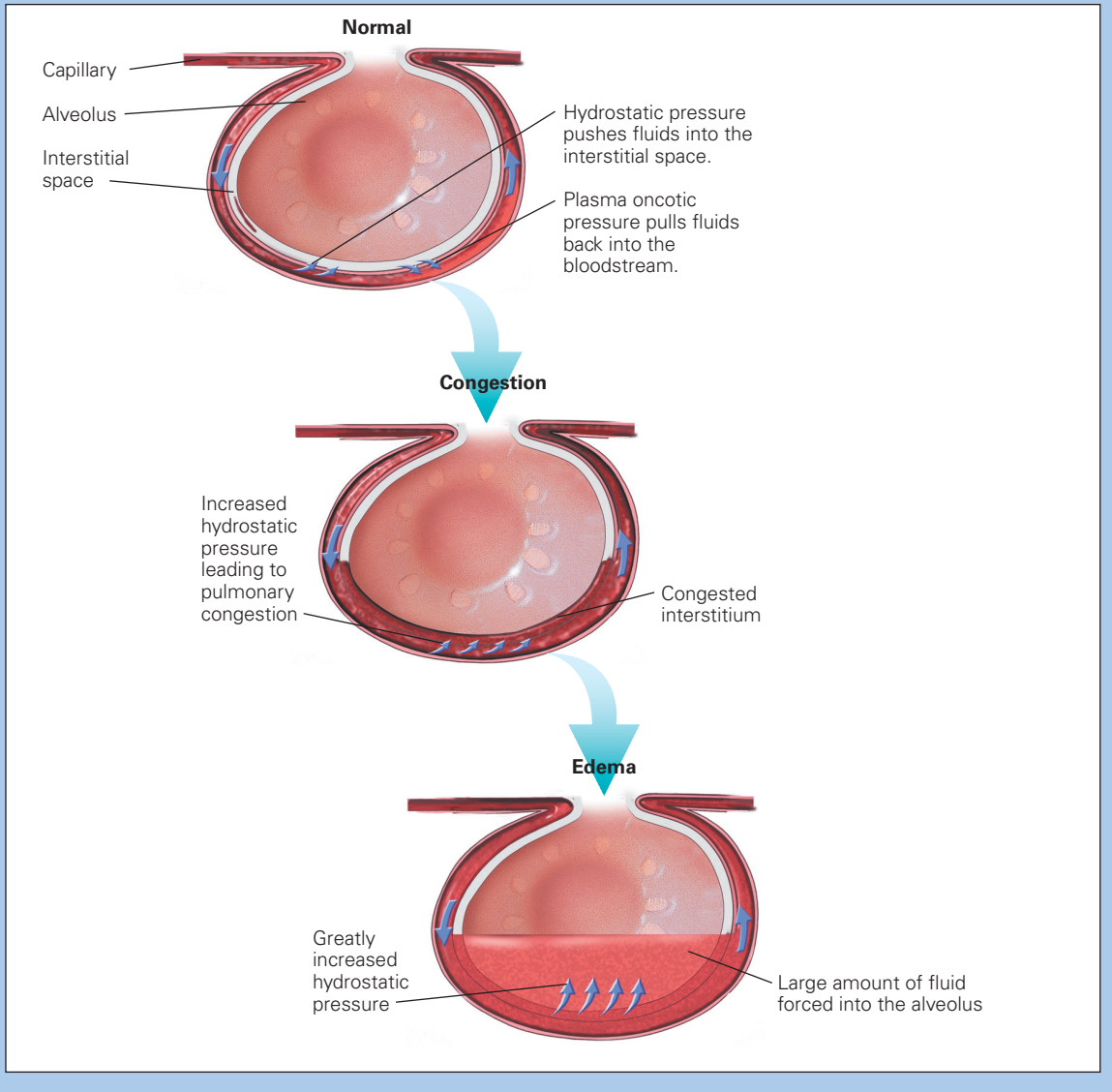
Source: *Surgical Care Made Incredibly Visual.* Philadelphia, PA: Lippincott Williams & Wilkins; 2007:112-113.

shared between two lungs. After a pneumonectomy, survivors generally become easily fatigued and have physical limitations because the cardiopulmonary reserve is significantly reduced and oxygen delivery may be limited as the heart can become easily strained. Mild to moderate exercise, or a hyperdynamic state (for example, sepsis) coupled with the reduced capillary surface area postpneumonectomy, diminishes the capacity of the pulmonary capillaries to accommodate higher flow without raising pulmonary arterial pressure.[2]

Increased blood flow through the reduced pulmonary capillary bed and resultant increased pulmonary pressure may lead to pulmonary edema. Pulmonary edema is a serious concern in the postoperative phase of a pneumonectomy patient and may impact mortality. Although pulmonary edema may worsen lung function, it also serves to reduce the pressure in the pulmonary capillary bed by the transudation of fluid into the interstitium of the lung, effectively reducing the circulatory volume and offloading pressure generated on the right heart.[2] If the pressure and load on the right heart is not relieved, the right heart ultimately fails and is almost uniformly fatal (See *Pulmonary edema*). The mechanical ventilator, mode, and settings chosen become important because ensuing lung edema will

Pulmonary edema

Pulmonary edema is marked by accumulated fluid in the extravascular spaces of the lung. It may occur as a chronic condition or may develop quickly and rapidly become fatal.



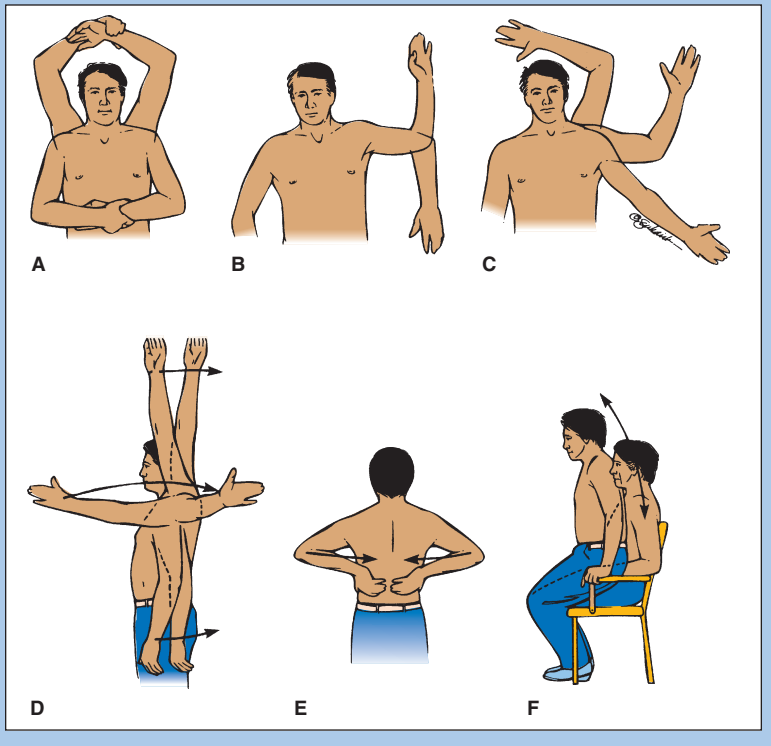
Source: *Pathophysiology Made Incredibly Visual.* Philadelphia, PA: Lippincott Williams & Wilkins; 2008:65.

ultimately decrease lung compliance and cause an increase in lung collapse (atelectasis).[3]

Atelectasis or loss of lung volume has been shown to increase pulmonary vascular resistance and worsen right heart load and systemic perfusion, ultimately contributing to right heart failure.[3] Pulmonary vascular resistance is elevated at extremes of lung volume (low and high) and optimized at normal functional residual capacity. Although counterintuitive, an increase in airway pressure resulting in lung recruitment (decreased atelectasis) can reduce right heart load and dilatation, preventing right heart failure.[3] The likelihood of developing pulmonary edema and right heart failure is potentiated by preexisting pulmonary hypertension or chronic lung disease and is a source of morbidity postpneumonectomy.

Performing arm and shoulder exercises

Arm and shoulder exercises are performed after thoracic surgery to restore movement, prevent painful stiffening of the shoulder, and improve muscle power.



(A) Hold hand of the affected side with the other hand, palms facing in. Raise the arms forward, upward, and then overhead, while taking a deep breath. Exhale while lowering the arms. Repeat five times. (B) Raise arm sideward, upward, and downward in a waving motion. (C) Place arm at side. Raise arm sideward, upward, and over the head. Repeat five times. These exercises can also be performed while lying in bed. (D) Extend the arm up and back, out to the side and back, down at the side and back. (E) Place hands in small of back. Push elbows as far back as possible. (F) Sit erect in an armchair; place the hands on the arms of the chair directly opposite the sides of the body. Press down on hands, consciously pulling the abdomen in and stretching up from the waist. Inhale while raising the body until the elbows are extended completely. Hold this position a moment, and begin exhaling while lowering the body slowly to the original position.

Source: Smeltzer SC, Bare BG, Hinkle JL, Cheever KH. *Brunner & Suddarth's Textbook of Medical-Surgical Nursing.* 11th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008: 769.

This phenomenon can also occur in trauma and younger patients without comorbidities, when the postoperative phase is complicated by hyperdynamic states from multiple trauma, fever, and septic shock.

Preoperative preparation

Teaching patients and their families preoperatively about the postoperative effects of pneumonectomy is important, so that they know what to expect from surgery. Teaching should include importance of pulmonary management, ambulation, arm/shoulder exercises of operative side, and pain control (See *Performing arm and shoulder exercises*). Patients may be intubated for several days, require opioid analgesics to control pain, have chest tubes in place, and require physical assistance until they gain strength. Early pulmonary hygiene and physical therapy are imperative for extubation and mobilization. Patient-controlled analgesia infusion pump may be used to control pain via I.V. or thoracic epidural delivery. Although it is important to control pain and anxiety, clinicians must remember that oversedation can lead to atelectasis, worsening lung function, and secretion retention, if an effective cough is diminished or eliminated. Therefore, utilization of a pain-scoring system may be helpful to reduce the potential for oversedation.[4]

Clinicians must also be mindful of how to prepare patients for a pneumonectomy. Traumatic injuries or emergent pneumonectomies may not provide an adequate time frame for ideal lung recruitment or volume management. If the patient is not intubated prior to surgery, incentive spirometry, coughing, and deep breathing exercises are encouraged. If intubated, modes of mechanical ventilation that promote alveolar recruitment should be considered; lung recruitment, preoperatively, is crucial to reduce the risk of atelectasis.

As with any major surgery, it is ideal to have the patient euvolemic prior to the surgery. This may be especially difficult in the traumatically injured patient if they are undergoing fluid resuscitation while preparing for surgery.

Intraoperative concerns

The patient undergoing a pneumonectomy requires a double lumen endotracheal tube (DL-ETT) also known as an endobronchial double-lumen tube, during the operative procedure. The DL-ETT has two separate lumens (one bronchial and one tracheal lumen) within a single tube. Depending on the lung to be removed, a right or left DL-ETT will be placed. If the left lung is to be removed, a right DL-ETT will be placed in the right bronchus and vice-versa. The DL-ETT allows the clinician to selectively oxygenate and ventilate the unaffected lung during the operative procedure (See *endobronchial double-lumen tube*).

After the affected lung is removed and the operation is complete, the DL-ETT should be changed to a single lumen ETT due to the increased size and airway resistance and difficulty passing a suction catheter to remove secretions. Airway resistance through a DL-ETT is significantly increased as the intraluminal diameter of each lumen is smaller, limiting effective pulmonary hygiene.[5] For example, a 39-French DL-ETT (Sheridan catheter) used for an averaged sized adult has a bronchial lumen of 6.9 mm and tracheal lumen of 7.1 mm.[6]

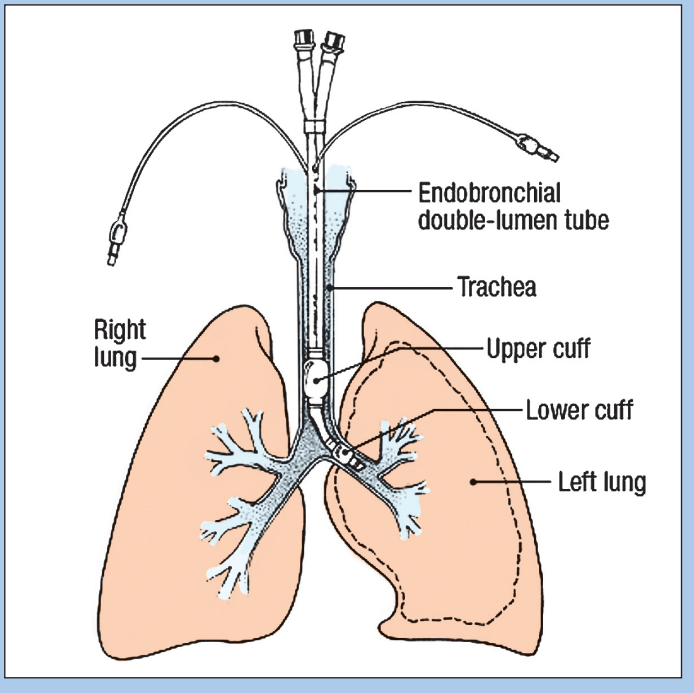
A pneumonectomy requires a thoracotomy to visualize and remove the lung intraoperatively. The patient is placed in the lateral position with the operative side facing upward. After the patient is appropriately prepped and draped, a posterolateral thoracotomy incision is started from the anterior chest around the curve of the ribs posteriorly to a point below the shoulder blade.

One or two ribs may need to be removed to access and remove the affected lung. The lung to be removed is deflated with cessation of ventilation and absorption of the gases. The pulmonary artery and vein are cleanly dissected and ligated, and the main bronchus of the operative lung is clamped prior to removal to ensure that fluid does not enter the airways. The lung and the hilar structures to be removed are dissected, divided, and ligated. The end of the bronchus (stump) is secured with staples or sutures to prevent air from leaking through the stump. Additionally, the bronchial stump may be reinforced with biological material such as a pericardial or intercostal flap to prevent leakage. The adjacent lymph nodes are removed, and the phrenic nerve is severed on the affected side.

After the affected lung is removed, the mechanical ventilator's settings and parameters for the remaining lung require close monitoring. Ventilator settings will require adjustment to maintain adequate recruitment of the remaining lung without creating overdistention. Chest tubes are placed between the pleural

Endobronchial double-lumen tube

An endobronchial double-lumen tube is used to intubate the patient and establish independent access to each lung.



Source: MediClip Clinical Cardiopulmonary. CD-ROM. Baltimore: Lippincott Williams & Wilkins. CCP02063.

space to facilitate drainage of air, serous fluid, and blood from the surgical site, and the thoracotomy is closed with staples.

Postoperative care

Fluids that leak from the parietal pleura and mediastinum fill the space where the affected lung was removed. The empty space (air) on the pneumonectomy side is gradually reabsorbed and replaced by the fluid. Over time, the hemithorax (chest wall) on the pneumonectomy side progressively contracts by narrowing the intercostal spaces and crowding the ribs. The affected hemi-diaphragm elevates to decrease the thoracic volume and the amount of fluid needed to obliterate the space vacated by the recently removed lung. Tracheal and mediastinal shifting towards the pneumonectomy side occurs because of the hemithoracic volume loss and hyperinflation of the remaining lung after a pneumonectomy. However, atelectasis of the remaining lung on the nonsurgical side or a bronchopleural (BP) fistula, hemorrhage, or empyema on the surgical side will cause a mediastinal shift away from the surgical side. Tracheal or mediastinal shift back to midline or away from the surgical side should be considered serious, warranting further investigation. Serial chest X-rays are important to closely monitor mediastinal shifting, in addition to atelectasis of the remaining lung.

Mechanical ventilation

Respiratory failure is a leading cause of death postpneumonectomy, and derecruitment or hyperinflation of the remaining lung may prove deleterious. The clinician is challenged to provide enough airway pressure so that the remaining lung stays adequately recruited but is not overdistended, while the surgical stump is protected from injury. Although using a lower airway pressure is important to minimize pressure on the bronchial stump, a nonjudicious reduction in airway pressure may result in atelectasis that increases injury to the airways and risk of BP fistula.[7] If the remaining lung becomes atelectatic, the patient's deteriorating condition may force clinicians to increase airway pressure for gas exchange and recruitment, increasing the risk of BP fistula or major breakdown of the bronchial stump.[7]

Balancing the appropriate airway pressure postpneumonectomy may be difficult. In cases of severe atelectasis of the remaining lung, a DL-ETT may be re-inserted and the patient placed on independent lung ventilation. This technique allows the clinician to regulate the ventilator settings independently for each "lung." In this case, the atelectatic lung may be recruited, while the bronchial stump is not exposed to airway pressure preventing further damage. Modes that raise mean airway pressure for recruitment such as high frequency oscillatory ventilation (HFOV) or airway pressure release ventilation (APRV) may be considered.[8]

Ventilator modes should also be considered, allowing unassisted, unrestricted spontaneous breathing early in the postoperative phase. Unassisted spontaneous breaths improve lung recruitment without increasing airway pressure, while simultaneously decreasing right atrial pressure and increasing venous return, cardiac output, and renal/gut perfusion.

Fluid loss may be compensated with volume resuscitation using crystalloids, colloids, and blood products. Fluid overload may be treated with fluid restriction or diuretics. Systemic hypertension postpneumonectomy can adversely affect peripheral oxygen delivery, produce heart strain, and precipitate pulmonary edema requiring prompt treatment. Afterload reducing agents, such as nitroprusside or hydralazine, may be used to treat systemic hypertension. However, negative inotropic agents, such as diltiazem, should be avoided in patients who exhibit signs of systemic hypoperfusion (for example, lactic acidosis or worsening organ function). Patients who exhibit systemic hypoperfusion or right heart dysfunction may benefit from dobutamine, as it can improve the energetics of the right ventricle.[9] Additionally, dobutamine and other beta-agonists have been shown to improve lung edema clearance, ultimately improving lung compliance.[10] In clinical trials, levosimendan has demonstrated similar [inotropic] effects as dobutamine, with the addition of producing direct pulmonary vasodilatation.[11] These agents may help maintain systemic oxygen demands improving cardiopulmonary function.[11]

Recovery

Patients are transferred to an ICU postoperatively where vital signs, hemodynamic and cardiopulmonary status are closely monitored. Additionally, patients should be monitored for cardiac dysrhythmias. The surgeon should be notified immediately of any changes that may indicate bleeding, BP fistula, or infection. Signs of a BP fistula postpneumonectomy include

persistent chest tube leak, inhaled tidal volume less than exhaled tidal volume, or pneumonthorax.

Increased heart rate and a drop in blood pressure may be signs of bleeding, and increased temperature and white blood cell count may indicate an infectious process. If the patient has a chest tube postpneumonectomy, the chest tube drainage and the thoracotomy site should be monitored for excessive bleeding. Typically, the chest tube is placed to straight drainage rather than wall suction. Patients may remain on the ventilator for several days to weeks depending on the overall status of the patient. Arterial blood gases and chest X-rays are used to monitor oxygenation, ventilation, and lung recruitment. If necessary, a bronchoscopy may be performed to remove secretions or to visualize the bronchial stump.

Physical therapy should be implemented as soon as possible to return the patient back to independent activities of daily living. Mechanical ventilation is weaned as tolerated to extubation, and chest tubes are closely monitored for air leaks and drainage and removed when clinically indicated. **OR**

REFERENCES

1. Nissen R. Classics in thoracic surgery: total pneumonectomy. *Ann Thorac Surg.* 1980;29(4):390-394.

2. Kopec S, Irwin R, Umali-Torres C, et al. The postpneumonectomy state. *Chest.* 1998;114:1158-1184.

3. Duggan M, McCaul C, McNamara P, et al. Atelectasis causes vascular leak and lethal right ventricular failure in uninjured rat lungs. *Am J Respir Crit Care Med.* 2003;167:1633-1640.

4. De Jong M, Burns S, Campbell M, et al. Development of the American Association of Critical-care Nurses' sedation assessment scale for critically ill patients. *Am J Crit Care.* 2005;14(6):531-544.

5. Hannallah M, Miller S, Kurzer S, Tefft M. The effective diameter and airflow resistance of the individual lumens of left polyvinyl chloride double-lumen endobronchial tubes. *Anesth Analg.* 1996;82:867-869.

6. Anantham1 D, Jagadesan R, Tiew P. Clinical review: independent lung ventilation in critical care. *Crit Care.* 2005;9:594-600.

7. Tsuchida S, Engelberts D, Peltekova V, et al. Atelectasis causes alveolar injury in nonatelectatic lung regions. *Am J Respir Crit Care Med.* 2006; 174:279-289.

8. Brambrink A, Brachlow J, Weiler N, et al. Successful treatment of a patient with ARDS after pneumonectomy using high-frequency oscillatory ventilation. *Intensive Care Med.* 1999;25:1173-1176.

9. Yi K, Downey F, Bian X, et al. Dobutamine enhances both contractile function and energy reserves in hypoperfused canine right ventricle. *Am J Physiol Heart Circ Physiol.* 2000;279:H2975-H2985.

10. Tibayan F, Chesnutt A, Folkesson H, et al. Dobutamine increases alveolar liquid clearance in ventilated rats by beta-2 receptor stimulation. *Am J Respir Crit Care Med.* 1997;156:438-444.

11. Morelli A, Teboul JL, Maggiore SM, et al. Effects of levosimendan on right ventricular afterload in patients with acute respiratory distress syndrome: a pilot study. *Crit Care Med.* 2006;34(9):2487-2493.

The authors have disclosed that they have no significant relationship with or financial interest in any commercial companies that pertain to this educational activity.

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