

Lung Volume



Reduction Surgery

A Treatment Option for Severe Emphysema

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Chronic obstructive pulmonary disease (COPD) is a significant health problem in the United States. It's the fourth leading cause of death and affects more than 12 million people. Of the top 10 causes of death, it's the only condition that's increasing in prevalence and mortality.¹ Emphysema, one of the two types of COPD, is a progressive disease that worsens over time, and is a major cause of disability in the United States (see *Risk factors for COPD*). Predominantly caused by smoking, emphysema is a chronic lung condition in which alveoli become damaged and trap air, leading to hyperinflation of the lung² (see *Chest X-ray showing pulmonary emphysema*). Normal lung tissue consists of approximately 300 million alveoli. In emphysema, the alveoli become destroyed and lose their shape and elasticity forming fewer, larger air sacs. The reduction in the surface area for gas exchange creates problems with oxygenation (see *Lung changes in emphysema*). The diaphragm and chest will become abnormally positioned as they're pushed out by hyperinflated lungs. The patient develops the characteristic barrel-shaped chest as a result of the air trapping in the lungs and the increased anteroposterior diameter of the chest wall. Subsequently, patients experience shortness of breath, coughing, fatigue, and alterations in their daily

activities because lung function is compromised. Early recognition of the disease is essential, but unfortunately, the disease may not be diagnosed until the later stages. Because the initial symptoms of dyspnea may occur only with strenuous exercise, patients may limit activities to help prevent the symptoms and may not seek medical attention until the symptoms affect their daily activities. As the disease progresses, it's common for patients to become symptomatic with minimal activity or when in a resting state.

Management of COPD includes smoking cessation, bronchodilators, glucocorticosteroids, anticholinergics, pulmonary rehabilitation, oxygen therapy, lung volume reduction surgery (LVRS), and lung transplantation. Treatment options that may increase the likelihood of survival in patients with COPD include smoking cessation, lung transplantation, and LVRS. For patients with predominantly upper lobe emphysema and a low baseline exercise capacity, LVRS provides a survival advantage over medical therapy alone. This palliative treatment involves resection of the severely emphysematous lung tissue, allowing the remaining lung tissue to recoil more normally. The chest wall and diaphragm are allowed to resume a more normal position, thus improving

the ability to breathe. Clinicians seeking to improve the dyspnea, quality of life, exercise tolerance, and survival may consider LVRS a therapeutic option in patients with severe upper lobe emphysema. A

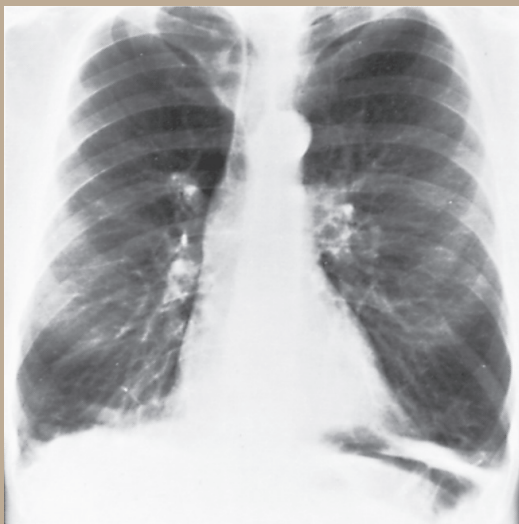
Risk factors for COPD²

Risk factors for COPD include the following:

- Tobacco smoke (cigarette, pipe, or cigar)
- Genetic risk factor (alpha-1 antitrypsin deficiency is found in some patients with emphysema; initial signs and symptoms in patients with alpha-1 antitrypsin deficiency usually develop between ages 20 and 50)
- Inhalation exposure to occupational dust and chemicals
- Urban air pollution
- Indoor air pollution (mainly from exposure to biomass fuels used for heating and cooking; occurs mainly in women in developing countries)
- Age (symptoms develop gradually in patients without genetic risk)
- Factors that affect lung growth and development (low birth weight)
- Respiratory infections

Chest X-ray showing pulmonary emphysema

Frontal and lateral views of the chest demonstrate severe overinflation of the lungs.



Source: Eisenberg RL. *An Atlas of Differential Diagnosis*. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003.

reduction in lung hyperinflation and improvements in exercise capability, airflow, and diaphragmatic function can be seen as approximately 20% to 35% of each lung is resected. While not a common surgery, this procedure requires an expert team of thoracic surgeons, pulmonologists, anesthesiologists, and nurses who specialize in treatment of complex lung diseases and are experienced with the procedure.

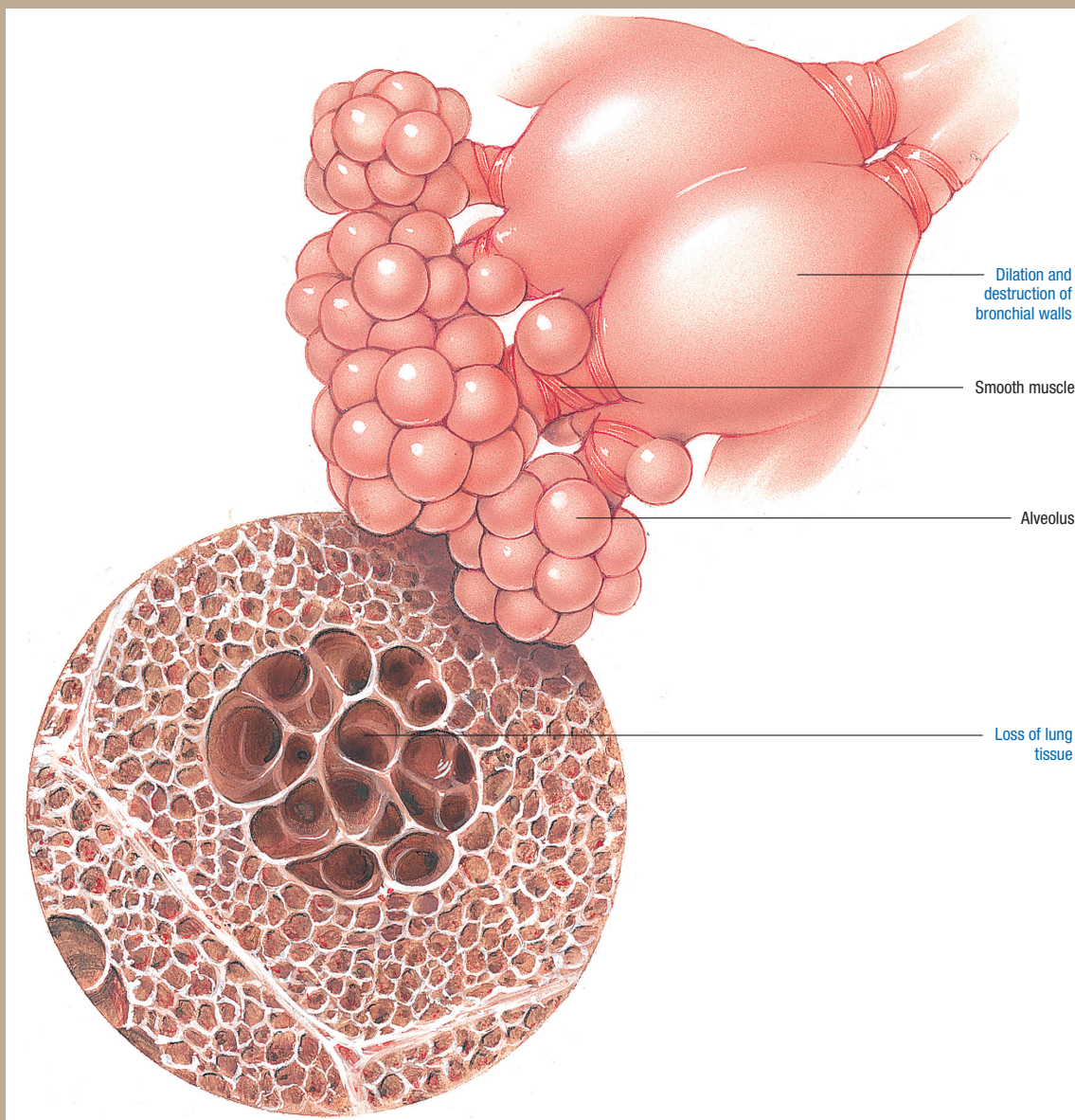
History of LVRS

Initial attempts using LVRS as a treatment option for emphysema began in the 1950s. The surgery was first proposed by Dr. Otto Brantigan. It was thought that by removing damaged lung tissue the mechanics of respiration and lung elasticity would improve and a decrease in airflow limitation would be seen.³ High morbidity and high mortality precluded widespread use. In the 1990s, Dr. Joel Cooper began a resurgence of the procedure with published data to suggest benefit received by the patient that were only previously achievable by lung transplantation.⁴ This created new interest in the procedure, and 40 years after the initial surgery, a large clinical trial was designed. As the medical community felt a consensus on patient selection criteria was lacking, results varied, and follow-up was inadequate, a research trial appeared appropriate. The clinical trial, which began in 1997, helped address a multitude of questions and, to date, has been the largest randomized controlled trial investigating long-term outcomes for LVRS. Additionally, it has served as the basis for development of disease-specific care certification guidelines as instituted by the Joint Commission (JC).

The national emphysema treatment trial (NETT) was a prospective, multicenter, randomized controlled, long-term study to compare optimum medical management with pulmonary rehabilitation with optimum medical management with pulmonary rehabilitation and LVRS.⁵ It was the first federally funded health research study using collaboration between three government agencies. The involvement of the Centers for Medicare and Medicaid Services (CMS), the National Heart, Lung, and Blood Institute, and the Agency for Healthcare Research and Quality with the cooperative efforts of 17 medical institutions took on the task of providing surgical and clinical data outcomes for LVRS up to 5 years after surgery. After receiving a comprehensive pulmonary rehabilitation program, 1,218 patients were

Lung changes in emphysema

Emphysema causes destruction of the alveolar walls, loss of lung elasticity, airflow limitation, and abnormal enlargement of the distal airspaces. The reduction in the surface area for gas exchange creates problems with oxygenation.



Source: The Anatomical Chart Company.

randomly assigned to an LVRS or continued medical care. The primary outcome was to determine maximum exercise capability and mortality 2 years after randomization. One of the secondary outcomes of the trial was to compare mortality, morbidity, and

functional outcomes between the two different surgical approaches, which will be discussed later.

In 2003, CMS began allowing LVRS as a treatment option for certain Medicare patients. To receive federal reimbursement, institutions performing the

surgical procedure on Medicare patients utilize the standards provided from the JC.⁶

Preoperative evaluation and care

An extensive preoperative workup is completed on all patients before LVRS. One of the first things to address is the smoking status of the patient. As smoking may delay recovery and increase operative risk, smoking cessation begins 4 months before the initial evaluation testing and continues throughout the evaluation process.⁷ Cotinine levels, usually via blood sample, are checked to assure compliance of a continued nonsmoking status. Patients complete the following tests before surgery: pulmonary function tests (pre and post bronchodilator spirometry, lung volumes, and diffusion capacity), 6-minute hall walk, cardiopulmonary exercise testing, arterial blood gas, chest X-ray, high-resolution chest computerized tomography, ECG, cardiac echocardiogram, pharmacologic cardiac stress test, and lung perfusion single-photon emission computed tomography to assess segmental three-dimensional distribution of lung perfusion. A pharmacologic cardiac stress test to assess for cardiac ischemia is the preferred test in patients with emphysema. A treadmill stress test could be inadequate because their disease status may preclude them from reaching a heart rate that would definitively rule out the presence of cardiac ischemia. Additionally, if cardiac studies warrant further testing, a cardiac catheterization and/or clearance by a cardiologist may be necessary. Smoking history, age, and limited exercise capability can increase the risk of occult coronary artery disease occurring during the surgical procedure so care should be taken to assure the patient is at a low risk for cardiac complications.

A comprehensive pulmonary rehabilitation program is completed before and after surgery, including educational components such as nutrition, breathing techniques, and proper use of inhalers. With pulmonary rehabilitation, endurance and exercise capacity can be increased, which may assist with early ambulation after surgery.⁸ The commitment of the patient to participate in supervised pulmonary rehabilitation speaks to their determination and can prepare a patient for the postoperative recovery demands in chest physiotherapy that are crucial to an early recovery. Instruction on the use of an incentive spirometer before surgery is beneficial. Also, overall education about emphysema, including the surgical procedure, may help reduce anxiety and postoperative pulmo-

nary complications.⁹ Preoperative education routinely includes proper use of an incentive spirometer, encouragement of walking, and continued participation in pulmonary rehabilitation before the surgical date.

Patients should be medically managed before surgery. Appropriate use of pharmacologic therapy can aid in decreasing COPD exacerbations and improve overall health. A decrease in symptoms and improvements in pulmonary function can also be obtained through the use of combination therapy such as long-acting inhaled beta₂-agonists and inhaled corticosteroids. Bronchodilators decrease airway resistance and open up the airways so airflow passage becomes easier. Corticosteroids aid in reducing airway inflammation. It's advantageous to use long-acting bronchodilators even on the day of surgery to help with decreasing postoperative pulmonary complications.

Pain control is essential with LVRS. Proper pain control helps facilitate early ambulation as well as coughing, deep breathing, and adequate use of an incentive spirometer. Generally, pain management is controlled via a thoracic epidural catheter placed by the anesthesia provider.

Surgical approaches

The two common approaches to lung volume reduction include median sternotomy (MS) and a more minimally invasive technique called video-assisted thoracoscopic surgery (VATS). While the optimal approach is still somewhat controversial, data from the NETT provide information on the comparison of the two approaches.

Median sternotomy

MS involves cutting longitudinally through the sternum and opening the chest to expose the lungs. A sternal retractor is placed following the incision into the chest. Single lung ventilation is instituted and a wedge resection of the upper lobe of the nonventilated lung is completed using a linear stapler with multiple buttressed applications to remove the most damaged upper lung targets. Identification of targets is based on the analysis of the computed tomographic scans and perfusion scintigraphy as the lung regions with the most pronounced emphysematous alteration and the greatest reduction in perfusion are surgically removed. Once the emphysematous tissue is removed from one lung the procedure is repeated on the other. Chest tubes are placed into the pleural cavity and

sutured to the skin. The sternum is sutured with steel wires. To avoid barotrauma and exacerbation of air leaks secondary to positive pressure ventilation, patients are extubated immediately after the procedure.

VATS

The more minimally invasive technique VATS uses a videoscope that allows the surgeon to visualize the lungs. The patient may be placed supine with arms spread, or sequentially placed in the lateral decubitus position. Three to four incisions are made in each hemithorax. The videoscope is placed through one of the incisions while the stapler and graspers are inserted through the remaining incisions. While the stapler device is in the thoracic cavity, it's used repeatedly until the desired resection is achieved. The lung is sealed using the stapler device and buttressing material to help eliminate air leaks at the staple line. As with the MS approach, two chest tubes are generally placed in each hemithorax. After completion of one lung, the identical procedure is carried out on the other lung. Both approaches attempt to achieve the same type of lung resection with a long length of buttressed staple line on the remaining lung. Immediate extubation is also desirable with the VATS approach.

Differences in surgical approach results

While hospital discharge may occur slightly earlier with the VATS (9 days versus 10 days for MS, $P = 0.01$), there's essentially no difference in complication rates, operative mortality, or functional results at 12 and 24 months post surgery between the two approaches.⁵ Functional outcomes measurements include exercise capacity, 6-minute walk distance, forced expiratory volume in 1 second percentage of predicted, and quality of life. With either approach the likelihood of air leak is high and the median air leak is about 7 days.¹⁰

Management and complications

Intraoperative complications in LVRS are similar to other heart or lung surgeries. These include cardiac dysrhythmia, cardiac arrest, hypoxemia, hypercarbia, uncontrolled air leak, infections, and hypotension. Hypoxemia does occur with a higher frequency in VATS (5.3%) than with MS (0.8%) ($P = 0.004$), but overall the intraoperative complications for both surgical approaches remain low.¹⁰ As pulmonary artery vasoconstriction and increasing pulmonary artery

pressure can be a result of hypoxia immediately after surgery, maintaining adequate oxygenation is critical. The most common postoperative complications to look for include cardiac dysrhythmias, air leaks, pneumonia, infection, and urinary retention. Specific complications are described in more detail below.

Air leaks

Post-op air leaks, almost inevitable with either surgical approach, are the most frequent immediate complications observed. Normally there's a space between the two pleural membranes that enclose the lungs (visceral pleura) and line the chest wall (parietal pleura). Within the pleural space is a small amount of serous fluid which allows the pleural membranes to slide smoothly over each other during inspiration and expiration. The pressure within this space is a negative pressure that normally prevents the lungs from collapsing. When air leaks occur within this space, it inhibits lung expansion and gas exchange becomes compromised. Proper placement and functioning of chest tubes help with reexpansion of the lungs. Whether to place the chest tubes to water seal, 10 cm H₂O, or 20 cm H₂O negative pressure is determined by the presence of air leaks and if a pneumothorax is present. The use of higher negative pressure may be needed if a large-size pneumothorax is present, but this can also worsen an air leak by placing increased suction on already fragile tissues. Placing the chest tubes to water seal as rapidly as possible may alleviate the risk of prolonged air leaks.

Pain control

As with any major chest surgery, pain can diminish the clearing of secretions and impair adequate ventilation. This can result in respiratory failure, hypoxia, and hypoventilation. Pain control is commonly achieved by a thoracic epidural catheter placed before the surgery begins. In the postoperative phase, the use of epidural analgesia may decrease the untoward effects that would be seen with systemic opioids. A team approach to pain management with the anesthesiologist and the use of a specialized pain team can improve pain control for the patient.

Extubation

Early extubation in the OR is the preferred method with either surgical approach. Using minimal inhalation agents for anesthesia, as well as close monitoring of vital signs, oxygen saturation, chemistry and

hematologic labs values assist with this process. Low hematologic values may indicate a blood loss. Altered chemistry values may prevent proper muscle function. Both of these situations could jeopardize the goal of an early successful extubation. Postoperative chest X-rays are useful in identification of a pneumothorax before extubation. Chest X-rays also help guide in the management of the chest tubes.

Frequently seen with the use of a general anesthetic is the increased likelihood of hypothermia. Heat loss occurs and as the body tries to regulate its temperature after receiving anesthesia, shivering can occur. Oxygen consumption and carbon dioxide production increase when shivering occurs. The already compromised lung surgical patient may incur a metabolic demand that exceeds the patient's ventilatory capacity. This can lead to respiratory failure and the continued need for mechanical ventilation. As with many other surgical procedures, common ways to maintain normothermia include using a forced-air warming device, administration of warmed I.V. fluids during the procedure, and maintaining appropriate OR temperature.

Extubation may be performed once the neuromuscular blockade has been reversed, the patient is conscious with adequate ventilatory effort, and there's no indication of bronchospasms, acidosis, or hypercapnia. The patient should be fully awake and the head of the bed placed upright. Supplemental oxygen is used following extubation. Because postoperative respiratory dysfunction can occur, continued close monitoring is crucial.

Pulmonary complications

Some postoperative pulmonary complications can be decreased by a proactive approach. As discussed earlier, smoking cessation is vital. After 8 weeks of smoking cessation the risk of developing post-op pulmonary complications decreases.¹¹ Because patients with emphysema are generally of advanced age with a lengthy smoking history, smoking cessation is imperative. The most frequently seen pulmonary complications, in addition to air leaks, include pneumonia and the need for reintubation with respiratory failure requiring mechanical ventilation. If the patient's clinical status is stable, a rapid emergence from anesthesia and an early extubation is preferred by the thoracic surgeon and anesthesia care provider.

Patients who have gastroesophageal reflux disease and other gastric disease have an increased risk of

aspiration. Nurses should be vigilant in helping to prevent aspiration by keeping the head of the bed upright in these patients especially immediately following extubation. Early mobilization of the patients can help prevent atelectasis and avoid muscle atrophy. Aggressive chest physiotherapy, continued psychological reassurance, and vigorous nursing care are instrumental in the prevention of postoperative pulmonary complications.

Cardiac complications

Overall intraoperative complications for LVRS are estimated to be less than 10%.¹² In the postoperative phase the incidence of cardiac complications rates second only to pulmonary complications. The incidence rate for cardiac dysrhythmias during surgery can be low but during the postoperative period the rate of observed dysrhythmias and dysrhythmias requiring treatment is much higher. Nurses need to be cognizant of changes in the heart rate and rhythm on the cardiac monitor as well as careful observation of any changes in the patient's condition. A nurse's understanding of the impact of intraoperative complications can effectively enhance the postoperative care phase.

Future treatments

Endoscopic techniques to achieve similar results from LVRS are being explored, including the use of endoscopically placed bronchial blockers, endobronchial one-way valves, or biological sealants. The goals with these techniques are to block the airways to the most diseased portions of the lung, thus decreasing the dead space and allowing the remaining lung tissue to work more effectively. Sufficient evidence about the long-term effectiveness of these methods is not yet available, but they appear to have less perioperative risks.¹³ Other groups are studying the potential of "reoperations" on emphysema patients who have already had LVRS, but have now had worsening symptoms, and have new targets for resection. This population is extremely high-risk and requires careful patient selection.¹⁴

Conclusions

Successful outcomes for LVRS require a multidisciplinary approach both preoperatively and postoperatively. While the procedure can have beneficial effects, morbidity and mortality outcomes can also be seen. Nurses, physicians, physical therapists, respi-

ratory therapists, and other health team members need to take a proactive collaborative approach in dealing with these patients on an individual basis. It's realized that individual outcomes can vary widely and one cannot accurately predict results in any one patient, but practitioners working with these patients need to be familiar with the surgical procedure, its potential complications, and be proactive in their approach to decrease complications and aid in a speedy recovery. **OR**

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