Overview of the Perioperative Management of Lung Volume Reduction Surgery Patients

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This article reviews management strategies that may improve the outcome of thoracic surgery and particularly lung volume reduction surgery (LVRS) in patients with severe emphysema. Maximal preoperative pharmacologic therapy includes bronchodilators and inhaled corticosteroids to attain peak lung function at the time of surgery. Nonpharmacologic measures include smoking cessation and pulmonary rehabilitation. Mechanical ventilation during the perioperative period should ensure adequate oxygenation, while avoiding dynamic hyperinflation. Keys to successful postoperative care include close monitoring while in the intensive care unit, early extubation, adequate pain control, chest physiotherapy and appropriate chest tube management. Aggressive management of early postoperative complications, including air leaks, respiratory failure, arrhythmias, and hemorrhage, can also be expected to improve outcomes.

Keywords: emphysema; lung resection; perioperative complications

Postoperative complications have been reported to be as high as 30% for thoracotomy and lung resection in patients with chronic obstructive pulmonary disease (COPD) (1). Most of the complications were due to change in lung volumes in response to dysfunction of respiratory muscles and changes in chest wall mechanics in response to surgery (2). In general, preoperative optimization of medical therapy combined with physical rehabilitation and early extubation and mobilization may improve clinical outcomes in high-risk surgeries, including upper abdominal and thoracic surgery in patients with severe emphysema (3). Using the prior knowledge about perioperative care of patients with severe emphysema, the National Emphysema Treatment Trial (NETT) delivered coordinated care by dedicated teams of thoracic surgeons, pulmonologists, anesthesiologists, and rehabilitation and nursing staff and implemented aggressive perioperative management strategies to reduce postoperative complications and increase recovery. This article reviews management strategies that may improve the outcomes of thoracic surgery, particularly lung volume reduction surgery (LVRS), in severe emphysema.

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MANAGEMENT ISSUES IN PATIENTS WITH EMPHYSEMA UNDERGOING LVRS

Candidates for LVRS typically have severe airflow obstruction and are markedly symptomatic. In addition to severe emphysema, LVRS candidates frequently suffer from other comorbid medical conditions. Optimization of pharmacologic and nonpharmacologic therapies for COPD and other comorbidities may reduce perioperative complication and accelerate recovery.

Importantly, smoking may increase operative risk and hamper recovery (4), thus the candidates should not undergo LVRS unless they have stopped smoking, ideally at least 6 to 12 weeks before the operation and before starting pulmonary rehabilitation (*see* Brister and coworkers, pages 432–437, this symposium [23]). In the NETT, nonsmoking status for 4 months before initial interview was mandatory and was objectively confirmed during screening.

Comprehensive pulmonary rehabilitation is effective in optimizing the medical condition of LVRS candidates and has been an integral part of LVRS trials, including the NETT (5). Pulmonary rehabilitation in patients with severe emphysema is discussed further by Ries and coworkers (*see* pages 524–529, this symposium [24]). In addition, teaching the patients about chest physiotherapy and use of incentive spirometry preoperatively may reduce postoperative respiratory complications (6). Patient education about the disease and the operation will help to reduce patients' anxiety (7).

As for any surgical procedure, optimization of expiratory flow with use of bronchodilators and inhaled corticosteroids is important in preparing patients for LVRS. Long-acting bronchodilators (e.g., tiotropium, salmeterol, and formoterol) and combined β-agonist/inhaled corticosteroid improve various outcomes, including lung function, exercise capacity, and quality of life, and reduce exacerbations in patients with severe COPD. In the immediate perioperative period, short-acting β-agonists (e.g., albuterol or salbutamol) and anticholinergics (ipratropium bromide) via nebulizer can relieve bronchoconstriction and may reduce the risk of pneumonia postoperatively (8). Prophylactic use of systemic corticosteroids may be beneficial in patients who have received long-term systemic corticosteroids within the past year (9).

Some centers advocate prophylactic use of antibiotics before LVRS and continuing up to 48 hours postoperatively to prevent infectious complications (7). Use of preventive measures for deep vein thrombosis, including compression devices and heparin, is recommended (7). Unfractionated heparin, as well as low-molecular-weight heparin, provides superior prophylaxis compared with compression devices. The decision to start prophylactic anticoagulation depends on the patient-related risk factors (10). Important risk factors include age over 40 years, previous venous thromboembolism, obesity, varices, and estrogen use (11). Another important consideration in patients undergoing LVRS is prevention of aspiration of oropharengeal and gastric contents into the lungs. The aspiration can cause pneumonitis, hypoxia, and adult respiratory distress syndrome. The American Society of Anesthesiologists recommends administration of acid suppres-

sants in patients who are at high risk of aspiration (12). Patients at increased risk of aspiration include those with increased gastric acid (e.g., patients with gastric ulcer, gastritis, or esophagitis), increased intragastric pressure, gastric or intestinal hypomotility, gastrointestinal structural disorders (e.g., impaired lower esophageal sphincter in hiatal hernia and gastroesophageal reflux disease), impaired gag reflex, epiglottic dysfunction, swallowing difficulty), neuromuscular incoordination, and depressed sensorium. Furthermore, the placement of nasogastric and endotracheal tubes may predispose patients to aspiration (12).

MANAGEMENT OF COMPLICATIONS DURING LVRS

In a report of complications and mortality of NETT, among 511 patients who underwent bilateral LVRS, 9% experienced complications intraoperatively (13). The most frequent complications included hypotension, arrhythmia, hypoxemia, cardiac arrest, and uncontrolled air leak (13). For more detail on intraoperative management issues, *see* Brister and coworkers, pages 432–437, this symposium (23).

Bilateral LVRS is performed in sequential steps. Single-lung ventilation during the resection of the contralateral lung may predispose the lung to hyperinflation. Thus, keeping tidal volume large enough for adequate ventilation while small enough to keep the peak airway pressure at a reasonable amount is important. Adequacy of ventilation can be monitored closely with capnography. In the case of difficulty in ventilation and high airway pressures, short-acting bronchodilators may be helpful. In situations where airway pressure remains high despite optimum bronchodilation, reduction in tidal volume and prolongation of expiratory time may help to reduce hyperinflation and prevent volutrauma (14). Furthermore, permissive hypercapnea can be used in cases in which hyperinflation and intrinsic positive end-expiratory pressure remains high.

Adequate oxygenation is crucial to prevent acute pulmonary artery vasoconstriction and pulmonary arterial hypertension. Inadvertent hypoxia may add to increased pulmonary artery pressure, which can be seen immediately after resection of the lung. In addition to maintaining adequate oxygenation and ventilation, adequate systemic blood pressure is necessary to prevent myocardial ischemia and ventricular dysfunction.

MANAGEMENT ISSUES IN LVRS PATIENTS IN THE POSTOPERATIVE PERIOD

Immediate Evaluation in the Recovery Room

Evaluation of vital signs, including blood pressure, pulse rate, respiratory rate, and oxygen saturation, is helpful in planning early extubation. Serum electrolyte measurements are useful in detecting any electrolyte abnormalities that may prevent optimum muscle function and hamper successful extubation, as is hemoglobin measurement in identifying excessive blood loss. A chest X-ray performed immediately postoperatively will help to identify any significant pneumothorax and will guide the management of chest tubes. In addition, an EKG will help to identify any possible ischemia. Some centers continue invasive or noninvasive cardiac output monitoring during the immediate postoperative period to detect early postoperative deterioration in cardiorespiratory function.

Early Extubation

In the overwhelming majority of patients, it should be possible to achieve immediate postoperative extubation and spontaneous breathing in the operating room. Due to underlying ventilatory problem in patients with COPD, extubation can be attempted even in the presence of higher arterial CO_2 pressure (Pa_{CO_2}) level. The proper anesthesia management and an experienced team are crucial for achieving this goal. Because postoperative shivering increases carbon dioxide production and oxygen consumption, postoperative shivering in patients with severe COPD may induce a metabolic demand that is larger than the ventilatory capacity and may lead to acute respiratory failure and the need for mechanical ventilation (15). After extubation, positioning the patient in an upright or semi-upright position may help diaphragm movement and improve efficacy of spontaneous ventilation (7). Adequate attention to functioning of chest tubes is crucial because large pneumothorax may result in hypoxemia and compromised ventilation. Furthermore, use of noninvasive ventilatory support should be considered in case of rising Pa_{CO_2} level after extubation if the patient is awake. Close attention to prevention of aspiration is crucial at this stage (*see above*).

Pain Control

Chest wall pain after thoracotomy impairs proper ventilation and adequate clearing of secretion, which in turn may result in hypoventilation, hypoxia, and respiratory failure (15). Many centers prefer epidural pain control to systemic narcotic use due to the latter's effects on control of breathing. In patients with severe COPD, involvement of a pain expert can improve pain control and reduce the deleterious effects of narcotics.

Chest Tubes and Control of Pneumothorax

Decisions about the management of chest tubes depend on the presence and severity of observed air leaks and pneumothorax. In some centers, if there is no, or only small, pneumothorax, the chest tubes are placed on water seal, whereas at other centers, the policy is to place the chest tubes on 10 cm H_2O negative pressure. In the presence of significant pneumothorax (>30% of the lung or a pneumothorax that compromises ventilation or oxygenation), the chest tubes can be placed on higher negative pressure. However, as soon as the pneumothorax is resolved, the pressure should be reduced, and ultimately the chest tube should be placed on water seal. This in turn may help to prevent prolonged air leak, although prospective data on this are lacking (16).

Pulmonary Toilet, Prevention of Atelectasis, and Chest Physiotherapy

Although the use of postoperative incentive spirometry and chest physiotherapy in patients undergoing lung resection is commonplace, prospective data examining their effectiveness is sparse. Varela and colleagues reviewed clinical outcomes and costs of 119 patients undergoing lobectomy who received incentive spirometry as well as chest physiotherapy and 520 historical control subjects who did not receive this care. The study reported significant reductions in length of stay, atelectasis, and cost in the chest physiotherapy group compared with control subjects (17).

Early Mobilization

Early postoperative mobilization after LVRS should be instituted whenever feasible to help reduce the incidence of atelectasis, minimize use of narcotic analgesics, reduce recovery time, and prevent muscle atrophy.

MANAGEMENT OF COMPLICATION OF LVRS

Air Leaks

In contrast to lung resection for lung cancer, the majority of patients undergoing LVRS have an air leak during the postoperative period. In the NETT, 496 of 552 (90%) patients experienced air leak at some time in the first 30 days after LVRS (18). DeCamp and colleagues (18) reported that patients with a predominantly

lower lobe distribution of emphysema had fewer air leaks than patients with other emphysema distribution. In addition, a low diffusing capacity and the presence of marked adhesions were strongly associated with the occurrence of air leak. Staple line buttressing technique (16), type of stapler used, and intraoperative adjunctive procedures were not reliably associated with the prevalence of air leaks (18).

Postoperative Respiratory Infection

Although the use of prophylactic antibiotics before LVRS remains controversial, the incidence of pneumonia after LVRS has been as high as 20% in some studies (5). If respiratory infection is suspected, use of antibiotics should not be delayed. The choice of antibiotic agent should be tailored to an individual patient's history (i.e., length of time in hospital before surgery, prior use of antibiotics, use of immunosuppressive agents and the antibiotic resistance pattern in the hospital) (19). Once microbiologic data are available identifying an organism and antibiotic sensitivities, therapy should be promptly narrowed and a predetermined stop date set.

Postoperative Bleeding

Assuming the LVRS candidate does not possess an underlying coagulation disorder and has normal coagulation studies and platelet counts, patients with severe emphysema are at no greater risk for bleeding complications perioperatively than those with normal lung function. In fact, patients with COPD may actually be more likely to suffer from thrombosis than bleeding (20). Because LVRS is performed without the use of anticoagulant agents or cardiopulmonary bypass, most bleeding complications result from surgical complications. If conservative measures do not control bleeding, surgical correction may be required.

Respiratory Failure and Prolonged Mechanical Ventilation

To prevent postoperative pneumonia and ventilator-associated lung damage, early extubation is a goal for every LVRS patient. Compared with surgeries involving lung resection for other reasons, rates of tracheostomy, prolonged ventilation, and reintubation were significant in the NETT but not unreasonable given the limited pulmonary reserve in this patient population (13). Minimized use of narcotic analgesics, appropriate and early use of antibiotics, and early mobilization will all help to minimize the incidence of respiratory failure. The routine use of noninvasive ventilation has been implemented at some centers in the immediate postoperative period to prevent hypoventilation, atelectasis, and hypoxia.

Cardiovascular Complications

In the NETT, arrhythmias were common postoperatively, occurring in 23.5% of patients (13). There is currently no consensus for pharmacologic management of post-LVRS arrhythmias, but agents implemented have included calcium channel blockers, β-blockers, digoxin, and amiodarone. Management guidelines for treatment of these arrhythmias should be followed (21, 22). Myocardial infarction and cardiac arrest are less common than arrhythmias after LVRS, occurring in less than 1% of patients. In the NETT, advanced age, corticosteroid use, and non-upper-lobe–predominant emphysema were shown in a multivariate analysis to be associated with an increased risk for major cardiac morbidity (13). However, it is not clear if preoperative identification of these risk factors will be of important clinical benefit (13).

CONCLUSIONS

Candidates for LVRS suffer from severe COPD. In many cases, these patients also have other comorbid conditions. A well-coordinated team of cardiothoracic surgeons and pulmonologists with expertise in LVRS is of utmost importance. The key to successful outcome lies in adequate evaluation of potential candidates, proper patient selection, optimization of patients' pharmacologic and nonpharmacologic therapies during rehabilitation and before the surgery, adequate attention to surgical techniques and anesthesia during the perioperative period, and early extubation and mobilization with adequate pain control after surgery.

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