Lung Volume Reduction Surgery
Anesthesia Guideline
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Overview

1. Candidates for lung volume reduction surgery (LVRS) have severe airflow obstruction and are usually markedly symptomatic. In general, patients must have stopped smoking, are maximized on their bronchodilator therapy, and have undergone pulmonary rehabilitation prior to undergoing LVRS.
2. The National Emphysema Treatment Trial (NETT) showed that patients with upper lobe-predominant emphysema benefit from LVRS in terms of improvements in lung function, exercise performance, quality of life, and a reduction in symptoms. Preoperative lung function tests can help identify suitable candidates.
3. Results from NETT have also shown, that patients with an FEV1 greater than 20%, a DLCO greater than 20%, and air trapping (residual volume more than 150%) are eligible for LVRS. Patients who do not meet these criteria are usually not operative candidates, as they have an unacceptably high operative risk and a 30-day mortality of 16%.
4. The surgery can be performed as an open (via a median sternotomy) or as a thoracoscopic procedure (via multiple bilateral small incisions). From a technical standpoint, stapler resection of emphysematous lung segments is performed, possible leaks are repaired, and bilateral chest tubes are inserted before closing. Normal duration of the procedure is about two hours.

Anesthesia setup

1. No cardiac infusion setup is required, but phenylephrine and/or vasopressin infusions should be readily available.
2. The anesthesia set-up is generally identical as for any major thoracic surgery case, including the double-lumen tube cart with fiberoptic bronchoscope.
3. Vascular access includes two large-bore peripheral IVs as well as an arterial line. Central lines or PA catheters are generally not used, unless indicated from a cardiac standpoint.
4. Double-lumen endotracheal tubes are always used.
Preoperative management

1. When the patient arrives in the holding area, an IV suitable for induction and an arterial line are placed.
2. Insertion of a functioning epidural catheter is paramount in the perioperative management of these high-risk patients. It should be placed in all patients for postoperative pain control and early extubation. In the case of contraindications for epidural catheter placement, potential alternatives should be discussed with the surgeon including other modalities of post-thoracotomy pain control and cancellation of the case.
3. Any sedative or analgesic drug should be used with caution as this may exacerbate hypercapnia and hypoxia.

Induction of anesthesia

4. Preoxygenation should be accomplished very deliberately to assure maximum total body oxygen content. Preoxygenation may have to be accomplished with the patient sitting if a completely supine posture is intolerable.
5. Choice of induction agents can be tailored to the individual patient based on the experience and preference of the anesthesiologist. Consider that right coronary perfusion pressure may be critically important in patients with severe pulmonary hypertension and right ventricular hypertrophy.
6. Beware of the following problems after intubation:
   a. Dynamic hyperinflation (air trapping, auto-PEEP) may impede venous return and produce hypotension. Disconnecting the circuit from the endotracheal tube usually resolves this problem.
   b. Rupture of blebs in COPD may produce a pneumothorax or tension pneumothorax. Rapid placement of a chest tube in this situation may be lifesaving.
   c. Patients with pulmonary hypertension can develop serious hemodynamic instability following induction of anesthesia and acute right heart failure can occur. Quickly obtaining TEE images can help establish a diagnosis. Consider using vasopressin instead of phenylephrine in this group since PVR is not increased by vasopressin.

Intraoperative management

1. A balanced anesthesia technique is used including sevoflurane, opioid analgesics and epidural local anesthetics, and muscle relaxants.
2. According to the NETT trial results, the most common intraoperative complications were hypotension, arrhythmias, hypoxemia, cardiac arrest, and uncontrolled air leak. Overall intraoperative morbidity was reported to be around 9%.

3. Hypotension is often caused by air trapping as described above. Sympathectomy caused by epidural infusion of local anesthetics is another potential cause. Monitoring using an arterial line is crucial, and treatment options include phenylephrine or vasopressin, the latter is preferred in the setting of pulmonary hypertension.

4. Intraoperative ventilatory management is directed toward maintaining an adequate minute ventilation to avoid hypoxia and excessive hypercapnia, and toward avoiding hyperinflation by using relatively small tidal volumes and increasing exhalation time. One-lung ventilation itself predisposes to hyperinflation. Adequacy of ventilation can be monitored with capnography. Pressure controlled mode with I:E Ratio of greater than 1:3 is very useful. This avoids air trapping and minimizes barotrauma.

5. In the case of ventilatory difficulties and increased airway pressures, short-acting bronchodilators may be helpful. Permissive hypercapnia is often well tolerated by emphysema patients, and allows for smaller tidal volumes to decrease hyperinflation. The pH should, however, remain above 7.2 in this setting of respiratory acidosis.

6. With adequate monitoring of F\textsubscript{i}\text{O\textsubscript{2}}, management of secretions, muscle relaxation, and treatment of bronchospasm, oxygenation is generally well maintained.

7. Initial reinflation of the resected lung has to be performed under direct vision and using extreme care as anastomoses and resected areas can become insufficient when exposed to high peak airway pressures.

8. Depending on the hemodynamic response to sympathectomy, the epidural catheter may be used for continuous infusion of local anesthetics throughout the procedure. This can help decrease time to extubation and early postoperative management by providing adequate pain control and reducing the patient's opioid requirements. At the latest, patients should receive a bolus dose of epidural local anesthetics at the time of chest closure to prepare for extubation. Long-acting opioids should be avoided, in particular in patients with baseline hypercapnia.

9. All patients need to have sufficient reversal of neuromuscular block prior to any extubation attempt. In general, early extubation should be attempted in the absence of significant bronchospasm, secretions, hypercapnia, and acidosis. In patients with baseline hypercapnia, other extubation criteria may apply. After extubation and initial stabilization, patients may be transferred to PACU. One might use monitoring of cardiorespiratory function for transport as those patients can deteriorate fairly rapidly.

10. Use as little crystalloid fluid as possible and no colloid (such as albumin or hetastarch), as these tend to worsen pulmonary edema and oxygenation.
Early postoperative management

1. Upon arrival in PACU and initial vital sign check, the patient should be assessed for adequate pain control. Additional epidural or intravenous analgesics may be titrated as needed.

2. Patients should be brought in a head-up position. This will improve diaphragm movements and overall respiratory mechanics. Frequent or continuous nebulization of bronchodilators is essential to improve ventilation and treat hypoxia. If progressive hypercapnia is noted in the arterial blood gas analysis, non-invasive ventilation may be used to stabilize gas exchange and decrease the work of breathing. However, in patients with altered mental status from hypoxemia or hypercapnia endotracheal reintubation may be the only feasible option.

3. Adequate attention to functioning chest tubes is important because large pneumothorax formation may result in hypoxemia and respiratory failure. After initial chest X-ray, the presence and extent of a pneumothorax can be assessed, and suction to the chest tubes can be adjusted accordingly. All interventions involving the chest tubes and the level of vacuum applied to them must be discussed with the fellow or attending thoracic surgeon. The differential treatment of persistent air leaks and pneumothorax often includes fine adjustment to chest tube suction.

4. Cardiac arrhythmias in the postoperative period are common, in the NETT population 23.5% of patients had perioperative arrhythmia events. These should be monitored and treated according to current guidelines for treatment of cardiac arrhythmias since there is no consensus on the treatment of arrhythmias in this special population.

5. Limiting the use of opioid analgesics, perioperative antibiotic prophylaxis, and early mobilization will all help minimize the risk of postoperative respiratory failure. One of the most important parts of anesthesia care is to provide adequate and functioning epidural pain control.

6. Please notify the Acute Pain Service for postoperative management of the epidural catheter. All patients will be transferred to the CT ICU from PACU after adequate recovery.

Summary

1. Place a working epidural catheter
2. Have a left-sided double-lumen tube in proper position
3. Perform bronchial toilet and bronchodilatation
4. Avoid high inflation pressures and PEEP
5. Use long I:E ratios
6. Allow (permissive) hypercapnea
7. Gently reinflate lungs to avoid excessive air leak
8. Extubate postoperatively.