OBJECTIVES
At the conclusion of this PBLD, the participant will be able to:
1. Appreciate the basic steps in the technique of extrapleural pneumonectomy and the anesthetic considerations
2. Understand patient selection criteria and preoperative preparation
3. Recognize the causes of hemodynamic perturbation during different phases of surgery and the immediate postoperative period
4. Discuss the principles of anesthetic management including one-lung ventilation, thoracic epidural analgesia, and optimal fluid management

CASE PRESENTATION
The patient is a 65 year old man diagnosed with mesothelioma 6 months ago. He completed 2 cycles of chemotherapy and now presents for left extrapleural pneumonectomy (EPP). He has a history of hypertension, hypercholesterolemia and a remote smoking history. Medications include Losartan and simvastatin. Preop laboratory data included Hb 11.2, Hct 32.7, platelets 247 000, Cr 0.83. Chemistry and coagulation within normal limits. TTE showed good biventricular function with estimated EF of 65-70%. Estimated PA systolic pressure 19.4 mmHg. Pulmonary function testing showed FEV$_1$ of 2.80 (73%) and FVC of 3.90 (78%).

Questions
1. What is the prognosis for patients diagnosed with mesothelioma? What are the surgical treatment options?
2. Which patients are suitable for surgery? What does extrapleural pneumonectomy involve and how is it different from pneumonectomy?
3. What preoperative workup should be included in preparation for EPP?

Case continuation
The patient received preoperative peripheral and arterial lines and a thoracic epidural under sedation. A right-sided double-lumen tube was placed after induction of anesthesia for lung isolation and a pulmonary artery catheter was then placed via the left internal jugular vein. Surgery proceeded in the right lateral decubitus position with right one-lung
ventilation (5-6 ml/kg tidal volume, respiratory rate of 10-12 and PEEP of 5 cmH_2O). Systolic blood pressure was maintained between 90-100mmHg with fluids and judicious use of vasopressors.

Questions
1. What is the current data for the use of central venous monitoring and PA catheters in Thoracic surgery? What about the role of TEE?
2. What are the ventilation goals during OLV and is there an ideal ventilation mode for OLV?
3. Which are the critical phases of surgery/anesthesia?
4. How should fluid management be optimized?
5. What should the target hematocrit be? What about the use of fibrinolytics?

Case continuation
The case proceeds relatively uneventfully, with estimated blood loss of 1L. Intermittent boluses doses of vasopressors were used and 2 units of packed cells transfused. The patient received 10 ml of 0.125% bupivacaine via the epidural catheter during chest closure. At the conclusion of the case, the patient is turned supine and the blood pressure decreases from 110/65 to 64/32 mmHg. After administration of bolus doses of phenylephrine, the blood pressure settles to 95/50 mmHg. The patient is then extubated uneventfully and transferred to the intensive care unit for monitoring.

Questions
1. What is the differential diagnoses of hypotension on supine positioning and what is your immediate management plan?
2. Is extubation the goal in all patients? What are the potential risks of postoperative mechanical ventilation?

DISCUSSION
2000-3000 cases of mesothelioma are diagnosed per year in the United States and the overall prognosis is guarded, with a median survival of 7-9 months from time of diagnosis. For non-surgical candidates, cisplatin and premetrexed combined therapy is currently considered the standard of care. Surgery for mesothelioma may be diagnostic, palliative or radical e.g. extrapleural pneumonectomy (EPP) or pleurectomy/decortication (P/D). Largest published series with multimodality therapy and EPP (neoadjuvant chemotherapy, EPP and postoperative radiotherapy) showed a median survival of 19 months with a mortality 3.8%. Variables affecting survival were epithelial histology, lack of extrapleural LN involvement and negative resection margins.

The preoperative patient selection process currently differs greatly between institutions. Eligible surgical candidates generally have to have good performance status, normal liver and renal function and no evidence of unresectabiligy by CT, MRI or echocardiogram. Pulmonary function testing and V/Q scans may be necessary, and patients with a predicted post-operative forced expiratory volume in 1 second (ppoFEV_1) of less than 0.8L are considered for P/D, rather than EPP.
EPP involves the en bloc resection of lung, pleura, pericardium and diaphragm.

<table>
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<tr>
<th>Anesthetic Issues for Extrapleural Pneumonectomy</th>
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<tr>
<td>Significantly greater blood loss compared to pneumonectomy</td>
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<tr>
<td>More delicate management of intravascular fluid &amp; blood components</td>
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<td>Greater operative impairment of venous return</td>
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<td>Greater danger of surgical disruption of major vascular structures</td>
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<tr>
<td>More complex and variable physiology of the nonoperative lung (restrictive &amp; obstructive)</td>
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<td>High probability for disruption of internal mammary artery coronary grafts (if present)</td>
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<td>High probability of dysrhythmias</td>
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<td>Frequent “pseudo-ischemic” ST changes on EKG during wash phase</td>
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<td>Greater potential for hemodynamic instability related to pericardial window and its patch and/or the diaphragmatic (right) patch</td>
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<td>Greater postoperative pain and pulmonary dysfunction related to the larger incision</td>
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Generous intravenous access is paramount and blood should be available in the operating room. If the superior vena cava is in jeopardy, lower extremity intravenous access is mandatory. A nasogastric tube aids posterior esophageal dissection intraoperatively and gastric decompression (and the prevention of gastric acid aspiration) postoperatively. Invasive monitors (arterial and central venous lines) are routine. The site of central venous access is important, as the potential for causing a pneumothorax in the nonoperative lung has to be weighed against injury to the subclavian vein during surgical dissection on the operative side.

Although pulmonary artery (PA) catheters have potential interpretation pitfalls during pneumonectomy, they may be useful for postoperative fluid and right heart management issues. Transesophageal echocardiography (TEE) is a more powerful and reliable monitor of right and left ventricular filling and function, and is a more sensitive monitor of myocardial ischemia, particularly during left EPP when the surgical incision precludes appropriate EKG lead placement. However, there is no direct evidence of improved outcome, and the cost and need of technical expertise make this tool worthwhile only in selected cases.

Lung-protective (5-6 ml/kg tidal volume, limiting peak airway pressure < 35 cmH\textsubscript{2}O and plateau airway pressure < 25 cmH\textsubscript{2}O) ventilation and dependent lung positive end-expiratory pressure (PEEP) with the intention of limiting dependent lung volutrauma and atelectasis is important. EPP patients, during OLV in the lateral decubitus position, often exhibit an element of restrictive physiology in the dependent lung imposed by the weight
of the tumor and surgical pressure during dissection. Frequent large changes in compliance require vigilance to prevent high airway pressures or volumes (depending on the mode of ventilation).

Average estimated intraoperative blood loss during EPP in the best of surgical hands is approximately 0.5-1.5 Litters. Most of this occurs in a gradual, continuous fashion during the processes of blunt separation of the parietal pleura from the chest wall, although catastrophic bleeding can occur from major vessels during dissection of the hilum or at the apex. Monitoring of the extent of blood loss requires vigilance and communication with the surgeons. Antifibrinolytics have not been shown to reduce packed red blood cell requirements in EPP surgery. As with any pneumonectomy, excessive crystalloid is to be avoided as it may exacerbate the pulmonary edema of post-lung resection acute lung injury. Fluid management thus becomes a balancing act in the setting of significant hemodynamic swings with intermittently moderate-to-major episodes of blood loss.

Herniation of the heart (particularly with right EPP), with torsion of great vessels and circulatory arrest may abruptly occur upon resumption of the supine position at the end of surgery. Immediate return to the lateral position is the appropriate reflex response. This usually improves hemodynamic parameters while preparation for re-operation made if necessary. The diagnosis is less obvious when only moderate hypotension occurs at this juncture. Culprits include partial cardiac herniation (loose or partially ruptured pericardial patch), tamponade (tight pericardial patch or retained pericardial effusion), inferior vena cava impingement (tight right diaphragmatic patch), hypovolemia, and deviated mediastinum, among others.

Reduced venous return is the common mechanistic denominator. A sluggish response to fluid boluses and vasopressors suggest that mechanical impediments to venous return should be ruled out before leaving the operating room. Aggressive bolus dosing of the epidural in anticipation of emergence may contribute to diagnostic confusion. A portable chest radiograph is usually helpful in ruling out partial cardiac herniation, or guiding medialization of the mediastinum by withdrawal of air from the chest drain. TEE may assist in the diagnosis.

Depending on center experience, majority of patients may be weaned and extubated in the operating room. This minimizes duration of positive pressure on the bronchial stump and avoids the potential problems of ventilator-associated alveolar barotrauma and infection. Prudence advised in difficult or complicated EPP with increased transfusion requirement or excessive fluid administration.

FURTHER READING

Hartigan PM, Ng JM. Anesthetic strategies for patients undergoing extrapleural


