Hypoxia during Thoracoscopy

Thoracic Anesthesia Symposium
SCA Annual Meeting
April 27th, 2012

Objectives
1. Identify predictors for hypoxemia during thoracoscopy
2. Discuss differences between thoracoscopy and thoracotomy
3. Discuss preventative measures to avoid hypoxemia
4. Discuss treatment approach to hypoxemia during thoracoscopy

Cases for discussion
1. 75 y.o. female with advanced emphysema undergoing thoracoscopic right lower lobectomy with a left-sided DLT.
2. 40 y.o. obese male (BMI 55) for thoracoscopic wedge resection of a right lower lobe nodule with a SLT and Fuji blocker.
3. 65 y.o. male ankylosing spondylitic undergoing right wedge resection with single lumen endobronchial tube placed into LMSB after awake fiberoptic intubation.
4. 50 y.o. female ICU patient in hypoxemic respiratory failure due to interstitial lung disease NYD presenting for diagnostic lung biopsy.
5. 59 y.o. female after left pneumonectomy presenting for thoracoscopic wedge resection of a right lower lobe nodule.

Minimally invasive surgery is replacing open procedures in almost all surgical specialties. In thoracic surgery the use of VATS has expanded far beyond minor diagnostic procedures and all types of lung resections (including pneumonectomy), esophageal resections and mediastinal surgery have been reported using the thoracoscopy approach.

1. Predictors for hypoxemia during OLV
Patient:
   - Preferential perfusion to operative lung
     - Prior contralateral resection
     - Right-sided surgery
• normal FEV1
• chronic vasodilator therapy
• poor oxygenation on TLV

Procedure:
• Preferential perfusion to operative lung
  o Right sided surgery
• Supine position
• Vasodilator use
• Excessive volatile anesthetic

2. Differences between thoracoscopy and thoracotomy
Due to the smaller incisions (which are mostly sealed by the trocars), the surgical pneumothorax is slower to develop. Lung collapse is slower and often incomplete unless aided by applying suction to the airway and facilitating air entry by opening the trocars. Surgical suctioning will re-expand the lung unless a vent is being used. CO₂ insufflation can be used to improve visualization, at the risk of creating tamponade physiology. The main indication for its use is inability to establish lung isolation (secondary to unfavorable airway anatomy or lack of appropriately sized device), which is why it is unusual outside of pediatric practice.
One-lung ventilation management of the down-lung is unchanged from the thoracotomy settings and should focus on maintaining open lung. Due to the need for ‘complete’ lung collapse for surgical exposure, techniques that involve partial or complete insufflation (CPAP) or ventilation (HFJV, TLV) of the operative lung are relatively contraindicated.
Mechanical restriction of the shunt fraction is possible, but more difficult than in the open scenario. Lung retraction is possible for the surgeons, while actual packing of the lung, which has shown to improve shunt fraction, is not. As a last resort, if thoracoscopy cannot be abandoned, the shunt fraction could be reduced by impairing ipsilateral PA blood flow byatraumatically side-clamping the PA (similar to reducing venous drainage on a CPB circuit) or by distorting the PA anatomy with a sponge stick.

3. Preventative measures to avoid hypoxemia
Due to the limited ability to use the operative lung for apneic oxygenation or ventilation, prevention of hypoxemia is crucial. Impaired HPV due to hypocapnea, vasodilators or excessive volatile anesthesia has to be avoided. Any shunt in the ventilated lung, due to de-recruitment, will be poorly tolerated. Appropriate and individualized ventilator settings focused on open lung ventilation are essential. Rather than using PEEP when hypoxia occurs, I routinely use PEEP for OLV and will discontinue it if excessive air trapping occurs (this is rarely the case with the use of permissive hypercarbia).
Depressed cardiac output due to neuraxial anesthesia, parenteral anesthetic agents or tamponade physiology from CO₂ insufflation will impair mixed venous oxygen concentrations, which is difficult to overcome in the setting of high shunt due to OLV. Restoration of normal cardiac output with inotropic agents (e.g. ephedrine) may be
required.

4. Treatment of hypoxemia during thoracoscopy
Severe hypoxemia should trigger resumption of two-lung ventilation. This will, however, impair visualization to the point where surgery is usually no longer feasible. It is for that reason that other treatments should be considered first if hypoxemia is mild. A decision making tree has been suggested by Rozé and colleagues for OLV hypoxemia (2011).

My approach would consist of the following:

1. Increase FiO₂ towards 1.0
   Lower FiO₂ is being used in light of concern about oxygen toxicity and potential acute lung injury. High FiO₂, however, is required in the setting of hypoxia, both to increase oxygen delivery and to act as a pulmonary vasodilator, which may improve V/Q matching.

2. Confirm position of the double-lumen tube or bronchial blocker
   Loss of lung isolation, especially partial obstruction of the ventilated bronchus will result in hypoventilation and de-recruitment. The need for actual fiberoptic bronchoscopy for confirmation will depend on the scenario and the index of suspicion, i.e. side ventilated, isolation device and adequacy of positioning. In many cases, at least transient ‘confirmation’ can be achieved by ensuring that ventilator parameters (pressures and volumes) are unchanged.

3. ‘Open Lung’ ventilation
a. Apply a recruitment maneuver to the ventilated lung (this will transiently worsen the hypoxemia).
b. PEEP titration
   • Increase PEEP, if recruitment maneuver improved oxygenation.
   • If no improvement in oxygenation, PEEP level may be appropriate or excessive. Consider a decrease depending on patients’ lung pathology.
c. Confirm ventilator settings
d. Consider Pressure Control Ventilation

The concept of open lung ventilation originated in the intensive care literature and is an evolution of the management of ARDS patients. It entails avoidance of cycling recruitment and de-recruitment for lung injury prevention. Maintenance of open lung additionally maintains FRC, optimizes V/Q matching and increases CO₂ elimination in the ventilated lung. While shunt fraction is primarily determined by the amount of perfusion through the collapsed operative lung, additional shunt through the ventilated lung in excess of the physiologic 5% is often poorly tolerated and entirely preventable.
De-recruitment is one of the most common reasons for desaturation during OLV. The dependent ventilated lung is non-compliant due external compression by abdominal and mediastinal contents and often inadequately distended by ‘protective’ ventilation with insufficient PEEP. Application of a manual recruitment/ vital capacity maneuver at a pressure of 30-40 cmH₂O will result in improved oxygenation in the majority of patients. Prolonged application of the vital capacity maneuver will result in a reduced cardiac output, which always manifests as a transient dip in saturations, but may also result in significant hypotension. Invasive arterial monitoring is likely mandatory for any recruitment maneuver in excess of 10-20 seconds. Recruitment maneuvers are successful in achieving improved oxygenation if de-recruited ventilated lung existed. This by definition means that ventilation, and in particular the amount of PEEP, was insufficient to prevent lung collapse. As such, a positive recruitment maneuver should be followed by up-titration in applied PEEP. A negative response may indicate adequate or excessive PEEP levels. This may be an appropriate time to review the appropriateness of all ventilator settings.

4. Optimize oxygen delivery
   a. normalize cardiac output
   b. confirm adequate hemoglobin

Inadequate oxygen delivery due to low cardiac output and/or low hemoglobin concentration must be ruled out. Transfusion will rarely be necessary or justified for maintenance of oxygenation. Cardiac output support, however, is more commonly necessary. Anesthetic agents and neuraxial sympatholysis depress cardiac output, which may not be tolerated in the frail, elderly, hypovolemic patient. Avoidance of excessive anesthetic depth and correction of severe
hypovolemia will often suffice. Occasional support with inotropic agents (e.g. ephedrine) may be necessary and will help to minimize fluid administration. Supra-normal cardiac outputs are not indicated and may be detrimental for oxygenation.

5. CPAP/ Partial ventilation of the operative lung
   a. CPAP
   b. Oxygen insufflation
      - into whole lung via oxygen ‘jet’ (Russell, 2009)
      - into a subsegment using the fiberoptic bronchoscope (Ku et al., 2009)
   c. High-frequency ventilation
      - CPAP-mode or actual ventilator mode depending on the driving pressures.
   d. Lobar collapse (i.e. lobar recruitment on the operative side)
   e. Intermittent TLV and apnea

Partial ventilation, or apneic oxygenation, of the operative lung is well known for thoracotomy procedures, however often considered contraindicated in the thoracoscopy setting. Partial lung reinflation is required for these techniques in order for oxygen to be delivered past the conducting airway, which may interfere with surgical exposure. In order to not impair the surgical procedure, reinflation can be limited to a subsegment of the lung that is remote to the surgical site or be minimal applied across the entire lung. Any reinflation should be monitored in real-time on the surgical monitors. After reinflation, oxygen can be delivered via CPAP circuit, fiberoptic bronchoscope, modified oxygen flush or high-frequency jet ventilation.

On rare occasions, actual lung isolation is not essential. Ventilation of a lobe on the operative side may rarely be possible using subsegmental blockade with a bronchial blocker. More commonly, particularly for peripheral procedures such as wedge resections, TLV and intermittent apnea may be possible.

7. Pulmonary blood flow manipulation
   a. optimize HPV
      - avoid inhibitors: hypocapnea, hypothermia, vasodilators, vapor anesthetics >> 1 MAC (consider TIVA)
      - consider potentiation with: almitrine, phenylephrine or vasopressin
   b. pulmonary vasodilation in the ventilated lung
      - Nitric oxide
   c. PA clamp
      - Flow can be restricted with an atraumatic clamp or distortion of the PA anatomy with a sponge stick

Hypoxic pulmonary vasoconstriction has to be maintained and all inhibitors should be avoided. Pharmacologic manipulation of pulmonary blood flow and HPV has been described for VATS. However, it is not without risk, requires invasive monitoring and is rarely justified in my mind.
8. Conversion to thoracotomy

Despite our best efforts, some patients may be hard to oxygenate with the limited options that are available during thoracoscopic procedures. Furthermore, some of the partial ventilation techniques may worsen surgical exposure to the point that surgical progress is slowed and the risk of complications increased. While a conversion may be undesirable, the morbidity of persistent hypoxia far outweighs that of a thoracotomy incision.

References


