Management of One-lung Ventilation
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The incidence of hypoxemia during one-lung ventilation (OLV) with an inspired oxygen concentration (FiO2) of 1.0 has declined from levels of 20-25% in the 1970’s to less than 10% today. Two advances in thoracic anaesthesia affect oxygenation. First, the routine use of fiberoptic bronchoscopy to position DLTs. Second, improved anesthetic techniques with lower doses of volatile agents.

Etiology: The major cause of hypoxemia is the shunt of de-oxygenated blood through the non-ventilated lung. Factors which influence this shunt are hypoxic pulmonary vasoconstriction (HPV), gravity, the pressure differential between the thoraces and physical lung collapse. HPV is inhibited by essentially all volatile anesthetics. Isoflurane seems to be less inhibitory than enflurane or halothane1 and equivalent to sevoflurane or desflurane. Intravenous anesthetic techniques have not been shown to provide better oxygenation than the newer volatile anesthetics in < 1MAC concentrations.

Manipulating the ventilating pressures and tidal volumes during one-lung anesthesia can improve the oxygenation for certain patients.2 It is not yet possible to predict the optimal ventilatory settings for an individual patient. The use of a 10 ml/kg tidal volume while limiting plateau airway pressure to 25 cm H2O at end inspiration are useful initial parameters for OLV in the majority of patients. Some patients, particularly those with COPD, showed better oxygenation during OLV with a pressure controlled vs volume controlled ventilation.

A third of the 35-40% shunt during OLV is due to ventilation-perfusion mismatch in the ventilated dependent-lung. Several factors under the control of the anesthesiologist can influence this dependent-lung shunt. An excess of intravenous crystalloids can rapidly cause desaturation of the pulmonary venous blood draining the dependent lung. Also, the use of nitrous oxide will lead to increased dependent-lung atelectasis since it causes greater instability of poorly ventilated lung regions than oxygen.

Monitoring: The risk of intraoperative hypoxemia is increased during OLV. Pulse oximetry is prone to malfunctions and does not give an early warning of the rapidly falling PaO2 that occurs during OLV before any change in saturation.4 Patients whose PaO2 declines rapidly are most likely to become hypoxemic. Side-stream spirometry permits on-line monitoring of pulmonary mechanics. This technology can provide an early warning of loss of lung isolation or accidental lobar obstruction. It may be possible to use this information to select the optimal ventilatory parameters for an individual patient during OLV.

Prediction of Hypoxemia: Several factors allow prediction of the risk of hypoxemia developing during OLV.5 First, the A-aO2 gradient during two-lung ventilation. Second, the side of lung collapse during OLV. The mean PaO2 level is 70 mmHg higher for left vs right thoracotomies. Third, patients with good preoperative spirometric pulmonary function tests tend to have lower PaO2 values during OLV than patients with poor spirometry. This may be related to auto-PEEP in patients with poor spirometry.

Prophylaxis and Treatment: Other potential causes of hypoxemia such as malposition of an endobronchial tube or inadequate oxygen delivery should be ruled out. The use of the highest possible FiO2 during OLV improves oxygenation. However, drugs such as Bleomycin, Mitomycin and Amiodarone, have been associated with pulmonary oxygen toxicity when an FiO2 >0.3 was used intraoperatively for thoracic surgery. Continuous positive airway pressure (CPAP) to the non-ventilated lung is the other first-line of defence and treatment.7 Useful increases in oxygenation can be achieved with 1-2 cm H2O CPAP8. CPAP must be applied to the fully inflated lung.9 Even short periods of lung collapse impair the efficiency of CPAP since the opening pressure of atelectatic lung units exceeds 20 cm H2O. Because of the problems which re-inflation may cause at an inopportune surgical moment, it is useful to predict which patients are most at risk of
hyperemia and to apply CPAP prophylactically at the onset of OLV. Increasing cardiac output during OLV increases PaO2 via an increase in mixed venous oxygen content since these patients have such a large shunt.1 PEEP to the ventilated lung decreases PaO2 in the majority of patients during OLV probably by exacerbating the pressure differential between the thoraces. A minority of patients, often those with the poorest PaO2 values, benefit from dependent-lung PEEP10. The beneficial effects of PEEP during OLV are related to changes in the end-expiratory dependent-lung volume and its static compliance curve11. The patients most likely to benefit from PEEP are those patients with an increased A-aO2 gradient in the lateral position during two-lung ventilation and a low level of auto-PEEP during OLV.

During pneumonectomy, lung transplantation or in life threatening situations, the ipsilateral pulmonary artery can be compressed or clamped by the surgeon. Pulmonary artery balloon-tipped floatation catheters can be placed under fluoroscopic control and inflated to decrease regional pulmonary blood flow. High frequency jet ventilation (HFJV) to the operative lung provides superior oxygenation.12 However, HFJV tends to increase the diameter of central airways and can impede surgery during pulmonary resections. HFJV is useful for non-pulmonary intrathoracic surgery. Various pharmacological methods of modulating the unilateral pulmonary vascular tone such as prostaglandin E1 and Nitric Oxide (NO) are now available. The combination of NO (20 ppm) to the ventilated lung and an intravenous infusion of Almitrene (a pulmonary vasoconstrictor) can restore PaO2 during OLV to levels close to these during two-lung ventilation.13 It has been shown that the use of combined thoracic epidural with general anesthesia may decrease PaO2 during OLV14. The clinical relevance of this finding remains to be determined.

Summary: Recent advances in anesthetic equipment and monitoring for lung isolation and in techniques of one-lung ventilation have improved the safety and reliability of one-lung anesthesia for thoracic surgery. The use of a high FiO2 and CPAP to the non-ventilated lung remain the first line of therapy for desaturation during OLV. It is now possible to identify in advance the minority of patients who will benefit from PEEP to the ventilated lung.

REFERENCES