PATIENT INTOLERANCE TO ONE LUNG VENTILATION

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Objectives:

1. To appreciate the individual patient factors which predict the development of hypoxaemia during one-lung ventilation (OLV)
2. To know the prophylactic measures during both two-lung ventilation and OLV that help avoid hypoxaemia during OLV.
3. To understand the recent advances and potential future developments in anaesthetic monitoring equipment and techniques to treat hypoxaemia during OLV.

Etiology of Hypoxaemia.

The major cause of this hypoxaemia is the pulmonary arteriovenous shunt of the de-oxygenated blood through the non-ventilated lung. Factors which influence this shunt are hypoxic pulmonary vasoconstriction, gravity, the pressure differential between the thoraces and physical lung collapse.

The lung, unlike any other organ, vasoconstricts in response to hypoxia. HPV can decrease the regional pulmonary blood flow by up to 50% and is triggered primarily by a decrease in alveolar oxygen tension. Mixed venous oxygen tension is a lesser trigger to HPV and the HPV reflex may fail during severe falls in PaO2.

HPV functions best during normal homeostasis and is inhibited by a wide variety of physical disturbances (acid/base imbalance, temperature changes, surgical trauma, etc.).

First, an excess of intravenous crystalloids can rapidly cause desaturation of the pulmonary venous blood draining the dependent lung. Even though the downstream vascular pressures for both lungs are identical during unilateral hypoxia, because of HPV and pre-capillary vasoconstriction, the hypoxic lung has a lower capillary pressure and less tendency to accumulated interstitial fluid. It is important to avoid intravenous fluid excess in these patients.

Second, the use of nitrous oxide will lead to increased dependent lung atelectasis since it causes greater instability of poorly ventilated lung regions than oxygen.

Third, the use of very small tidal volumes in the relatively non-compliant dependent lung with its reduced functional residual capacity will increase ipsilateral pulmonary vascular resistance and promote alveolar collapse.

Prediction of Hypoxaemia

Several factors have been identified which allow prediction of the risk of hypoxaemia developing during one-lung anaesthesia. The PaO2 during two-lung ventilation either preoperatively when breathing air or, more specifically, during ventilation with a high FiO2 in the lateral position intra-operatively correlates with the PaO2 during one-lung ventilation.
The side of lung collapse affects the PaO$_2$ during one-lung anaesthesia. The larger right lung receives approximately 10% more pulmonary blood flow than the left. Patients with good preoperative spirometric pulmonary function tests tend to have lower PaO$_2$ values during one-lung anaesthesia than patients with poor spirometry.

**Prophylaxis and Treatment**

When hypoxaemia occurs during one-lung anaesthesia, the major cause is shunt in the non-ventilated lung. However, other potential causes such as malposition of an endobronchial tube or inadequate oxygen delivery should be ruled out. Since treatment and prophylaxis of hypoxaemia in this setting have the same underlying principles, they will be discussed together.

Continuous positive airway pressure (CPAP) to the non-ventilated lung is the other first-line of defence and treatment. When compared to a variety of other mechanical techniques to improve oxygenation such as PEEP to the ventilated lung or simple oxygen insufflation of the non-ventilated lungs, CPAP is consistently superior.

The anaesthetic technique has an impact on oxygenation during one-lung ventilation. Among the volatile anaesthetics, Isoflurane has been shown to provide better PaO$_2$ levels than Halothane or Enflurane. At present no intravenous technique such as propofol-alfentanil or other infusions have been shown to be superior to 1 MAC Isoflurane.

A major variable in the choice of anaesthetic technique is maintenance of cardiac output. The current popularity of combining neuraxial blockade with low dose volatile/narcotic anaesthesia for thoracic surgery may have an indirect benefit on PaO$_2$ during one-lung anaesthesia by maintaining cardiac output.

High frequency jet ventilation (HFJV) to the operative lung provides superior oxygenation. 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 such as thoracic aortic aneurysm or oesophageal resections. Re-inflation of the non-dependent lung is a rapid and reliable method of managing hypoxaemia during one-lung anaesthesia. This can be done prophylactically every 5 minutes and may allow a procedure to continue that would otherwise have to be aborted. Due to the individual surgical circumstances, it is not always possible to re-inflate the non-ventilated lung. Depending on the case, it is sometimes viable to individualize a method of oxygen delivery to the non-ventilated lung such as with a separate catheter passed through the operative field into the distal lung during a sleeve or carinal resection.