

Hypoxia

Hypoxemia is defined as a low oxygen tension in the blood. Hypoxia reflects decreased oxygen delivery at the cellular level. Intraoperative hypoxemia is a fall in oxygen saturation of more than 5% absolute value of oxygen saturation below 90%, or an absolute value of arterial pO₂ below 60 mmHg.

ANESTHETIC CONSIDERATIONS:

- Causes of hypoxemia: low FiO₂, hypoventilation, low mixed venous, V/Q mismatch, shunt
- Management:
 - Increase FiO₂ to 100%
 - Check that ventilation is adequate
 - Check the position of the ETT
 - Verify function of the pulse oximeter
 - If situation does not resolve, look for conditions that increase venous admixture
 - Use aggressive pulmonary toilet
 - Consider the addition of PEEP to breathing circuit and maintain large tidal volumes (12-15 mL/kg)
 - Restore adequate circulating blood volume to maintain cardiac output and Hb levels
 - Inform surgeons if difficulty in maintaining oxygenation persists

ANESTHETIC GOALS:

- Simultaneously diagnose and treat a potentially life threatening emergency.
- Prevention and detection of early manifestations and sequelae

ETIOLOGY

- A. **Low FiO₂**
 - Relative – inadequate for the patient's condition eg. high altitude
 - Absolute – problems delivering oxygen to the breathing circuit, hypoxic mixture
- B. **Hypoventilation**
 - Failure to maintain airway
 - Upper airway obstruction
 - Decreased level of consciousness
 - Failure to ventilate
 - Machine issues
 - Surgical issues
 - Retraction
 - Intra-abdominal insufflation
 - Patient issues
 - Pneumothorax
 - Bronchospasm
 - Light anesthesia
 - Morbid obesity
 - Drugs causing respiratory depression
- C. **Low mixed venous**
 - Low cardiac output
 - Anemia
 - Hemorrhage
 - High oxygen consumption
- D. **V/Q mismatch**
 - Pre-existing lung disease
 - Pulmonary edema
 - Atelectasis
 - Aspiration
 - Pulmonary embolus
- E. **Shunt**
 - Cardiac lesions with potential for right to left shunt (ASD, VSD, PDA)
 - Intrapulmonary shunts eg. hepatopulmonary syndrome, pregnancy

OTHER CLASSIFICATION

- A. Machine
 - Problems delivering oxygen
- B. Circuit
 - Leaks, problems – disconnects, rebreathing
- C. Tube
 - Endotracheal
 - Endobronchial
 - Kinked / obstructed
- D. Large airways
 - Mucus / plug / pus / clot
- E. Small airways
 - Reactive – asthma, anaphylaxis
- F. Lung space
 - Pre-existent: obstructive, interstitial, restrictive
 - Acquired: aspiration, pneumonia, pulmonary edema
- G. Pulmonary vasculature
 - Emboli

- Shunt (R to L)
- H. Pleural
 - Pneumothorax
 - Hemothorax
 - Hydro or chylothorax
- I. Chestwall
 - Rigid chest wall – narcotics
 - Inadequate depth of anesthesia, coughing or straining
 - Excess depth
- J. Low mixed venous oxygen
 - Low cardiac output
 - Low Hb

TYPICAL SITUATIONS

- Inadequate ventilation from any cause
 - Failure to maintain the airway during general anesthesia
 - Failure to ventilate adequately during general anesthesia
 - Morbid obesity
- Patients with increased A-a gradient
 - Pre-existing lung disease
 - Pulmonary edema
 - Aspiration of gastric contents
 - Atelectasis
 - Pulmonary embolus
- Patients at extremes of age are more likely to have anatomic features or disease states that compromise oxygenation

MANIFESTATIONS

- Decreased or low oxygen saturation measured by pulse oximetry is the cardinal sign of hypoxemia
- Pulse oximetry may not function properly in the presence of
 - Hypothermia
 - Poor peripheral circulation
 - Artifacts due to electrocautery, motion, or ambient lighting
- Cyanosis or dark blood in the surgical field
 - Clinically detectable cyanosis corresponds to an arterial oxygen saturation of approximately 85% and requires 5g of reduced hemoglobin; it may therefore be masked by anemia
 - Hypoxemia can be difficult to recognize clinically under anesthesia, as the circulatory and respiratory responses to hypoxemia are blunted by anesthetic agents; late signs of hypoxemia include:
 - BRADYCARDIA
 - Myocardial arrhythmias/ischemia
 - Tachycardia
 - Hypotension
 - Cardiac arrest

MANAGEMENT

- Assume that low oxygen saturation indicates hypoxemia until proven otherwise
 - Development of hypoxemia within 10 minutes of intubation must be assumed to be due to esophageal intubation unless the ETT can be visualized passing through the cords or capnography demonstrates normal end-tidal CO₂
- Increase FiO₂ to 100%
 - Use high oxygen flow to equilibrate the breathing circuit rapidly
 - Verify that FiO₂ approaches 100%
- Check that ventilation is adequate
 - Check end-tidal CO₂ if available (may not reflect adequacy of ventilation if V/Q mismatch is large)
 - Switch to hand ventilation to assess pulmonary compliance
 - Hand ventilate with large tidal volumes to expand collapsed lung segments
 - Auscultate the breath sounds bilaterally, assess the adequacy and symmetry of chest movement
 - Obtain ABGs including Hb
- Check the position of the ETT
 - Auscultation
 - Direct visualization of ETT at mouth opening
 - Direct visualization of ETT cuff below cords
 - Fiberoptic bronchoscopy to visualize tracheal rings and the carina
 - Adjust the position of the ETT if necessary
- Verify function of the pulse oximeter
 - Do not fixate on oximeter function. Monitor the patient carefully while ruling out artifacts and transients
 - Correlate oximeter readings with activation of electrocautery
 - Check the probe position
 - Shield the probe from ambient light
 - Assess adequacy of oximeter signal amplitude
 - Change the site of the probe (from finger to ear)
- If situation does not resolve, look for conditions that increase venous admixture
 - Pulmonary aspiration of gastric contents
 - Massive atelectasis/aspiration of foreign body
 - Pulmonary emboli
 - Bronchospasm
 - Increased intracardiac shunting in congenital heart disease
 - Check again to rule out pneumothorax, with a CXR if necessary
- Use aggressive pulmonary toilet
 - Suction ETT
 - Consider bronchoscopy
- Consider the addition of PEEP to breathing circuit and maintain large tidal volumes (12-15 mL/kg)

- Restore adequate circulating blood volume to maintain cardiac output and Hb levels
- Inform surgeons if difficulty in maintaining oxygenation persists
 - Check for retractors causing difficulty with ventilation
 - Check that patient in the prone position has not slipped off chest supports, placing pressure on the diaphragm; prepare to transfer the patient to the supine position emergently
 - Terminate surgery as soon as possible
 - Arrange for ICU transfer for postoperative care

PREVENTION

- Perform a careful check of the anesthesia machine, oxygen analyzer, and alarms before use
- Maintain adequate ventilation, using appropriate clinical and electronic monitors
- Monitor and adjust FiO₂ as necessary to maintain patient oxygenation
- Keep lung volumes in high normal range with large tidal volumes during mechanical ventilation
- Avoid spontaneous ventilation in patients with lung disease or when the patient is not in the supine position

COMPLICATIONS

- Cardiac arrest (when hypoxemia precipitates cardiac arrest it is frequently associated with permanent neurologic injury regardless of the success of CPR)
- Neurologic injury manifested as confusion, coma, delayed recovery from anesthesia
- Arrhythmias
- Hypotension
- Bradycardia

REFERENCES

- Crisis Management in Anesthesiology
- Dr. Haugen's lecture on Hypoxia