Independent Lung Ventilation

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Learning Objectives:

- Explain the rationale and physiological basis for independent lung ventilation (ILV)
- Identify clinical indications for ILV.
- Describe the permutations of ILV.
- Describe the equipment applied to ILV.
- Explain the airway management procedures applied to ILV.
- Explain the monitoring techniques applied to ILV.
- Explain the ILV strategies applied to specific conditions.

Description- ILV

- ILV is a ventilation strategy wherein the lungs are ventilated separately using a double-lumen tracheal tube (DLT).
  - Initially developed to isolate lungs during surgical procedures
  - Subsequently applied beyond the operating room for unilateral lung conditions

ILV Indications & Rationale

- During thoracic surgical procedures- ventilate one lung, while other one is resected, removed.
- Lung lavage- ventilate each lung while other lung is lavaged, as for:
  - Alveolar proteinosis
  - Cystic fibrosis

FYI - Link to information on lung lavage
http://respiratory-research.com/content/6/1/138

ILV Indications & Rationale

- Massive hemoptysis- may ventilate only one lung
- Unilateral purulent infection- prevent spread of infection to healthy lung
- Single lung transplant- donor lung may have significantly different mechanical properties

FYI - Link to indications and rationale for lung isolation
http://www.anesthesia.org/winterlude/w097/W_LungIsolation.html
ILV- Indications & Rationale
- Bronchopleural fistula (BPF) - ventilate diseased lung (DL) with decreased volume & pressures to permit healing
- Unilateral lung disease; e.g., pulmonary contusion - ventilate diseased lung (DL) without injuring normal lung (NL)

ILV- Permutations
- Synchronized ILV- ventilators interconnected to synchronize triggering
- Asynchronous ILV- ventilators operated independently

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- ILV with conventional ventilation and high-frequency ventilation

ILV Equipment

Airways
- Double-lumen tracheotomy tubes
- Double-lumen endotracheal tube
- Endotracheal tubes with blocker-used for one-lung ventilation
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- Double-lumen tracheotomy tubes
- Double-lumen endotracheal tube
- Endotracheal tubes with blocker - used for one-lung ventilation
  - Arndt wire-guided endobronchial blocker (Cook Critical Care)
  - Univent TCB tube

Double-lumen endotracheal tube (DLT) AKA Carlens tube
- Bronchial cuff
- Tracheal cuff
- Ventilator connectors

Univent Torque Control Blocker (TCB) tube
- CPAP
- Insufflation
- Exhaust

Monitoring equipment
- End-tidal CO2 monitors (2)
- Ventilation graphic monitors
- Cuff pressure manometer

SILV Capable Ventilators
- Siemens Servo 900C
- Siemens 300
- Bennett 7200
- Draeger Evita
- Note - non-synchronized ILV may be as effective
ILV Airway Management

Intubation
- Done by trained anesthesiologist
- Estimation of depth - preoperative radiograph
- Selection of tube size
  - too small - inadequate isolation
  - too large - airway trauma

Intubation
- Placed with:
  - standard fiberoptic bronchoscopy
  - video-assisted bronchoscopy
  - video-optical stylet

Click to see intubation with video-optical stylet
http://www.youtube.com/watch?v=Dyjq6BlEkps

Intubation
- Left bronchus intubated, because:
  - it is longer (4-5 cm) - correct placement and maintenance is more likely than with right
  - intubation of right bronchus (1.5-2 cm) is more difficult
- Right bronchus intubated for left bronchial surgery

Click for video on function of left DLT
http://www.youtube.com/watch?v=HfY5060Q2h4

Confirmation of Tube Placement
- auscultation - unreliable as sole indicator - 61% failure rate (left)
- sequential ventilation of individual lungs - listen & observe for ventilation of contralateral lung
- bronchoscopy - gold standard

Functional Separation
- failure of ventilatory separation results from tube cuff failure or underinflation
- detected by sequentially ventilating lungs and detecting tidal volume from non-ventilated lung - place on spontaneous mode
Maintaining Tube Placement

- movement by as little as 16 mm can compromise ILV
- prevention of misplacement
  - paralysis, sedation of patient
  - secure tube-anchoring technique
  - ventilator tube suspension; e.g. ventilator arms, angel frames
  - extreme caution, if and when turning patient

Suctioning

- preoxygenate with both ventilators
- suction catheter
  - 8-10 Fr.
  - 22-24 cm (adult length)
- thick secretions difficult to suction through smaller catheters ==> adequate humidification is critical

Cuff Management

- As little as 4.0 ml in cuff may generate excessive pressure on tracheal/bronchial wall
- With appropriate-size tube, a seal should be accomplished with 2.0-3.5 ml.

Cuff Management

- Monitoring should include:
  - minimal occlusive volume
  - cuff pressure

Complications of DLTs

- tracheal or bronchial trauma-rupture
  - inappropriate tube size
  - excessive cuff volume
  - nitrous oxide anesthesia- diffuses into cuff, increasing volume

Complications of DLTs

- malpositioning
  - lack of functional separation
  - unilateral ventilation
  - inability to suction
- increased airway resistance
- laryngeal, vocal cord trauma
- patient discomfort

FYI - Click for article on lung isolation techniques
http://www.anesthesia.org/winterlude/wl97/W_LungIsolation.html
Ventilation Techniques

General Strategies
- One lung ventilation
- Ventilation for bronchopleural fistula
- Ventilation for unilateral lung disease

One Lung Ventilation
- Primarily, an operating room technique
- Airways used
  - Univent tube
  - DLT with bronchial blocker
- Poorly-tolerated in some patients
- Invokes a 35-40% shunt, which is worse if:
  - larger, right lung is non-ventilated
  - ventilated lung is diseased
  - nitrous oxide anesthesia is used

Shunt, which can be reduced by:
- applying CPAP to non-ventilated lung
- using isoflurane anesthesia
- intermittent re-inflation of non-ventilated lung
- administering inhaled vasodilator to ventilated lung to increase perfusion:
  - nitric oxide
  - prostacyclins (e.g., Flolan)
**ILV For BPF**

- BPF defined: persistent bronchopleural airleak
- Associated with high mortality

**BPF**

**Causes:**
- Ventilator-induced lung injury
- Surgical complication; e.g. bronchial stump rupture
- Trauma
- Necrotizing pulmonary infection
- Bullous emphysema (predisposing factor)

**BPF**

**Manifestations:**
- Persistent airflow through chest tube
- Exhaled tidal volume significantly less than inhaled volume
- Ventilatory failure refractory to increased ventilation settings

**BPF**

**Manifestations:**
- $\text{PaCO}_2, \text{EtCO}_2$ likely decreased, due to excretion of $\text{CO}_2$ through chest tube
- Elevated $\text{PaCO}_2$ reflects severe disease in the lung without fistula

FYI - Click to download article on BPF
http://www.chestjournal.org/content/128/6/3955.full.pdf

**BPF**

**Problem:** Conventional ventilation applies equal pressures to lungs, worsening leak, preventing healing of fistula.

- ILV permits ventilation of DL at reduced pressure & volume, while ventilating NL.

**BPF**

**Alternative measures:**
- Manipulation of chest tube suction
- Obstruction of chest tube during inspiration
- High-frequency ventilation - success is not substantiated
**Goals**
- Oxygenate, ventilate patient
- Permit healing of BPF
- Avoid tension pneumothorax

**Procedure**
- Place chest tube large enough to accommodate leak to avoid tension pneumothorax
- Minimize pleural suction

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**Procedure**
- Connect to two ventilators
- If synchronized, label ventilators
- If synchronized, rate for both will be adjusted with master ventilator
- Secure, suspend ventilator circuit

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**Procedure**
- Ventilate DL to minimize air flow through fistula
  - Adjust TV, PIFR for PIP < 30 cm H2O
  - PEEP ≤ 6 cm H2O

**Procedure**
- Ventilate NL
  - Adequate oxygenation
  - CO2 removal usually not problematic
  - Lung protective strategies
ILV For BPF

- Monitoring
  - tube position
    - tube length markings
    - auscultation
    - bronchoscopy, if misplacement suspected

- Monitoring
  - tube position
    - tube length markings
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  - cuff inflation
    - cuff pressure
    - minimal occlusive volume

ILV For BPF

- Monitoring
  - volume of bpf leak = (TVi - TVe)
  - lung mechanics
    - static compliance
    - airway resistance
    - plateau pressure
    - total PEEP
  - EtCO2- increased CO2 from DL indicates less leakage

- Monitoring
  - when air leak reaches minimal volume
  - replace DLT with ETT and ventilate with minimal plateau pressure (Ppt)

ILV For Unilateral Lung Disease

- Conditions- unilateral:
  - blunt trauma- pulmonary contusion
  - pneumonia, aspiration pneumonitis
  - ARDS
  - re-expansion/re-perfusion pulmonary edema
  - single lung transplant

FYI - Link to information on re-expansion/reperfusion pulmonary edema
http://www.learningradiology.com/notes/chestnotes/reexpandpulmedepage.htm

- Problem- DL has decreased compliance =>
  - with conventional ventilation, tidal volume goes to NL
ILV For Unilateral Lung Disease

Problem: DL has decreased compliance =>
- with conventional ventilation, TV goes to NL
- increasing ventilation pressures causes:
  - perfusion to shift to DL => increased shunt
  - overexpansion of NL => volutrauma

Goals

- improve ventilation-perfusion matching by maximizing recruitment in DL
- avoid barotrauma/volutrauma by using lung-protective strategies for each lung

Procedure

- determine need for ILV
  - unilateral disease, as per chest radiograph
  - failure to oxygenate with conventional ventilation

- place & confirm placement of DLT as for BPF
- connect to two ventilators, as for BPF
- adjust frequency to physiologic range- avoid inadvertent PEEP
- adjust each TV for plateau pressure Ppt < 26 cm H2O

- identify best PEEP for DL
- maintain TV for plateau pressure Ppt ≤ 26 cm H2O
- as Ppt in DL decreases, increase TV to attain 26 cm H2O

Monitoring

- tube position, as for BPF
- cuff inflation, as for BPF
- lung mechanics, as for BPF
- EtCO2 (if available)- evaluates ventilation-perfusion matching
- usual critical care monitors- ECG, SPO2, etc.

FYI - Link to information on EtCO2 monitoring with DLTs
http://www.capnography.com/Thoracic/dlt.htm
ILV For Unilateral Lung Disease

◆ Discontinuation
  ▶ determining readiness
    ▶ when Cst between lungs differs less than 20%
    ▶ when TVs are within 100 ml
    ▶ when EtCO2 equalizes
  ◆ replace DLT with standard ETT
  ◆ apply conventional ventilation

Final Notes

◆ ILV is a complex procedure, requiring special knowledge, skills and attention to detail on the part of all caregivers.
◆ ILV should not be undertaken by those without the requisite skills, knowledge or attentiveness.

Summary and Review

◆ Indications for ILV
◆ Rationale
◆ Permutations for ILV
◆ ILV equipment
  ◆ special endotracheal tubes
  ◆ ventilators
  ◆ monitoring equipment

Summary and Review

◆ Techniques for ILV
  ◆ single lung ventilation
  ◆ bronchopulmonary fistula
  ◆ unilateral lung disease

References


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