Independent Lung Ventilation

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This Presentation is Approved for
1 CRCE Credit Hour

Learning Objectives

- Explain the rationale & 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

ILV Indications & Rationale

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 see links below for information on lung lavage

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 see links below for indications
& rationale for lung isolation

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

ILV: Permutations

- Synchronized ILV: ventilators interconnected to synchronize triggering
- Asynchronous ILV: ventilators operated independently
- ILV with conventional ventilation & high-frequency ventilation

ILV: Permutations

- ILV, using pressure-controlled, inverse ratio ventilation to one lung
- Single lung ventilation

ILV Equipment

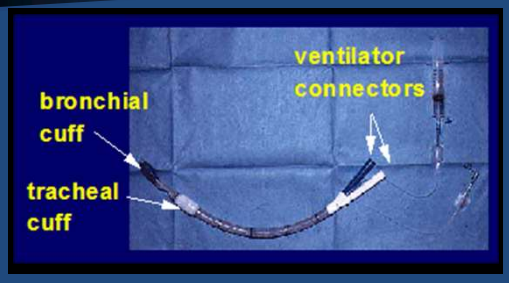
Airways

- Double-lumen tracheotomy tubes
- Double-lumen endotracheal tube
- Endotracheal tubes with blocker: used for one-lung ventilation

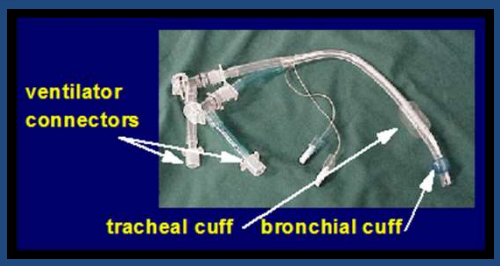
Airways

- 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 Tracheostomy Tube



Double-Lumen Endotracheal Tube (DLT) AKA Carlens Tube



Univent Torque Control Blocker (TCB) Tube

- CPAP
- Insufflation
- Exhaust

Next Lesson: Video of bronchial blocker insertion

SILV Capable Ventilators

- Siemens Servo 900C
- Siemens 300
- Bennett 7200
- Draeger Evita
- Note: non-synchronized ILV may be as effective

Monitoring Equipment

- End-tidal CO_2 monitors (2)
- Ventilation graphic monitors
- Cuff pressure manometer

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

Up next: Video of intubation with video-optical stylet

Intubation

- Left bronchus intubated, because
  - It is longer (4 - 5 cm): correct placement & 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

Up next: Video on function of left DLT

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 & 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 & 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

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

One Lung Ventilation

- 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

One Lung Ventilation

- Shunt, which can be reduced by
  - Applying CPAP to non-ventilated lung
  - Using isoflurane anesthesia
  - Intermittent re-inflation of non-ventilated lung

One Lung Ventilation

- Shunt, which can be reduced by
  - Administering inhaled vasodilator to ventilated lung to increase perfusion
    - Nitric oxide
    - Prostacyclins (e.g. Flolan)

ILV for BPF

- BPF defined: persistent bronchopleural air leak
- 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 air flow through chest tube
  - Exhaled tidal volume significantly less than inhaled volume
  - Ventilatory failure refractory to increased ventilation settings

BPF

- Manifestations
  - $PaCO_2$, $EtCO_2$ likely decreased, due to excretion of CO_2 through chest tube
  - Elevated $PaCO_2$ reflects severe disease in the lung without fistula

FYI see links below for article on BPF

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

ILV for BPF

- Goals
  - Oxygenate, ventilate patient
  - Permit healing of BPF
  - Avoid tension pneumothorax

ILV for BPF

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

ILV for BPF

- Procedure
  - Place DLT
  - Minimize cuff pressure
  - Monitor tube position
    - Tube length marks @ teeth
    - Auscultation
    - Ability to suction
    - Bronchoscopy, if misplacement suspected

ILV for BPF

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

ILV for BPF

- Procedure
  - Ventilate DL to minimize air flow through fistula
    - Adjust TV, PIFR for PIP < 30 cm H_2O
    - PEEP ≤ 6 cm H_2O

ILV for BPF

- Procedure
  - Ventilate NL
    - Adequate oxygenation
    - CO_2 removal usually not problematic
    - Lung protective strategies

ILV for BPF

- Monitoring
  - Tube position
    - Tube length markings
    - Auscultation
    - Bronchoscopy, if misplacement suspected

ILV for BPF

- Monitoring
  - Tube position
    - Tube length markings
    - Auscultation
    - Bronchoscopy, if misplacement suspected
  - 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
  - $EtCO_2$: increased CO_2 from DL indicates less leakage

ILV for BPF

- Discontinuance of ILV
  - When air leak reaches minimal volume
  - Replace DLT with ETT & 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 see links below for information on re-expansion/re-perfusion pulmonary edema

ILV for Unilateral Lung Disease

- Problem: DL has decreased compliance →
  - With conventional ventilation, TV 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

ILV for Unilateral Lung Disease

- Goals
  - Improve ventilation-perfusion matching by maximizing recruitment in DL
  - Avoid barotrauma/volutrauma by using lung-protective strategies for each lung

ILV for Unilateral Lung Disease

- Procedure
  - Determine need for ILV
    - Unilateral disease, as per chest radiograph
    - Failure to oxygenate with conventional ventilation

ILV for Unilateral Lung Disease

- Procedure
  - 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 H_2O

ILV for Unilateral Lung Disease

- Procedure
  - Identify best PEEP for DL
  - Maintain TV for plateau pressure Ppt ≤ 26 cm H_2O
  - As Ppt in DL decreases, increase TV to attain 26 cm H_2O

ILV for Unilateral Lung Disease

- Monitoring
  - Tube position, as for BPF
  - Cuff inflation, as for BPF
  - Lung mechanics, as for BPF
  - $EtCO_2$ (if available): evaluates ventilation-perfusion matching
  - Usual critical care monitors: ECG, SPO_2, etc.

FYI see links below for information on $EtCO_2$ monitoring with DLTs

ILV for Unilateral Lung Disease

- Discontinuation
  - Determining readiness
    - When Cst between lungs differs less than 20%
    - When TVs are within 100 ml
    - When $EtCO_2$ equalizes
  - Replace DLT with standard ETT
  - Apply conventional ventilation

Final Notes

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

Summary & Review

- Indications for ILV
- Rationale
- Permutations for ILV
- ILV equipment
  - Special endotracheal tubes
  - Ventilators
  - Monitoring equipment

Summary & Review

- Techniques for ILV
  - Single lung ventilation
  - Bronchopulmonary fistula
  - Unilateral lung disease

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