Independent Lung Ventilation

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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

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.

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

Click for video of lung lavage (2.5 min)
https://www.youtube.com/watch?v=n4sSEb_o9L8

ILV Indications & Rationale

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

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

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

ILV- Permutations

- synchronized ILV- ventilators interconnected to synchronize triggering
- asynchronous ILV- ventilators operated independently

ILV Equipment

ILV- Permutations

- synchronized ILV- ventilators interconnected to synchronize triggering
- asynchronous ILV- ventilators operated independently
- ILV with conventional ventilation and high-frequency ventilation

Airways

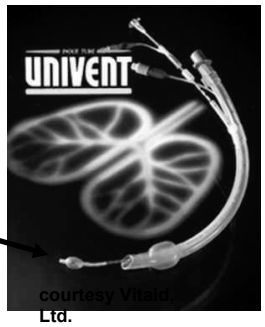
- double-lumen tracheotomy tubes
- double-lumen endotracheal tube
- endotracheal tubes with blocker- used for one-lung ventilation

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

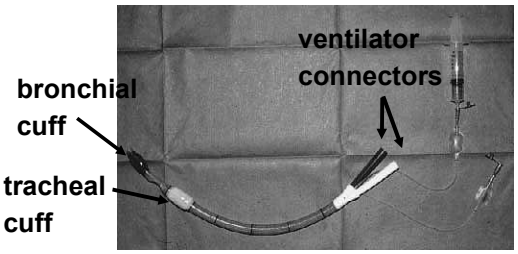
Univent Torque Control Blocker (TCB) tube

- CPAP
- insufflation
- exhaust



Click to see video of bronchial blocker insertion (1.5 min)
http://www.youtube.com/watch?v=FilZIDtQNDM

Double-lumen tracheostomy tube

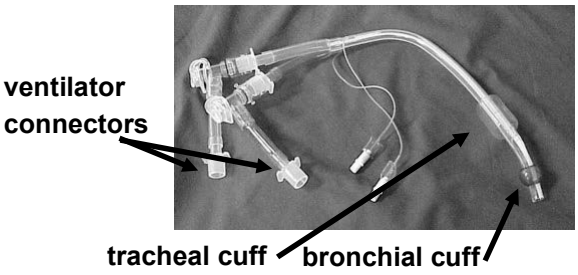


SILV Capable Ventilators

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

Click for photo of patient with ILV
https://file.scirp.org/Html/8-1960090/2fb957e9-b004-43bb-b815-daf233aafc55.jpg

Double-lumen endotracheal tube (DLT) AKA Carlens tube



Monitoring equipment

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

ILV Airway Management

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 (1 min)
http://www.youtube.com/watch?v=HfY5060Q2h4

Intubation

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

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

Intubation

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

Click to see intubation with video-optical stylet (3.5min)
http://www.youtube.com/watch?v=Dvjq0B6E8qs

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

Cuff Management

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

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

Complications of DLTs

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

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.

Complications of DLTs

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

Ventilation Techniques

Single 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

General Strategies

- Single lung ventilation
- Ventilation for bronchopleural fistula
- Ventilation for unilateral lung disease

Single 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

- Primarily, an operating room technique
- Airways used
  - Univent tube
  - DLT with bronchial blocker

Single 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

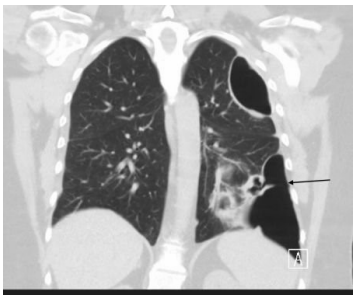
- BPF defined- persistent bronchopleural airleak
- Associated with high mortality

Click for video about bronchppleural fistula
https://www.youtube.com/watch?v=73Ce19z0ry0

BPF

- Manifestations:
  - persistent air flow through chest tube
  - exhaled tidal volume significantly less than inhaled volume
  - ventilatory failure refractory to increased ventilation settings

BPF



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

BPF

- Causes:
  - ventilator-induced lung injury
  - surgical complication; e.g. bronchial stump rupture
  - trauma
  - necrotizing pulmonary infection
  - bullous emphysema (predisposing factor)

BPF Medical, Surgical Management

- Prevention is best
  - avoid CMV in post-op pneumonecty, lobectomy patients
  - gentle ventilation when necessary
- Surgical correction
- Antibiotics
- Bronchial blockers
- Bronchoscopic instillation of solutions to granulate fistula
- Laser procedure

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.

ILV For BPF

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

BPF

- Alternative measures:
  - manipulation of chest tube suction
  - obstruction of chest tube during inspiration
  - high-frequency ventilation- success is not substantiated

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

- Goals
  - oxygenate, ventilate patient
  - permit healing of BPF
  - avoid tension pneumothorax

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 H2O
    - PEEP ≤ 6 cm H2O

ILV For BPF

- Monitoring
  - tube position
    - tube length markings
    - auscultation
    - bronchoscopy, if misplacement suspected
  - cuff inflation
    - cuff pressure
    - minimal occlusive volume

ILV For BPF

- Procedure
  - ventilate NL
    - adequate oxygenation
    - CO2 removal usually not problematic
    - lung protective strategies

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

ILV For BPF

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

ILV For BPF

- Discontinuance of ILV
  - 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

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

- Problem- DL has decreased compliance ==>
  - with conventional ventilation, tidal volume goes to NL

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

- 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

- 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 $\leq$ 26 cm H2O

ILV For Unilateral Lung Disease

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

ILV For Unilateral Lung Disease

- 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.

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

- Slinger P. Lung isolation techniques. http://www.anesthesia.org/winterlude/wl97/W_Lung Isolation.html
- Slinger P. The patient intolerant of one-lung ventilation. http://www.anesthesia.org/winterlude/wl97/L_1LungVent.html
- Hitoshi Taguchi, et al. Airway troubles related to the double-lumen endobronchial tube in thoracic surgery. J Anesth 1997 11:173-178. http://old.anesth.or.jp/JOURNAL2000/J11-3.HTM
- Cinnella, et al. Independent lung ventilation in patients with unilateral pulmonary contusion. Monitoring with compliance and EtCO2. Intensive care med 2001;27:1860.
- Ost D, Corbridge T. Independent lung ventilation. Clin in chest medicine 1996;17:591.
- Feeley, TW, Keating D. Nashimura T. Independent lung ventilation in the management of bronchopleural fistula. Anesthesiology 1988;69:420.

END

References

- Watts DC, et al. Pressure-controlled inverse ratio synchronized independent lung ventilation for a blast wound to the chest. Clinical intensive care 1991;2:356.
- Hurst JM, DeHaven B, Branson R. Comparison of conventional mechanical ventilation and synchronized independent lung ventilation in the treatment of unilateral lung injury. J of Trauma 1985;25:766.
- Pierson DJ. Management of bronchopleural fistula in the adult respiratory distress syndrome. New Horizons 1993;1:512.
- Klafka J. Bronchial blockers offer certain advantages for lung separation. Society of cardiovascular anesthesiologists newsletter 2002. http://www.scahq.org/sca3/newsletters/2002june/con.shtml

References

- Weiss M, Kern K, Gerber AC. Management of left-sided double lumen tube placement using a video-optical intubation stylet. The internet journal of anesthesiology. http://www.ispub.com/ostia/index.php?xmlFilePath= journals/ija/vol3n3/dltvideo.xml
- Slinger P. Fiberoptic bronchoscopic positioning of double-lumen tubes. J of Cardiothoracic Anesthesia 1989;3:486.
- Berg S, Bittner EA, Berra L, Kacmarek RM, Sonny A. Independent lung ventilation: Implementation strategies and review of literature. World J Crit Care Med. 2019;8(4):49–58. Published 2019 Jul 31. doi:10.5492/wjccm.v8.i4.49