

Independent Lung Ventilation

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<http://www.geocities.com/jonesapjr/index.html>

Learning Objectives

- ^ Describe the rationale, clinical indications and equipment needed for independent lung ventilation (ILV)
- ^ Describe the implementation, monitoring and discontinuation procedures for ILV.

ILV Indications & Rationale

Description- ILV

- ^ ILV is a ventilation strategy wherein the lungs are ventilated separately using a double-lumen tracheal tube.

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

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

link to indications and rationale for lung isolation
http://www.anesthesia.org/winterlude/w197/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

ILV- Permutations

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

ILV- Permutations

- ^ ILV, using pressure-controlled, inverse ratio ventilation
- ^ ILV using one ventilator and a variable resistance valve
- ^ one-lung ventilation

ILV Equipment

ILV- Equipment

^ Airways

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

Link to Cook Critical Care web site
<http://www.cookmedical.com/cc/home.do>

ILV- Equipment

^ Airways

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

Link to information on bronchial blockers
<http://www.scahq.org/sca3/newsletters/2002june/con.shtml>

ILV- Equipment

^ Univent Torque Control Blocker (TCB) tube

- ◆ CPAP
- ◆ insufflation
- ◆ exhaust

Link to Vitaid web site
<http://www.vitaid.com/canada/about/privacycode.htm>

ILV- Equipment

^ Ventilators capable of synchronized ILV, with master-slave cable

- ◆ Siemens Servo 900C
- ◆ Siemens 300
- ◆ Bennett 7200
- ◆ Draeger Evita

^ Note- non-synchronized ILV may be as effective

ILV- Equipment

^ Monitoring equipment

- ◆ End-tidal CO2 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

Link to information on video-optical stylet
<http://www.ispub.com/ostia/index.php?xmlFilePath=journals/ija/vo13n3/dltvideo.xml>

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

Link to information and images on function of left DLT
<http://www.usyd.edu.au/su/anaes/lectures/dlt.html>

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
 - ◆ inflation of balloon, placed over connector for non-ventilated lung

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

- ^ pre-oxygenate 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 or minimal leak technique
 - ◆ 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 vasodilator to ventilated lung to increase perfusion:
 - f* nitric oxide
 - f* prostacyclins (e.g., Flolan)

ILV For BPF

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

BPF

^ Causes:

- ◆ excessive ventilation plateau pressure, as with ARDS
- ◆ surgical complication; e.g. bronchial stump rupture
- ◆ trauma
- ◆ necrotizing pulmonary infection
- ◆ 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:

- ◆ PaCO₂, EtCO₂ likely decreased, due to excretion of CO₂ through chest tube
- ◆ elevated PaCO₂ reflects severe disease in the lung without fistula

Link to information and images pertaining to BPF
<http://www.webio.hu/broncho/album/album28.php>

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
 - f* tube length marks @ teeth
 - f* auscultation
 - f* ability to suction
 - f* 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
 - f* adjust TV, PIFR for $PIP < 30 \text{ cm H}_2\text{O}$
 - f* $PEEP \leq 6 \text{ cm H}_2\text{O}$

ILV For BPF

^Procedure

- ◆ventilate NL
 - f* adequate oxygenation
 - f* CO₂ removal usually not problematic
 - f* lung protective strategies

ILV For BPF

^Monitoring

- ◆tube position
 - f* tube length markings
 - f* auscultation
 - f* bronchoscopy, if misplacement suspected

ILV For BPF

^Monitoring

- ◆ tube position
 - f tube length markings
 - f auscultation
 - f bronchoscopy, if misplacement suspected
- ◆ cuff inflation
 - f cuff pressure
 - f minimal leak technique or minimal occlusive volume

ILV For BPF

^Monitoring

- ◆ volume of bpf leak = $(TV_i - TV_e)$
- ◆ lung mechanics
 - f static compliance
 - f airway resistance
 - f plateau pressure
 - f total PEEP
- ◆ EtCO₂- increased CO₂ from DL indicates less leakage

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

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

ILV For Unilateral Lung Disease

^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:
 - f perfusion to shift to DL ==> increased shunt
 - f 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
 - f* unilateral disease, as per chest radiograph
 - f* 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 H₂O (5-7 ml/kg)

ILV For Unilateral Lung Disease

^Procedure

- ◆ 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

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.

Link to information on EtCO₂ monitoring with DLTs
<http://www.capnography.com/Thoracic/dlt.htm>

ILV For Unilateral Lung Disease

^Discontinuation

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

Special Personnel Requirements

- △ Anesthesiologist
 - ◆ physically available around- the- clock (ATC)
 - ◆ skilled with bronchoscopy and DLT placement

Special Personnel Requirements

- △ Primary physician (pulmonologist or anesthesiologist)
 - ◆ available for communication ATC
 - ◆ knowledgeable and skilled in:
 - f* lung protective strategies
 - f* ventilatory mechanics
 - f* EtCO₂ monitoring

Special Personnel Requirements

- △ respiratory therapist
 - ◆ within seconds of bedside ATC
 - ◆ knowledgeable and skilled in:
 - f* patient assessment
 - f* airway management
 - f* ventilator management
 - f* lung protective strategies
 - f* monitoring/interpreting ventilatory mechanics
 - f* monitoring/interpreting EtCO₂

Special Personnel Requirements

- △ critical care nurse
 - ◆ within seconds of bedside ATC
 - ◆ knowledgeable and skilled in:
 - f* patient assessment
 - f* airway management
 - f* recognition of ventilator malfunction
 - f* critical care monitoring

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

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