THORACIC ANESTHESIA

A. NEYRINCK
LUNG ISOLATION DEVICES
indications for one-lung ventilation

INDICATIONS FOR ONE-LUNG VENTILATION

**ABSOlute**

1. Isolation of each lung to prevent contamination of a healthy lung  
   a. Infection (abscess, infected cyst)  
   b. Massive hemorrhage
2. Control of distribution of ventilation to only one lung  
   a. Bronchopleural fistula  
   b. Bronchopleural cutaneous fistula  
   c. Unilateral cyst or bullae  
   d. Major bronchial disruption or trauma
3. Unilateral lung lavage
4. Video-assisted thoracoscopic surgery

**Relative**

1. Surgical exposure—high priority  
   a. Thoracic aortic aneurysm  
   b. Pneumonectomy  
   c. Upper lobectomy
2. Surgical exposure—low priority  
   a. Esophageal surgery  
   b. Middle and lower lobectomy  
   c. Thoracoscopy under general anesthesia

devices for one-lung ventilation

- bronchial blocker
  - Univent tube
  - fogarty catheter
  - bronchus blocker
    - wire guided (Arndt bronchus blocker)
    - flex-tip (Cohen bronchial blocker)
    - Fuji uniblocker
    - fogarty catheter
    - EZ-blocker

- double lumen tube
  - right sided
  - left sided
bronchial blockers
bronchial blockers: Arndt

AVAILABLE SIZES

9 Fr Spherical
9 Fr Elliptical
5 Fr Pediatric Spherical
bronchial blocker: arndt
bronchial blocker: EZ-blocker
bronchial blocker: univent tube

UNIVENT – The new concept for one lung anesthesia

PHYCON
UNIVENT
INOUE TUBE
double lumen tube: left versus right sided
double lumen tube: left versus right sided
1. CONFIRM ADEQUATE DEPTH OF ANESTHESIA AND MUSCLE RELAXATION FIRST
2. direct/indirect laryngoscopy (insert gastric tube first when good visualisation)
3. turn DLT 90° to the right
4. insert bronchial cuff through vocal cords with stiff stylet in situ
   – cave not to injure left vocal cord
   – if insertion is not succesful, then turn DLT en head more to the right
5. remove stiff stylet and turn DLT 90° to the left
6. insert DLT until tracheal cuff passes vocal cords
7. inflate tracheal cuff and start mechanical ventilation and inhaled anesthetics
8. **FIBEROPTIC CONTROL OF POSITION**
   1. forward fiberoptic scope through bronchial lumen
      • identification of proximal airway anatomy and left/right side
      • forward bronchial cuff in in left main stem bronchus proximal to secundary carina
   2. forward fiberoptic scope through tracheal lumen
      • upper side of left bronchial cuff just visible (blue)
      • radio-opaque marker is situated 1 cm proximal to bronchial cuff
      • check inflation of bronchial cuff to exclude herniation
9. optional: **check for functional lung isolation**
   1. clamp left and right lumen sequentially and check for air-leak in water slot to opposite side
   2. clamp left and right lumen sequentially and check ventilation by auscultation
   3. clamp left and right lumen sequentially and check for air-leak on anesthesia-machine
      cave: adjust ventilatory settings for OLV when clamping one lumen!
10. reconfirm position with fiberoptic scope after installation in lateral decubitus (BEFORE SURGERY)
    – DLT tends to herniate proximal during lateral decubitus
11. *(confirmation of DLT with fluoroscopy only when fiberoptic scope is not available or on specific request)*
INSERTION OF BRONCHIAL BLOCKER

1. direct/indirect laryngoscopy (insert gastric tube first when good visualisation)
2. standard intubation with SLT – cuff just distal to vocal cords to allow sufficient space between carina and distal end of SLT (minimum distance for EZ-blocker is 4 cm)
3. optimal lung collaps with bronchial blocker:
   1. deconnect both lungs from ventilator first to allow complete collaps of left and right lung
   2. inflate bronchial blocker
   3. resume OLV on dependent lung
   – (do not inflate bronchial blocker first, since the central lumen is too small for optimal collaps)

4. ARNDT® BRONCHIAL BLOCKER
   1. forward BB to non-dependent lung with wire connected to fiberoptic scope
   2. check inflation of cuff with fiberoptic scope
   3. (confirm functional isolation (cfr *insertion of double-lumen tube*))
   4. reconfirm position with fiberoptic scope after installation in lateral decubitus (BEFORE SURGERY)
   5. cuff to be inflated with minimal volume to allow air-seal (+/- 3 ml)

5. EZ-BLOCKER®
   1. forward BB blindly until slight resistance occurs (+/- 55 cm)
   2. check position with fiberoptic scope
   3. identify and label left and right cuff with fiberoptic scope (slightly inflate cuffs)
   4. (confirm functional isolation (cfr *insertion of double-lumen tube*))
   5. reconfirm position with fiberoptic scope after installation in lateral decubitus (BEFORE SURGERY)
   6. cuff to be inflated with minimal volume to allow air-seal (+/- 7 ml)
The average distance from the tracheal carina to the take-off of the right upper bronchus is 2.0 cm in men and 1.5 cm in women. The distance from the tracheal carina to the take-off of the left upper and left lower lobes is approximately 5.0 cm in men and 4.5 cm in women. These anatomical distances apply to individuals with a height of 170 cm.

Campos JH. Curr Opin Anaesthesiol 2009; 22: 4-10

A shows a clear view of the tracheal carina. B shows the take-off of the right upper bronchus. C shows the apical, anterior, and posterior segments of the right upper lobe bronchus (RULB). D shows the right middle lobe (RML) and the right lower lobe bronchus (RLL). E shows a view of the left upper lobe (LUL) and the left lower lobe bronchus (LLL).
The proximal edge of the fully inflated cuff is approximately 5–10 mm below the trachea carina. (a) A bronchial blocker in the right mainstem bronchus; and (b) a bronchial blocker in the left mainstem bronchus.
COMMON PROBLEMS AND PITFALLS DURING OLV

• INFLATION OF BRONCHIAL CUFF OR BRONCHIAL BLOCKER:
  – lung separation: ONLY inflated at time of OLV – otherwise deflated (cave positioning!)
  – lung isolation: ALWAYS inflated (before lateral decubitus if necessary!)

• SUDDEN CHANGE IN VOLUME – PRESSURES DURING OLV
  – malpositioning of DLT
    • often occurs during surgical manipulation
    • most common proximal herniation during positioning in lateral decubitus; optimize tube fixation!
    • deconnect ventilator (if oxygenation acceptable) – deflate bronchial cuff – check with fiberoptic scope
  – pneumothorax – tension pneumothorax in dependent lung
    • ↑ pressure and ↓ tidal volume
    • HEMODYNAMIC COLLAPSE (↑CVP; ↓MAP)
    • INFORM SURGEON – DECONNECT VENTILATOR – CHEST TUBE

• UNEXPECTED VENTILATION OF NON-DEPENDENT LUNG
  – surgeon will “tell” you…
  – malpositioning of DLT
  – deconnect ventilator – deflate bronchial cuff – check with fiberoptic scope

• AIR-LEAK ON ANESTHESIA MACHINE WHEN RESUMING VENTILATION IN NON-DEPENDENT LUNG
  • ↓ pressure en ↓ tidal volume (on ventilator) (VCV)
  • ↓ tidal volume (PVC)
  • most common parenchymal lesion in surgical field (smell volatile anesthetics)
  • inform surgeon – postop spontaneous ventilation will solve this
  • MONITOR BLOOD GASES TO CHECK VENTILATION
**MALPOSITIONING OF DLT DURING PROCEDURE**

- **MALPOSITIONING/DISLOCATION OF DLT-LEFT SIDED DURING PROCEDURE**
  - most common problem: **PROXIMAL HERNIATION OF ETT**
  - deconnect ventilator (when oxygenation acceptable) – deflate bronchial cuff – check with fiberoptic scope

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<td>↓ TV</td>
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malpositioning
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<th>Double-lumen endotracheal tubes</th>
<th>Bronchial blockers (Arndt, Cohen, Fuji)</th>
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<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
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<tr>
<td>Large lumen facilitates suctioning</td>
<td>Easy recognition of anatomy if the tip of a single tube is above carina</td>
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<tr>
<td>Best device for absolute lung separation</td>
<td>Best device for patients with difficult airways</td>
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<td>Conversion from 2 to 1-lung ventilation easy and reliable</td>
<td>No cuff damage during intubation</td>
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<td>No need to replace a tube if mechanical ventilation is needed</td>
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<td>Small channel for suctioning</td>
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<td>Conversion from 1- to 2- then to 1-lung ventilation (problematic for the novice)</td>
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<td>High maintenance device (dislodgement or loss seal during surgery)</td>
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<td>Major tracheo-bronchial injuries</td>
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DOUBLE-LUMEN TUBE (DLT) OR BRONCHIAL BLOCKER (BB) FOR ONE-LUNG VENTILATION (OLV)

LUNG ISOLATION
- to avoid contamination with blood, pus, secretions, lavage

OLV

LUNG SEPARATION
- functional – to optimize surgical exposure

DLT

LEFT
- lesion left main stem bronchus
- (large thoracic aortic aneurysm)

RIGHT
- bilateral intervention
- pneumectomy
- sleeve lobectomy
- lobectomy
- lung transplantation (SLTX – SSLTX)

BB

LEFT
- ETT – SLT in situ
- unanticipated OLV required during procedure
- (tracheal bronchus)

RIGHT
- segmentectomy
- mediastinal surgery
- esophagectomy
- cardiac surgery
- other non-pulmonary surgery requiring OLV

IF PATIENT REQUIRES PROLONGED POSTOP INTUBATION: SWITCH TO SINGLE LUMEN TUBE (SLT) AT THE END OF PROCEDURE (EXCEPT IF LUNG ISOLATION IS REQUIRED)
- POST SSLTX: SLT 8 FOR FEMALE AND SLT 9 FOR MALE
- ALWAYS INDIRECT/DIRECT LARYNGOSCOPY WHEN SWITCHING TO SLT – CONSIDER USE OF TUBE EXCHANGER
DIFFICULT AIRWAY REQUIRING OLV

DIFFICULT AIRWAY

SLT

(avoid DLT)

forward in main stem bronchus

BB

change to DLT

• ALWAYS use tube exchanger
• ALWAYS direct laryngoscopy

Tracheotomy

ETT – SLT in situ
SIZE OF DOUBLE LUMEN TUBE – LEFT SIDED

- No consensus in literature on prediction of DLT size (poor correlation with height, predictive models are weak)
- Rules of thumb
  - largest tube that allows a leak when bronchial cuff is deflated
  - male: 39 Fr
  - female: 37 Fr
  - more than one correct size is possible
- Direct measurement of diameter of left main stem bronchus on AP chest X-ray (or CT if available) currently “gold standard”

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SIZE AND TYPE OF BRONCHIAL BLOCKER

• **ARNDT® ENDOBRONCHIAL BLOCKER (COOK)**
  • Spherical balloon
  • (elliptical balloon: not available anymore; manufacturing stopped in 2011)

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<th>catheter size</th>
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<th>catheter length</th>
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*contact department of pediatrics/ Prof Dr Proesmans

• **EZ-BLOCKER® (IQ-MEDICAL)**
  • diameter of lumen too small for suctioning and CPAP

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LATERAL DECUBITUS AND ONE-LUNG VENTILATION
DISTRIBUTION OF VENTILATION
DISTRIBUTION OF VENTILATION
DISTRIBUTION OF PERFUSION

The four zones of the lung:

1. Collapse
2. Waterfall
3. Distention
4. Interstitial pressure

Pressure relationships:
- Zone 1: $P_a > P_{pa} > P_{pv}$
- Zone 2: $P_{pa} > P_a > P_{pv}$
- Zone 3: $P_{pa} > P_{pv} > P_a$
- Zone 4: $P_{pa} > P_{ISF} > P_{pv} > P_a$

Blood flow direction and distance:
- $P_{pv} = P_a$
• zone 1 WEST: PA > Ppa > Ppv
  – vessels collapsed
  – no blood flow
  – no gas exchange
  – alveolar dead space (wasted ventilation)
  – under normal conditions: little or no zone 1
  – cave: hypotension/high PA
• zone 2 WEST: Ppa > PA > Ppv
  – blood flow determined by mean Ppa – PA difference
  – waterfall over a dam (waterfall, starling resistor, sluice effect)
  – mean blood flow increases linearly downwards zone 2 (PA=constant)
  – cave: cyclic variation of the pressures
• zone 3 WEST: Ppa > Ppv > PA
  – blood flow determined by pulmonary arteriovenous pressure difference
  – capillary systems permanently open
  – gravity causes increase of Ppa and Ppv at same rate: perfusion pressure unchanged
  – vessel radii increase because of increase in transmural distending pressures
• zone 4 WEST: Ppa > PISF > Ppv > PA
  – in case of accumulation of excessive fluid into interstitial connective tissue compartment
  – in case of very low lung volume
  – positive interstitial pressure, causing extra-alveolar vessel compression, increased extra-alveolar vascular resistance and decreased regional blood flow.
VENTILATION-PERFUSION RATIO
awake – closed chest
aneshtesia – spontaneous ventilation – closed chest

daling FRC because of anesthesia
anesthesia – mechanical ventilation – closed chest

- dependent lung volume further reduced
  - compression of abdominal organs
  - compression of mediastinum
anesthesia – mechanical ventilation – open chest

- further overventilation of non-dependent lung
ONE-LUNG VENTILATION

OPTIMIZE COLLAPSE

AVOID HYPOXEMIA

AVOID LUNG INJURY

PROTOCOLIZED APPROACH
People say you can't live without love....
....I think oxygen is more important.

PREVENTION OF HYPOXEMIA
DETERMINANTS OF HYPOXEMIA

• shunt equation
  – \( \frac{Q_s}{Q_t} = \frac{(CcO_2 - CaO_2)}{(CcO_2 - CvO_2)} \)
  – \( CaO_2 = CcO_2 - (CcO_2 - CvO_2) \cdot \left( \frac{Q_s}{Q_t} \right) \)

• mixed venous oxygen content
  – \( CvO_2 = CaO_2 - \left( \frac{VO_2}{Qt} \right) \cdot \left( \frac{Q_s}{Q_t} \right) \cdot \frac{(Q_s/Q_t)}{(10(1 - Q_s/Q_t))} \)

• \( CaO_2 = CcO_2 - \left( \frac{VO_2}{Qt} \right) \cdot \).
DETERMINANTS OF HYPOXEMIA

• $\text{VO}_2$: oxygen consumption (mixed venous saturation)

• $\text{Qs/Qt}$: shunt fraction

• $\text{Qt}$: cardiac output

• $\text{CcO}_2$: haemoglobin content – alveolar ventilation
SHUNT: APPROACH TO NON-DEPENDENT LUNG

- insufflation
- CPAP
- IPAP (intermittent positive airway pressure)
- modified CPAP
- HFJV
- COMPRESSION
PEEP - CPAP

Dependent lung-peep: ventilation

Non-dependent CPAP: oxygenation

Differential CPAP/PEEP
Limited use during thoracoscopic procedures due to decreased visualisation
HFJV non-dependent lung

one-lung ventilation
air-trapping
improved RV function

as alternative for CPAP
optimal exposure

to avoid one-lung ventilation (2-lung HFJV)
lower peak pressures

Settings:
frequency +/- 180
pressure 1.8 – 2.2 bar
higher PCO2 levels
CARDIAC OUTPUT

PaO2

Qs/Qt

SvO2
REDISTRIBUTION OF PERFUSION
hypoxic pulmonary vasoconstriction

- optimizes V/Q (reduction 40%)
- contraction smooth muscle
- PAO2 40-100 mmHg
- determinants: PAO2 and PvO2
- early response 15 min
- maximal response 4 h
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<td>acetyl cysteïne</td>
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AVOIDING LUNG INJURY
PATHOPHYSIOLOGY OF LUNG INJURY: volutrauma versus atelectrauma

Overdistention (baby lung)
- volutrauma in functional reduced lung volume
- reduction in tidal volume

Atelectrauma (open lung concept)
- Repetitive opening and closure of atelectatic zones
- recruitment and
PATHOPHYSIOLOGY OF LUNG INJURY: multiple hits

VILI (ventilation induced lung injury)

MECHANICAL FORCES
- DISTENTION / VOLutrauma
- ATELECTRAUMA

BARRIER DYSFUNCTION

INFLAMMATION / BIOTRAUMA

LUNG INJURY
- Increased permeability

UNDERLYING LUNG INJURY

ARDS/ALI

VALI (ventilation associated lung injury)

MULTIPLE HIT
LUNG INJURY DURING OLV
historical facts and pitfalls

- **high tidal volumes**
  - oxygenation
  - “end-inspiratory alveolar recruitment”

- **PPE** (postpneumonectomy pulmonary edema)

- low tidal volume in **ARDS** is beneficial

- **outcome**? surrogate markers

- effect of protective lung ventilation on **healthy lungs**
LUNG INJURY DURING OLV
risk factors

- **PATIENT**
  - poor postoperative predicted lung function
  - preexisting lung injury
    - trauma
    - infection
    - chemotherapy
  - ethanol abuse
  - female gender

- **PROCEDURE**
  - lung transplantation
  - major resection (pneumonectomy > lobectomy)
  - esophagectomy – fluid administration
  - transfusion
  - prolonged OLV (>100 min) Peak pressure > 35-40 cmH2O
  - plateau pressure > 25 cmH2O
LUNG INJURY DURING OLV
pathophysiology

VENTILATED LUNG

hyperoxia
  • reactive oxygen species
  • oxygen toxicity
hyperperfusion
  • endothelial damage
  • vasculare pressure
ventilatory stress
  • volutrauma
  • atelectrauma
  • barotrauma

COLLAPSING LUNG

• ischemia/reperfusion
• reexpansion
• cytokine release
• altered redox state
• Surgery
  • manipulation trauma
  • lymphatic disruption

SYSTEMIC

• cytokine release
• reactive oxygen species
• overhydration
• chemotherapy/radiation

ARDS/ALI
PROTECTIVE LUNG STRATEGY

- low tidal volume
  - 5-6 ml/kg

- PEEP
  - 5-10 cmH2O

- PROTECTIVE
  - lower shunt fraction
  - improved oxygenation
  - less atelectasis
  - lower cytokine release

Yang et al Chest 2011; 139: 530-537
RECRUITMENT

BEFORE OLV (2-LUNGS)

NON-DEPENDENT LUNG (OLV)

DEPENDENT LUNG (OLV)
- 20 – 40 cmH2O
- followed by PEEP
- improves oxygenation
- reduces inflammation
- transient decrease in CO – significance?
- repeated recruitment?

Unzueta et al BJA 2012
Park et al EJA 2011; 28: 298-302
REEXPANSION INJURY

- reexpansion pulmonary edema
- with longer intervals of OLV
- gradual opening of non-dependent lung
- low FiO2 (ROS)
- Cave stapler lines
MODE OF VENTILATION

• up to date no clear benefit for PCV or VCV
• more homogeneous distribution with PCV?
• historical impact of limited AwP
ONE SIZE DOES NOT FIT ALL

TAILORED APPROACH
VENTILATORY MANAGEMENT OF OLV

GOAL

AVOID-THREAT HYPOXIA (CHECK BLOOD GASES REGULARLY!)

OPTIMAL LUNG COLLAPS FOR SURGICAL EXPOSURE (LOOK IN SURGICAL FIELD!)

AVOID ALI – PROTECTIVE VENTILATION (RELATED TO OUTCOME!)

<table>
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<th>parameter</th>
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</table>
| FiO2        | 0.9 - reduce to 0.5 if possible (after onset of HPV) | • adjust 5 min prior to OLV  
• less inflammation with lower FiO2  
• re-inflation of non-dependent lung with air + recruitment |
| Tidal Volume| 4-6 ml/kg                                   | • reduce stretch                                                       |
| Respir Rate | increase to maintain MV                     | • cave: increased Vd: higher RR necessary to maintain Va  
• cave: airtrapping if inadequate E-time  
• obstructive: I:E = 1:3 / restrictive: I:E = 1:1 |
| Pplat AwP   | limit to 25-30 cmH20                        | • allow hypercapnia if necessary  
• air leak with BB when higher than 25 cmH20                           |
| PEEP        | 5-10 cmH20                                  | • titrate to oxygenation (LIP)  
• reduces atelectasis – shear-stress  
• reduces auto-PEEP                                                        |
| PCO2        | 40 – 60 mmHg                                | • permissive hypercapnia is protective  
• permissive hypercapnia in case of airtrapping or high Pplat AwP    |
| ventilatory mode | PCV - VCV                      | • until now, no evidence for beneficial effect of a specific mode. allow PpeakAwP to be higher during VCV  
• cave: pressure in circuit is higher than alveolar pressure. |
VENTILATORY MANAGEMENT OF OLV

• RESUMING VENTILATION OF NON-DEPENDENT LUNG
  – re-inflate with low FiO2 to limit oxidative stress (lung and right ventricle) (air – FiO2 0.3)
  – gradually re-inflate lung
    • recruitment of collapsed alveoli
      • AwP 20-30 cmH2O during 30 sec
      • followed by PEEP
      • cave: reduction in C.I.
    • avoid hyperinflation with large tidal volumes
    • consider use of CPAP device to re-inflate lung

• EMERGENCE OF ANESTHESIA FOR THORACIC PROCEDURE
  • NEVER SPONTANEOUS BREATHING WITH DLT/SLT IN SITU
    • PRESSURE-SUPPORT VENTILATION ALLOWED TO MAINTAIN RECRUITMENT - MV
  • ALWAYS MAINTAIN PEEP/CPAP
  • CONSIDER RECRUITMENT
  • OPTIMIZE ANALGESIA BEFORE EXTUBATION
  • AVOID HYPERCAPNIA
  • ASPIRATION OF SECRETIONS
  • CHECK FOR REMOVAL OF NEUROMUSCULAR BLOCKADE
  • CHECK CHEST X-RAY BEFORE EXTUBATION (EXCLUDE ATELECTASIS)
  • MOST COMMON PROBLEM AFTER THORACIC SURGERY IS ATELECTASIS: OUTCOME!
MANAGEMENT OF HYPOXIA DURING OLV

**HYPOXIA:** Sat < 91% (incidence 1%)

1. increase FiO2 to 1.0
2. check position DLT/BB
3. optimize cardiac output
   - preload: 250-500 CC colloids
   - contractility
   - arrhythmias
4. recruitment dependent lung
   - AwP 20-30 cmH20 during 30 sec
   - followed by PEEP
   - cave: reduction in C.I.
5. optimize PEEP dependent lung towards LIP (↑ or ↓)
6. CPAP to non-dependent lung
   - recruitment first
   - 5-10 cmH20
   - NOT during VATS (surgical exposure)
7. intermittent inflate non-dependent lung (communicate with surgeon)
8. partial ventilation of non-ventilated lung
   - lobar re-inflation
   - selective lobar collapse (BB)
   - oxygen insufflation (consider insufflation in surgical field, cave combustion)
   - (high frequency ventilation)
9. reduce blood flow to non-ventilated lung
   - clamping of pulmonary artery (cave increased afterload to right ventricle)
10. maintain oxygen carrying capacity
11. (ECMO as rescue)

**SHUNT**

**MALPOSITION DLT/BB**

MILD/GRADUAL

SEVERE (<85%)

1. resume 2-lung ventilation
2. (communicate with surgeon)
3. increase FiO2 to 1.0
4. check position DLT/BB

**SHUNT MALPOSITION DLT/BB**

MILD/GRADUAL

SEVERE (<85%)
PREDICTION OF HYPOXIA DURING OLV

- **INCREASED RISK**
  - low PO2 preoperatively and during two-lung ventilation
  - distribution of perfusion on V/Q scan
  - operative side (R>L)
  - dorsal decubitus > lateral decubitus
  - (FEV1)
  - compliant pulmonary vascular bed (younger patients)
  - use capnography:
    - change in ETCO2 during TLV and OLV
    - large change predicts low oxygenation!

- **DECREASED RISK**
  - obstructive lung disease (airtrapping and AUTO-PEEP)
  - large central tumors have less perfusion to non-dependent lung
RISK FACTORS FOR ALI POST-OLV

• PATIENT RELATED
  – poor postoperative predicted lung function
  – preexisting lung injury
    • trauma
    • infection
    • chemotherapy
  – ethanol abuse
  – female gender

• PROCEDURE RELATED
  – lung transplantation
  – major resection (pneumonectomy > lobectomy
  – esophagectomy with large perioperative fluid load
  – transfusion
  – prolonged OLV (>100 min)
  – peak AwP > 35 – 40 cmH20
  – plateau AwP > 25 cmH20

• re-inflation of non-dependent lung with air (limits inflammation)
HEMODYNAMIC OPTIMIZATION DURING OLV

• AFTERLOAD to right ventricle is increased
  – pneumonectomy
  – hypoxic pulmonary vasoconstriction
  – less compensation of right ventricle to increased afterload
  – optimize reduction in PVR (recruitment to FRC, normal pH, avoid hypoxia, avoid hypercapnia, avoid surgical stress, consider use of selective pulmonary vasodilators: inhaled NO / inhaled Prostacyclins)
  – check with TEE if necessary
  – consider use of PA-catheter

• CONTRACTILITY
  – cave sympathetic blockade due to epidural catheter
  – less sympathetic blockade when continuous infusion of local anesthetic
  – consider inotropic support if necessary (dobutamine / corotrope)
  – consider reduction in afterload with inhaled NO / inhaled prostacyclines when RV dysfunction
  – re-inflation of non-dependent lung with air to minimize oxidative stress
  – check with TEE if necessary
  – consider use of PA-catheter

• PERFUSION PRESSURE
  – perfusion of right ventricle dependent on systolic pressure
  – maintain adequate perfusion pressure with levophed (start at 0.05 gamma)

• PRELOAD-CARDIAC OUTPUT
  – optimal preload and cardiac output necessary for oxygenation
  – consider adequate preload (250-500 cc fluid challenge)
  – consider use of inotropics (ephedrine>dobutamine>corotrope)