MANAGEMENT OF ONE-LUNG VENTILATION

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

LUNG SEPARATION
- functional – to optimize surgical exposure
  - LEFT
  - DLT
  - bilateral intervention
  - pneumectomy
  - sleeve lobectomy
  - lobectomy
  - lung transplantation (SLTX – SSLTX)
  - RIGHT
  - DLT
  - BB
  - ETT – SLT in situ
  - unanticipated OLV required during procedure
  - (tracheal bronchus)
  - 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

SLT

BB

close to DLT

• ALWAYS use tube exchanger
• ALWAYS direct laryngoscopy

ETT – SLT in situ

Tracheotomy
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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<td>41 Fr</td>
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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)

<table>
<thead>
<tr>
<th>catheter size</th>
<th>smallest ETT</th>
<th>catheter length</th>
<th>multiport adapter</th>
<th>size fiberoptic scope</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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SIZE AND TYPE OF DOUBLE-LUMEN TUBE

left sided DLT

CPAP device
SIZE AND TYPE OF BRONCHIAL BLOCKER

Arndt® endobronchial blocker

EZ® blocker
INSERTION OF DOUBLE-LUMEN TUBE – LEFT 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. disconnect both lungs from ventilator first to allow complete collapse 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 deflation)

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 doule-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)
FIBEROPTIC ANATOMY

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 lower lobe 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
http://www.thoracic-anesthesia.com

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).
FIBEROPTIC ANATOMY

(a) An unobstructed view of the entrance of the right mainstem bronchus when the fibroscope is passed through the tracheal lumen and the edge of the fully inflated endobronchial cuff is below the tracheal carina in the left bronchus. (b) An unobstructed view of the left upper and left lower bronchos when the fiberoptic bronchoscope is advanced through the endobronchial lumen. (c) The take-off of the right upper bronchus with the three segments (apical, anterior, and posterior): this is a landmark to reconfirm a right bronchos.

(a) The take-off of the right upper bronchus with three segments (apical, anterior, and posterior) when the fiberoptic bronchoscope emerges from the opening slot located in the endobronchial lumen. (b) An unobstructed view of the entrance of the left mainstem bronchus when the fibroscope is passed through the tracheal lumen and the edge of the left inflated endobronchial cuff is below the tracheal carina in the right bronchus.

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.

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### VENTILATORY MANAGEMENT OF OLV

**GOAL**
- **AVOID-THREAT HYPOXIA (CHECK BLOOD GASES REGULARLY!)**
- **OPTIMAL LUNG COLLAPS FOR SURGICAL EXPOSURE (CAVE MINIMAL INVASIVE TECHNIQUES!-LOOK!)**
- **AVOID ALI – PROTECTIVE VENTILATION (RELATED TO OUTCOME!)**

<table>
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<tr>
<th>Parameter</th>
<th>Target</th>
<th>Remark</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 and compliance (LIP)  
• reduces atelectasis – shear-stress  
• consider auto-PEEP  
• always implement intermittent RECRUITMENT  
• always recruitment of both lungs before onset of OLV |
| **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

• RECRUITMENT MANEUVER
  – maintain AwP at +/- 30 cmH₂O during 30 sec (cave reduction in cardiac output!)
  – DO NOT OVERINFLATE ACUTELY WITH LARGE VOLUMES – recruitment is time-dependent!
  – RECRUITMENT ALWAYS FOLLOWED BY PEEP
  – Consider REPETITIVE recruitment maneuvers in time if necessary

• 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
    • 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 - PNEUMOTHORAX)
• MOST COMMON PROBLEM AFTER THORACIC SURGERY IS ATELECTASIS: OUTCOME!
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 – DISCONNECT VENTILATOR – CHEST TUBE

- UNEXPECTED VENTILATION OF NON-DEPENDENT LUNG
  - surgeon will “tell” you…
  - malpositioning of DLT
  - disconnect 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
  - disconnect ventilator (when oxygenation acceptable) – deflate bronchial cuff – check with fiberoptic scope

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MANAGEMENT OF HYPOXIA DURING OLV

HYPOXIA: Sat < 91% (incidence 1%)

SHUNT

MILD/GRADUAL
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-dependent lung
   • lobar re-inflation (modified CPAP)
   • selective lobar collapse (BB)
   • oxygen insufflation (consider insufflation in surgical field, cave combustion)
   • (high frequency ventilation: frequency 180 / pressure 1.8-2.2 bar)
9. reduce blood flow to non-ventilated lung
   • clamping of pulmonary artery (cave increased afterload to right ventricle)
10. maintain oxygen carrying capacity (hemoglobin)
11. (ECMO as rescue)

SEVERE (<85%)

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

MALPOSITION DLT/BB

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

SEVERE (<85%)

SHUNT
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 inotrope 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)
PRONE THORACOSCOPY - OLV

• INDICATION
  – Minimal Invasive Esophagectomy: right thoracoscopic phase

• AIRWAY MANAGEMENT
  – Armed single lumen tube (8 for female; 8.5 or 9 for male)
  – Insertion of bronchial blocker (preferable EZ blocker®)
  – Fixation of ETT preferable with HAID® (secretions in prone positioning)
  – (Use of DLT not recommended: increased risk of injury, dislocation, malfunction)

• PRONE POSITIONING
  – Use of hard shell protective helmet with mirror to support head (ProneView®)
  – check if abdomen is free (support of chest and pelvis) to reduce pressure on diaphragm
  – Support the left hemithorax of the patient with negative pressure bean bag for emergency conversion
    (rotation of surgical table sufficient for thoracotomy)

• OLV IN PRONE POSITIONING
  – start OLV with FiO₂ 100%
  – inflate BB before complete collapse of lung (non-dependent lung remains +/-inflated)
    • Surgical exposure is better in prone positioning - OLV is relative indication
    • compensation for lateral decubitus
  – blood gas every 20-30 min with registration of ventilatory parameters
PRONE THORACOSCOPY - OLV

- **POTENTIAL PHYSIOLOGICAL ADVANTAGES OF OLV DURING PRONE POSITIONING**
  - improved oxygenation (reason multifactorial)
  - better preserved FRC
  - less atelectasis
  - better clearance of secretions
  - improved respiratory outcome
  - decreased blood loss

- **POTENTIAL PHYSIOLOGICAL DISADVANTAGES OF OLV DURING PRONE POSITIONING**
  - ↑CVP
  - ↑PaCO₂
  - ↑mean PAP
  - negative effect on compliance (evidence ?)