INDEPENDENT LUNG VENTILATION

Giuseppe A. Marraro, MD
Director Anaesthesia and Intensive Care Department
Paediatric Intensive Care Unit
Fatebenefratelli and Ophthalmiatric Hospital
Milan, Italy

gmarraro@picu.it

Indications

- Lung pathology with unilateral prevalence
- Bilateral lung pathology complicated by monolateral atelectasis, pneumothorax or fistulae
- Bilateral lung pathology with the patient in obliged decubitus on one side
- One lung ventilation during cardiothoracic surgery
- Re-ventilation of the collapsed lung after cardiothoracic surgery. Post-operative phase of cardiothoracic surgery.

Advantages

1. Increase of functional residual capacity and effective ventilation in the more damaged lung
2. Reduction of hyperventilation and barotrauma in the less damaged lung
3. Use of selective PEEP in the two lungs
4. Isolation of secretions of the infected pulmonary areas hence less risk of diffusion by contiguity of the infection from one lung to the other.
5. One lung ventilation during cardiothoracic surgery
6. Reventilation of the collapsed lung after cardiothoracic surgery

Selective bronchial intubation

1. Bronchial intubation using conventional monolumen tube
2. Univent tube®
3. Bronchial blocker
4. Bilumen tube

Bronchial intubation with a tube

- cuffed or uncuffed tracheal tube
- smaller calibre according to the bronchus
- oral intubation is preferable, due to the sufficient length of the tube
- Nasal intubation, however, often requires a special, longer tube.
- accentuating the anatomical position of the bronchus facilitates positioning

Use of Univent tube®

- single lumen, tracheal tube with a movable bronchial blocker
- blocker is advanced into the bronchus to be excluded
- may be done blindly or under direct vision using a fiberoptic bronchoscope
- bronchial balloon must be inflated with large volumes of air to seal the bronchus

Fiberoptic bronchoscopy is needed for accurate placement

Complications
- severe mucosal ischemia
- difficult re-expansion of the collapsed lung

Bronchial blockade
- Fogarty embolectomy catheters, below the age of six
- Arterioseptostomy catheter [46] and Pulmonary artery catheters
- Swan Ganz catheter

*advantage of a central lumen which would permit suctioning or the application of oxygen and CPAP to the affected lung.

Bronchial blocker
- Positioning requires fiberoptic broncoscopy even though a blind technique can be used.
- Correct placing: by auscultation of the lungs or by chest x-ray
- Risk of displacement during surgery.
- Limited use in small infants and young children due to the reduction in diameter of the trachea

Use of bilumen tube.
- Bronchocath Mallinckrodt® 26-28 Fr. or Bronchoport Rusch® in children >8 years
- Marraro Paediatric Endobronchial Bilumen Tube, SIMS - Portex®, in neonate and children < 2-3 years

Characteristics of Endobronchial Bilumen Tube (Portex Ltd)
- uncuffed
- no spur for securing to the carina (less trauma)
- radiopaque stripe along its whole length (x-ray visualisation)

Selective bronchial intubation using bilumen tube
General anaesthesia and muscle paralysis
Direct laryngoscopy

Methodology of selective bronchial intubation
Positioning of the double lumen tube
- bronchial lumen through the vocal chords
- double lumen tube is rotated to the right or the left, after passing the vocal chords
- double lumen tube is advanced to reach bronchial intubation

Complications
- inexperience in intubation
- exclusion of the upper lobe bronchus in right bronchial intubation
- dislodgment and obstruction of the tube
- trauma of the trachea and bronchi
- difficult bronchosuctioning

Check of correct positioning of the bilumen tube
- auscultation of the lungs
- chest wall movements

- chest x-ray
- fiberoptic bronchoscopy

Advantages, disadvantages and limitation of selective endobronchial materials

	Advantages	Disadvantages	Limitation in the use
Bronchial intubation by single tube	- Easy to perform - Total exclusion of one lung - no need for sophisticated equipment	- Easy dislocation of the tube - Inadequate ventilation in case of obstruction - Difficult expansion of collapsed lung	- ILV is impossible
Univent tube®	- Total exclusion of one lung	- Severe bronchial mucosae ischemia - Difficult expansion of collapsed lung	- Need fiberoptic bronchoscopy - ILV is impossible
Bronchial Blockers	- Total exclusion of one lung - Broncho suctioning, O_2 supplementation and CPAP application (Arterioseptostomy and Pulmonary artery catheters)	- Severe bronchial mucosae ischemia - Dislocation during surgical operation - Difficult expansion of collapsed lung	- Need fiberoptic bronchoscopy - Insufficient ventilation due to reduction of tracheal ID - High costs - ILV is impossible
Paediatric bilumen tube	- Total exclusion of one lung - ILV - Bilateral bronchosuctioning - Optimal expansion of collapsed lung	- Easy obstruction of the tube in prolonged treatment	- Positioning needs experience - The use is limited to patients < 3 years

One Lung Ventilation

Setting the ventilator
Tidal volume 12-15 ml/kg body weight
Minute ventilation to maintain $PaCO_2$ of 4.5-5.2 kPa (35-40 mm Hg)
Respiratory rate 20-40 / min
PEEP 5 cm H2O

Monitoring
SpO2
EtCO2
Cardiac rate
Arterial pressure
Central venous pressure
EGA

Hypoxia and hypercarbia
- contralateral lung not collapsed and perfusion not excluded
- insufficient tidal and minute volume
- insufficient PEEP
- tecnical problems with ventilator
- incorrect selective intubation

Use of tidal volume less than 5 to 7 ml/kg
- deterioration of gas exchange
- airways closure for greater percentage of tidal volume
- atelectasis

Risks of hyperventilation
- increase of mean airway pressure
- increase pulmonary vascular resistance in dependent lung
- reduction of PaO_2 and cardiac output.

Return to two lung ventilation
Progressive distension of collapsed lung
- atelectasis
- alveolar and bronchiolar rupture
- interstitial emphysema

*Application of independent lung ventilation
- progressive re-expansion of the collapsed lung
- return to normal ventilation perfusion ratio of dependent lung

Independent lung ventilation (ILV)

Equipment
two ventilators suitable for electronic synchronisation
one ventilator and a flow deviator (in experimental phase)

Synchronisation of ventilators
- avoid shifting of the mediastinum
- reduce obstacles to venous return and fall in cardiac output
- avoid ventilation disorders

These complications occur mostly at low respiratory frequencies (<30 breaths/min).

Tidal volume distribution during ILV and PEEP
- each lung can be set at 50% of the calculated tidal volume of the total lungs
- 2/3 of tidal volume to the more diseased lung and 1/3 to the less affected lung.
- appropriate PEEP can be set to each lung

Subsequent ventilation of two lungs
According to:
compliance

respiratory airway resistance
end tidal CO_2
central venous pressure
arterial pressure.

Inspired flow of oxygen (FiO_2) according to PaO_2

Timing for the discontinuation of ILV
Premature discontinuation can minimise the benefits obtained
Delayed discontinuation, can increase the risks of complications

- Improvement of chest x-ray
- Reduction of FiO2 < 40%
- Improvement of compliance

Indications of ILV
In the pulmonary resuscitation field

– cases of monolateral pneumonia, emphysema, unilateral atelectasis;

– bilateral pulmonary pathology, both of infectious and degenerative origin, complicated by unilateral atelectasis, pneumothorax and fistulae;

– disease of the trachea and of the main bronchi.

In cardio-thoracic surgery

– possibility of complete exclusion of one lung during surgical operation;

– maintenance of reduced ventilation in collapsed lung so as to avoid formation of atelectasis, without interfering with surgical operation;

– correct re-ventilation of collapsed lung at end of operation.

In post-operative intensive care

– after open-chest surgery, in order to re-expand completely the lung which is kept collapsed and to correct the atelectasis which has been created;

– to rebalance the ventilation/perfusion ratio in the lung which as remained dependent for a long time;

– to treat pulmonary complications, such as aspiration syndromes, pneumothorax, etc: which have occurred during general anaesthesia and surgical operation.

Possible new indications:

– Bilateral pulmonary pathology, in which areas of emphysema (lobar) alternate with atelectasic areas, such as bronchopulmonary dysplasia
Selective administration of drugs in one lung, such as antibiotics or surfactant.