

LUNG SEPARATION TECHNIQUES

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The second half of this century has seen refinements of the double-lumen tube (DLT) from that of Carlens¹ to a tube specifically designed for intraoperative use (Robertshaw)² with larger, D-shaped, lumens and without a carinal hook. Current disposable polyvinyl chloride DLTs have incorporated high-volume low-pressure tracheal and bronchial cuffs.³ These recent DLT refinements have two major drawbacks: 1) These tubes now require fiberoptic bronchoscopy for positioning.^{4,5} 2) A satisfactory right-sided DLT has not yet been designed, to deal with the short (average 2 cm) and variable length of the right main stem bronchus.⁶ Recently, there has been a revival of interest in bronchial blockers (BBs) due to several factors: design advances such as the Univent tube⁷ and Arndt catheter⁸ greater familiarity of anesthesiologists with fiberoptic placement of BBs, and cost.

Indications for Lung Separation:

Since it is impossible to describe one technique as best in all indications for one-lung ventilation (OLV), the various indications will be considered separately.

1. Elective pulmonary resection, right-sided: This is the commonest adult indication for OLV. The first choice is a left-DLT. There is a wide margin of safety in positioning left-DLTs.⁶ With blind positioning the incidence of malposition can exceed 20% but is correctable in virtually all cases by fiberoptic adjustment.⁹ A partial resection can proceed to a pneumonectomy, if required, without loss of lung isolation. There is continuous access to the non-ventilated lung (NV-lung) for suctioning, fiberoptic monitoring of position, and continuous positive airway pressure (CPAP). There are differences in the designs of the bronchial cuffs which result in different mean bronchial cuff inflation volumes and pressures during one-lung ventilation.¹⁰ possible alternatives are: a) Single lumen EBT. A standard 7.5 mm, 32 cm length endotracheal tube (ETT) can be advanced over a fiberoptic bronchoscope (FOB) into the left mainstem bronchus.¹¹ b) Univent tube or BB. The BB can be placed external to or intraluminally with an ETT.⁸
2. Elective pulmonary resection, left-sided: a) not pneumonectomy: There is no obvious best choice, between a Univent and a left-DLT. The use of a left-DLT for a left thoracotomy is occasionally associated with obstruction of the tracheal lumen by the lateral tracheal wall and subsequent problems with gas exchange in the ventilated lung (V-lung). A right-DLT is an alternate choice, problems with lung isolation and/or positioning with routine FOB placement occur much less frequently than previously thought.¹² b) Left pneumonectomy. There is no completely satisfactory choice. Any left pulmonary resection may unforeseeably

become a pneumonectomy. When a pneumonectomy is foreseen, a right-DLT is the best choice. A right-DLT will permit the surgeon to palpate the left hilum during OLV without interference from a tube or blocker in the left mainstem bronchus. The disposable right-DLTs currently available in North America vary greatly in design depending on the manufacturer (Mallinckrodt, Rusch, Kendall). The Mallinckrodt design is currently the most reliable. All three designs include a ventilating side-slot in the distal bronchial lumen for right upper lobe ventilation. Positioning this slot can be time-consuming. These tubes require relatively high bronchial intra-cuff pressures (40-50 cm H₂O vs 20-30 cm H₂O for left-DLTs). However, this is lower than the range of pressures required by a Univent¹⁵ or non-disposable DLTs.³ Rarely, left lung isolation is impossible in spite of extremely high pressures in the right-DLT bronchial cuff. In these cases a Fogarty catheter can be passed into the left main bronchus after estimation of depth with a FOB. As an alternative, there is no clear preference among a Univent, left-DLT or other bronchial blocker. These will all require repositioning intraoperatively, but this usually is not a major problem.

3. Thoracoscopy: Lung biopsies, wedge resection, bleb/bullae resections, even some lobectomies can be done using this technique. Video-assisted thoracoscopic surgery (VATS) under general anesthesia requires OLV.¹⁴ During open thoracotomy the lung can be compressed by the surgeon to facilitate collapse prior to inflation of a bronchial blocker. This is not possible during thoracoscopy. The operative lung deflates more easily when the NV-lung lumen of a DLT is opened to atmosphere than via the 2 mm suction channel of a Univent tube. A left-DLT is preferred for thoracoscopy of either hemithorax.¹⁵ Spontaneous ventilation without lung isolation is an alternative in some patients.¹⁶
4. Pulmonary hemorrhage: Instances of life threatening pulmonary hemorrhage can occur due to a wide variety of causes (Aspergillosis, Tuberculosis, PA catheter trauma, etc). The anesthesiologist is often called to deal with these cases outside the operating suite. The primary risk for these patients is asphyxiation, and first line treatment is lung isolation. There are several problems associated with using any sort of bronchial blocker in the acute situation: a) It is often not known which side to occlude. b) Visualization below the vocal cords to aid placement is difficult. c) After the blocker is placed there is no access to the involved lung to monitor bleeding. In patients with pulmonary hypertension, endobronchial blockade can lead to lobar rupture from continued bleeding.¹⁷ A left-DLT avoids these problems.¹⁸ Tracheobronchial hemorrhage from blunt chest trauma will usually resolve with suctioning, only rarely is lung isolation necessary.¹⁹ PA catheter induced hemorrhage during weaning from bypass should be dealt with by resumption of full bypass, bronchoscopy, and lung isolation. Weaning may then proceed without pulmonary resection in some cases.^{20, 21}
5. Bronchopleural fistula: The anesthesiologist is faced with the triple problem of avoiding tension pneumothorax, ensuring adequate ventilation, and protecting the healthy lung from the fluid collection in the involved hemithorax. Management

- depends on the site of the fistula and the urgency of the clinical situation. For a peripheral bronchopleural fistula in a stable patient, some form of BB such as a Univent tube may be acceptable. For a large central fistula, and in urgent situations, the rapidest and most reliable method of securing one-lung isolation and ventilation is a DLT. In life threatening situations, a DLT can be placed in the awake patients with direct FOB guidance.²²
6. Purulent secretions: Lung abscess, hydatid cysts, etc. Lobar or segmental blockade is the ideal. Loss of lung isolation in these cases is not merely a surgical inconvenience, but may be life threatening. Univent tubes can be used for lobar blockade. A secure technique in these cases is the combined use of a bronchial blocker and a DLT.²³
 7. Non-pulmonary thoracic surgery: Thoracic aortic and esophageal surgery require OLV. Since there is no risk of V-lung contamination, a left-DLT or a Univent tube are equivalent choices.
 8. Bronchial surgery: An intra-bronchial tumor, bronchial trauma, or a bronchial sleeve resection during a lobectomy require that the surgeon have intraluminal access to the ipsilateral mainstem bronchus. Either a single lumen EBT²⁴ or a DLT in the V-lung is preferred.
 9. Upper airway abnormalities: It is occasionally necessary to provide OLV in patients who have abnormal upper airways due to previous surgery, trauma, etc. The Univent tube may be useful in some of these patients. Smaller DLTs (28 and 26 Fr) are available, but will not permit passage of a FOB of the diameter commonly used to monitor positioning (3.5 - 4.0 mm). An ETT designed for microlaryngoscopy (5 - 6 mm ID and > 30 cm length) can be used as an EBT, with FOB positioning. If the patient's trachea can accept a 7.0 mm ETT, a Fogarty catheter (8/10 Fr venous thrombectomy catheter with a 4 cc balloon) can be passed through the ETT via a fiberoptic bronchoscopy adapter for use as a BB.²⁵
 10. Unilateral lung lavage,²⁶ independent lung ventilation,²⁷ and lung transplantation are all best accomplished with a left-DLT.

Avoiding Airway Trauma:

Iatrogenic injury has been estimated to occur in 0.5 - 2 per 1000 cases with DLTs.²⁸

- a) The majority of difficult endobronchial intubations can be predicted from viewing the chest x-ray²⁹ or CT scan.³⁰ There is no substitute for the anesthesiologist assessing the film him/herself prior to induction.

- b) b) Use of an appropriate size tube. Too small a tube will make lung isolation difficult. Too large a tube is more likely to cause trauma. Useful guidelines for DLT sizes in adults are: females height < 1.6 m (63 inch), 35 Fr; females 1.6 m, 37 Fr; males < 1.7 m (67 inch), 39 Fr; and males 1.7 m, 41 Fr. Tracheobronchial dimensions correlate with height.³¹ The average depth at insertion, from the teeth, for a left-DLT is 29 cm in an adult and varies + 1 cm for each 10 cm of patient height above/below 170 cm.³²
- c) c) Avoid nitrous oxide: Nitrous oxide 70% can increase the bronchial cuff volume from 5 to 16 ml intraoperatively.³³
- d) d) Inflate the bronchial cuff/blocker only to the minimal volume required for lung isolation and for the minimal time. This volume is usually < 3 ml.¹⁰ Inflating the bronchial cuff does not stabilize the DLT position when the patient is turned to the lateral position.³⁴
- e) e) Endobronchial intubation must be done gently and with fiberoptic guidance if resistance is met. A significant number of case reports are from cases of esophageal surgery,²⁸ where the elastic supporting tissue may be weakened and predisposed to rupture from DLT placement.

Other Complications

Malpositioning: Initial malpositioning of DLTs with blind placement can occur in over 30%³⁵ of cases. Verification and adjustment with FOB immediately prior to initiating OLV is mandatory since these tubes will migrate during patient positioning.³⁶ Malpositioning after the start of OLV due to dislodgment is more of a problem with bronchial blockers than DLTs.

Airway resistance: The resistance from a 37 Fr DLT exceeds that of a #9 Univent by < 10% over this range. These flow resistances are both less than a 8.0 mm ID ETT but exceed a 9.0 mm ETT. For short periods of postoperative ventilation and weaning, airflow resistance is not a problem with a DLT.³⁷

Summary:

The three basic techniques for lung isolation have not changed in the past 60 years: single-lumen endobronchial tubes, double-lumen tubes and bronchial blockers. The anesthesiologist must be comfortable with all three methods of lung-isolation to provide adequate lung separation in the wide variety of patients and clinical situations for which lung separation is now indicated. The ABC's of lung isolation will always apply: know the tracheobronchial Anatomy, use the fiberoptic Bronchoscope, look at the Chest X-ray and CT scan in advance.

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