Understanding
Anesthetic Equipment & Procedures
A Practical Approach

Editors
Dwarkadas K Baheti
Vandana V Laheri

Includes 2 Interactive DVD-ROMs



Foreword
Dipankar Dasgupta

2nd Edition

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Understanding Anesthetic Equipment & Procedures

A Practical Approach

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A Practical Approach

Second Edition

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Foreword

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Technicians, Engineers, Scientist, and Doctors
Who made Anesthesiology
What It Is Today!!!

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FOREWORD

The editors have come out with the much needed textbook "Understanding Anesthetic Equipment & Procedures: A Practical Approach."

I am exceptionally happy and privileged to write a foreword as most of these contributors are closely acquainted with me for years. To introduce an editor with his team of authors is one of the most difficult tasks. Hope I am able to do total justice to them.

The editors have done a fine job in selecting an accomplished group of contributors who are well known in each of their respective academic inclination, capability, and dedication. Authorship helps dedicate ones efforts in nurturing the best outcome to be appreciated across the globe. This experienced group has done a wonderful literature search and documented them in their novel way in front of the world of anesthesiology.

Dr Baheti himself is a respected dolorologist with a prolonged and profound experience as a senior consultant anesthesiologist. He is a rare combination of practising both his specialties (anesthesiologist and pain physician) with success. In addition, he reared up a parallel urge towards academy. This classical production under our scrutiny is a proof of his dedication and efforts.

Dr Laheri is a passionate teacher and is exceptionally vibrant with the knowledge of basic physics as well as the mechanism involved in the appliances of anesthesia and critical care.

Man has to live his life with a long-standing determination, and for a doctor, it has to be added with proper intervention of disease and disability. For anesthetists like us, the motto is to combat critical illness and alleviate pain. There is anthropological evidence that medicine evolved from man's earliest attempt to get spirituality in his grasps and attain his position in the cosmos.

While practising the essence of ignorance to be corrected by ultra-modern textual knowledge, the book will provide us with deep insight, inward understanding, and deeper observation. I quote from the "Principles and Art of Plastic Surgery" by Dr Ralph Millard JR— "There is little that can be called original since a sharp flint opened an abscess and some horse hair threaded through the fine thorn needle sewed up a wound. Yet, it all goes on bit by bit and the wheel of progress turns just a little in a man's life."

Under the editorial guidance of Dr Baheti and Dr Laheri, the contributors have compiled a comprehensive textbook that will tremendously help the national and international students. During our clinical functioning, we constantly search for literatures on anesthetic equipment. I have been lucky to observe their academic performances through different meetings and publications.

I conclude with hearty congratulations to the editors and the contributors for taking up this academic challenge. As I always say, full effort is full attainment. Well done champs! Until you spread your wings, you have no idea how far you can fly!

Wish the book awards Dr Baheti and Dr Laheri the much desired academic glory along with all their associates and will reach to the international fraternity of learners.

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PREFACE TO THE SECOND EDITION

We are basking in the glory of our first ever book *Understanding Anesthetic Equipment & Procedures – A Practical Approach*. We express our heartfelt gratitude to the readers for stupendous response to the first edition which boasted us to bring out the second edition.

The medical world is witnessing medical, technological, and medical engineering advances. Anesthesiology as specialty and anesthesiologist are also adapting themselves to the technological and monitoring devices. These advances are at times challenging for practicing anesthesiologist which they are happily accepting.

The feedback and response from undergraduates and postgraduates have prompted us to re-edit many chapters. We are confident the changes and practical tips will find readers very helpful in their day-to-day practice and science of anesthesia.

We express our heartfelt gratitude to all the contributors; without their help, this herculean task would be impossible. We have taken utmost care to bring out the book of an international quality at an affordable price.

We sincerely hope that our efforts to bring out with the second edition will further benefit the undergraduates, postgraduates, and practicing anesthesiologists.

This will ultimately provide better patient care, improve surgical outcome, and more cost effective.

Dwarkadas K Baheti

Vandana V Laheri

PREFACE TO THE FIRST EDITION

Anesthesiology as specialty over the decades is witnessing the revolution in the understanding of the technological advances in medicine. The highly sophisticated equipment built on high engineering and physical standards (e.g., flow-meters, valves, vaporizers, breathing circuits, ventilators, monitoring equipment, use of nerve stimulator, ultrasonography, and fluoroscopy) has provided an edge and expertise to anesthesiologists.

Many undergraduates, postgraduates, and practicing anesthesiologists are enthusiastic to understand basics of the equipment and learn the procedure techniques while administering anesthesia. These anesthesiologists do not have access for a comprehensive reference book.

We, the practicing anesthesiologist, have recognized the problem and realized the need for such a book on anesthesia equipment and procedures with DVDs. It is our sincere attempt to come out with a book on anesthesia equipment to fill the vacuum.

We express our heartfelt gratitude to all the contributors; without their help, this herculean task was impossible. We have taken utmost care to bring out the book of an international quality at an affordable price.

We sincerely hope that our efforts to bring out with the book will benefit the undergraduates, postgraduates, and practising anesthesiologists, who will ultimately provide better patient care and improve surgical outcome.

Dwarkadas K Baheti

Vandana V Laheri

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CHAPTER

Double Lumen Tubes and Bronchial Blockers

Vijaya P Patil, Bhakti D Trivedi, Madhavi D Desai

ABSTRACT

The lung isolation techniques are required not only to facilitate surgical exposure in many thoracic and sometimes other surgeries like spine surgeries; but also in nonsurgical situations like pulmonary hemorrhage, or whole lung lavage. This chapter will discuss various indications, and devices available for lung isolation in current clinical practice, various techniques of lung isolation, merits and demerits of each isolation device and choice of device in various situations.

INTRODUCTION

The lung isolation techniques are mainly employed to facilitate surgical exposure for procedures in the thoracic cavity. This has advantages such as to prevent contamination of the contralateral lung in cases of massive bleeding or presence of abscess; to achieve effective ventilation in patients with bronchopleural fistula requiring mechanical ventilation and for independent lung ventilation in intensive care unit (ICU) for patients with unilateral parenchymal lung injury. The various sizes of double lumen tubes and variety of endobronchial blockers (EBBs) are available for the same purpose.

HISTORY OF LUNG ISOLATION

In 1931, Gale and Waters used cuffed rubber endotracheal tube (ETT) inserted into the bronchus for thoracic procedure for the first time.[1] In 1935, Archibald used rubber EBB positioned by radiography to achieve lung isolation. In following year Sir Ivan Magill used rubber EBB that could be accurately positioned under direct vision using a rigid endoscope passed down the blocker tube's lumen. This was followed by introduction of double-lumen bronchial tubes (DLTs) by Gebauer and later Carlen's and thus started the era of lung isolation.

HISTORY OF DOUBLE LUMEN TUBES

The left-sided DLTs were introduced for the first time in 1939 by Gebauer; which were designed for broncho spirometry. However, this tube had a single channel for inflation of both tracheal as well as bronchial cuffs. An year later, Zavod introduced a similar double lumen tube with two separate channels for inflation of individual cuffs.[2] In 1949, Carlen's, a clinical physiologist reported lung separation with a similar DLT, which was also primarily meant for Broncho spirometry; but this tube had a hook to secure it in correct position (Fig. 1A).[1] In 1960, White introduced right-sided version of Carlen's DLT which also had carinal hook. At the same time, realizing problems associated with carinal hook; in 1959, Bryce-Smith designed a left-sided DLT without a carinal hook. One year later Bryce-Smith along with Salt and White made right-sided DLT with a slotted bronchial cuff; which was also without carinal hook.

The previous DLTs had two main drawbacks, namely difficult placement and high airway resistance that restricted their use. In 1962, Roberts Shaw made the red rubber DLT, which had wide lumens and a molded curvature to reduce kinking and improve gas flow during one lung ventilation (Fig. 1B). This tube became the prototype of the modern day DLT.

These tubes provided main modality for lung separation until disposable, polyvinyl chloride (PVC) double lumen tubes of the Robert Shaw design were introduced in 1980s. The rubber tubes have thick wall, and therefore, lesser internal to external diameter ratio. Also, these tubes have low volume-high pressure cuff subjecting tracheal and bronchial mucosa at risk of pressure necrosis.

New PVC double lumen tubes (Fig. 1C) are thin-walled and have larger internal to external diameter ratios as compared with rubber DLTs. Their transparent material allows observation of moisture during ventilation and the presence of secretions or blood in either lumen. They are also less irritant and therefore, can be retained in body for longer time. The tracheal as well as bronchial cuffs of these tubes are high volume-low pressure. All these properties reduce the danger of ischemic pressure damage to the airway mucosa. With more and more indications for lung isolation, new tube designs continue to come in the market. There are short DLTs for patients with tracheostomy

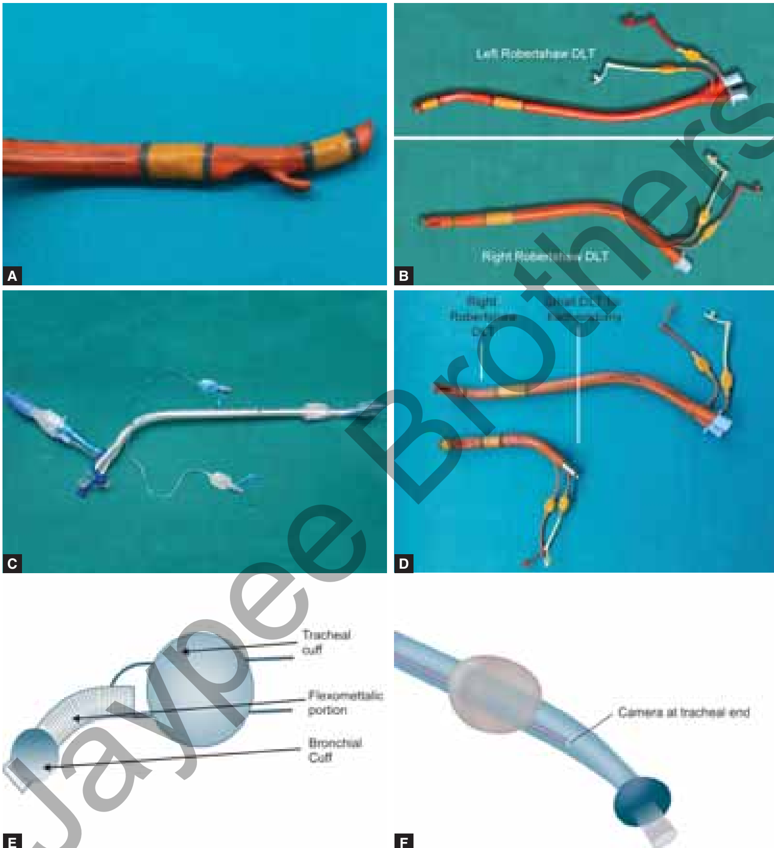


Fig. 1: **A,** Carlen's double lumen tube; **B,** Robertshaw double lumen endotracheal tube; **C,** left double lumen tube (polyvinyl chloride); **D,** small for tracheostomy; **E,** silbroncho double lumen endotracheal tube; **F,** vivaSight double lumen tube

(Fig. 1D). The new Silbroncho tube has distal 5.1–5.8 cm portion wire-reinforced to maintain tip angulation at 45° (Fig. 1E). Wire enforcement prevents obstruction and kinking from mediastinal compression when the tube is positioned in the dependent lung. They are available in both right- and left-sided versions in 33, 35, 37, and 39 Fr sizes.

Viva Sight DLT is manufactured in a left-sided version, in sizes 35, 37, 39, and 41 Fr. (Fig. 1F) Its shape is identical to that of other commonly used DLTs. It has a camera embedded at the distal end of its tracheal lumen and can be connected to an external monitor with a video cable. This helps in real-time visualization of the intubation. It has an extra side-port attached to flush the camera lens with saline. The confirmation of intubation is like with any other DLTS (the carina should be clearly visible and the upper edge of the bronchial cuff seen in the main-stem bronchus.) The proposed advantage is reduction in the need of fiber optic bronchoscopic confirmation during DLT placement however current literature doubts this.[3] Another advantage is that it allows real time monitoring of the tube placement throughout the surgery. The downside of this is overheating and melting on the distal portion of the tube due to the heat generated by camera light.[3]

All modern double lumen bronchial tubes except Viva Sight are either right- or left-sided and they all have:

- Longer bronchial lumen entering one of the bronchus with a cuff
- Shorter tracheal lumen with a cuff
- Preformed curve to facilitate entry in to the bronchus
- Malleable stylet
- Radiographic marker along the length of the tube.

INDICATIONS FOR THE USE OF LUNG SEPARATION TECHNIQUES

In Operation Room

- Before anesthetizing a patient with massive intrapulmonary bleed: Open surgery or interventional radiologic procedures
- Patients with bronchiectasis and lung abscess undergoing surgeries for same
- Surgeries for major bronchopleural or broncho esophageal fistula repair
- Major bronchial disruption or trauma repair
- Unilateral lung lavage for pulmonary alveolar proteinases
- Video-assisted thoracoscopic procedures: Lung resections and esophageal surgeries
- Open thoracic surgeries of esophagus, spine surgeries those require transthoracic approach, and minimally invasive cardiac surgeries.

In Intensive Care Unit

- Unilateral parenchymal injury
  - Aspiration
  - Pulmonary contusion
  - Pneumonia
- Single lung transplant (postoperative complications)
- Bronchopleural fistula needing mechanical ventilation.

SELECTING SIZE OF DOUBLE LUMEN BRONCHIAL TUBE

There is no absolutely accurate method for selecting the correct sized tube. The age, gender, height, or weight are relatively poor predictors of airway size. The selection of a DLT based on these criteria often results in a tube that is either too large or too small. Following tips are suggested:

- Based on sex and height of patients: Size 35 Fr is recommended for females of height less than 160 cm, 37 Fr for females of height more than 160 cm, 37 Fr for males of height less than 170 cm, and 41 Fr for males of height more than 170 cm.[4]

  One can also use a formula based on height to decide optimal depth of insertion for left-sided DLTs.

  Depth of insertion in cm (at incisors) = 12 + patient height (cm)/10

  Studies have shown that in small below average Asian population, DLT size cannot be predicted from the height[5] and hence alternative methods need to be used.

  Brodsky and Lemmens[6] based on their vast experience of 1170 left-sided DLT placements; found that the average depth of left DLT placement in a 170 cm, tall man or woman was 28–29 cm, with a change of approximately ± 1.0 cm for each 10 cm, change in height.
- Based on radiological studies: Regarding the selection of the proper size of DLT, all studies have focused on the left-sided DLT, in part due to the infrequent use of the right-sided DLT. Direct measurement of bronchial width by X-ray chest (Fig. 2)[7] or chest computed tomography (CT) scan (Fig. 3)[8] is a better way to select a DLT. Unfortunately, the left main bronchus is not visible on as many as 25–50% of chest radiographs. When the bronchus cannot be directly measured, tracheal width can be used to estimate left-bronchial width.[9] The diameter of the left bronchus is directly proportional to the diameter of the trachea. If tracheal width (WT) is known, left bronchial width (WLB) in millimeters can be calculated as:

$$WLB = (0.4 \times WT) + 3.3 \text{ or}$$

$$\text{Predicted left bronchial width} = WT\ (mm) \times 0.68.^{10}$$

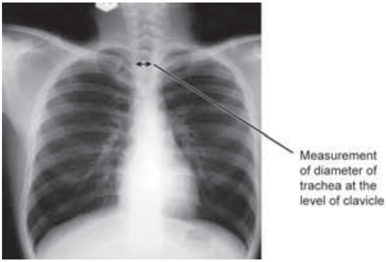


Fig. 2: X-ray-guided measurement of tracheal width

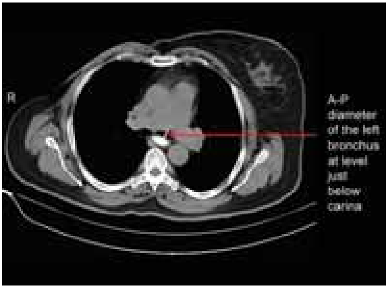


Fig. 3: Computed tomography-guided measurement of left bronchus

INSERTION TECHNIQUE

There are two ways of placing the DLT:

1. The "blind" technique: Polyvinyl chloride DLTs are straight with curve only at bronchial tube level and have malleable stylet to retain memory of curve.
   - The DLT is inserted with concavity facing anteriorly (tip directed upwards) and rotated by 90° towards the bronchus to be intubated after bronchial cuff (distal cuff) passes through vocal cords
   - After the tube passes through glottis, remove the stylet to avoid trauma to airway. Advance the tube while keeping 90° rotation towards the side to be intubated until moderate resistance is felt; this depth is usually 28–30 cm in a normal adult. Avoid using excess force while inserting the tube to prevent airway damage
   - Connect the DLT to the anesthesia circuit, inflate the tracheal cuff and auscultate chest for breath sounds as well as confirm presence of end-tidal CO_2 on the capnogram
   - Take note of the peak airway pressures now
   - Clamp the fresh gases to tracheal lumen and open the port of tracheal lumen. Inflate the bronchial cuff gradually until no air entry is detected on the contralateral lung and no air leak is felt at the tracheal opening during ventilation
   - Auscultate the lung to ensure that there is good air entry at the apex and base of the lung unilateral, and there is no air entry in the contralateral lung
   - Note peak airway pressures. In an adult with normal lungs, rise in peak airway pressure for same tidal volume should not be more than 8–12 cmH_2O
   - Ventilate both lungs again
   - Clamp fresh gas flow inlet of bronchial lumen and start tracheal ventilation. Confirm unilateral air entry by auscultation and unilateral chest expansion
   - Note the peak airway pressures again. If there is larger airway pressure rise, or reduced air entry it suggests that either the bronchial cuff is causing obstruction by herniation across the carina or tube is far too in and tracheal lumen has entered the bronchus
   - Deflate the bronchial cuff and auscultate. If there is no difference in air entry or if there is no change in airway pressures on deflation of the cuff, it suggests that the tracheal portion of the tube is endobronchial, and the tube should be slightly withdrawn. However, if on deflation of bronchial cuff, air entry improves and airway pressure comes down, it suggests probable herniation of bronchial cuff and tube needs to be pushed further into the bronchus
   - After clinical confirmation of placement of tube, insert fiber optic bronchoscope (FOB) down the tracheal lumen and visualize carina. At this point, one should be able to see the carina in front and the blue cuff of endobronchial tube in the main bronchus (Fig. 4A). Refer to video 6.2 for bronchoscopic confirmation of DLT
   - Next, insert FOB down the bronchial lumen and visualize secondary carina (Fig. 4B). In addition, in right-sided tube, confirm opening of the right upper lobe bronchus against hole in the endobronchial portion of tube. Refer to video 6.1 on orientation of bronchoscopic view
   - Any mal positioning of the tube can be visualized and corrected under FOB guidance. Figure 4C shows herniation of bronchial cuff in to the trachea. This DLT needs to be advanced in to the left bronchus.

   "Head Turn" maneuver: Another major problem while inserting left DLT by blind method is entry of tube in right main bronchus. If left DLT enters right main stem bronchus repeatedly; deflate both cuffs, withdraw the tube into the trachea. Turn patient's jaw toward the left shoulder while bending the right ear to the right shoulder and then advance the tube. This maneuver was proposed by Brodsky and in his study, this "head turn" maneuver was successful in 208 of the 269 (77.4%) patients.[6]
2. The "direct vision" technique: Another reliable method of DLT placement is by using FOB.
   - Insert the DLT through the glottis with direct laryngoscopy, rotate it 90° to the side of endobronchial tube, and advance it till the proximal edge of the tracheal cuff is just beyond the vocal cords so that the tip of the bronchial lumen is supra carinal
   - With inflation of tracheal cuff, initiate ventilation of both lungs and confirm tube placement by auscultation and capnometry
   - Place FOB through the bronchial lumen and advance until the carina and main stem bronchi are clearly identified
   - Advance the FOB into the desired main stem bronchus and after deflation of the tracheal cuff, slide the DLT over FOB until its bronchial lumen comes into view beyond the tip of the FOB.

Whether DLT is inserted blindly or under vision, monitoring of the position of tube is necessary when the patient's position is changed from supine to lateral decubitus because displacement can occur in up to 32% of cases.[11] The distal displacement is more common than proximal displacement. Movements of 16–19 mm of a left double lumen tube and 8 mm of a right

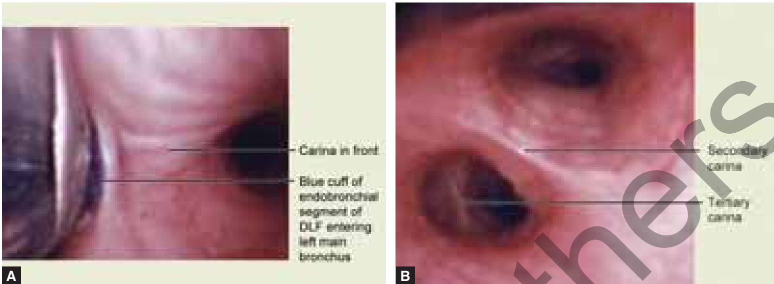


Fig. 4: Fiber optic view through tracheal lumen; **B,** secondary carina; **C,** left double lumen endotracheal tube bronchial cuff herniation in to trachea; needs to be advanced further to the bronchus

double lumen tube can compromise functional lung separation in an adult.[12]

Advantages of Double Lumen Tubes

- Easier to position
- Can be positioned without bronchoscopy
- Less time is required to position as compared with EBB
- More rapid lung collapse, as compared with EBB
- Less likely to be displaced as compared with EBB
- Allows either lung to be ventilated, collapsed, and re-expanded
- Each lung can be suctioned adequately
- Each lung can be inspected with a bronchoscope
- Continuous positive airway pressure (CPAP) can be easily applied to operated lung
- Enables independent lung ventilation in ICU.

Disadvantages of Double Lumen Tubes

- It may be impossible to place a DLT in a patient with a difficult airway
- The large size and design of DLTs can cause airway damage during insertion, prolonged use, and removal
- There can be a problem in proper placement especially if the tracheal or bronchial anatomy is severely distorted
- Lesions within the trachea, like tumors, are relative contraindications to DLT placement
- If patient's condition necessitates mechanical ventilation postoperatively, changing a DLT to a single-lumen ETT at the end of surgery can be hazardous
- Intubated patient from ICU coming for a surgery requiring lung isolation would require change of single-lumen ETT to a DLT, which can be dangerous in patients who are fluid resuscitated and have airway edema, those with cervical spine injuries, difficult airways, and in those that cannot tolerate periods of apnea
- Double-lumen tubes are manufactured in limited sizes 28, 35, 37, 39, and 41 Fr and are often too big for most of pediatric patients
- Lumens of DLTs are narrow as compared to single lumen tube.

Method of Sterilization

All current double lumen tubes are disposable; recommended for single use.

BRONCHIAL BLOCKERS

In 1935, Archibald used a rubber bronchial blocker to facilitate lung surgeries first time in history.[1] Since then a variety of balloon tipped catheters have been used as bronchial blockers including Fogarty embolectomy catheter, Foley catheter and even Swan Ganz catheter. However, problem with these devices are many, and include difficult placement due to their lack of directing mechanism, inability to perform suction or oxygen insufflation due to lack of lumen and poor occlusion of bronchus due to the high pressure-low volume spherical shaped cuff. To overcome these problems, a combined endotracheal tube and bronchial blocker, the Univent tube, was introduced in the 1980s.[13] Recently, several blockers have become available like Coopdech (Fig. 5), Cohen, Arndt (Fig. 6), and EZ blocker. (Fig. 7) Bronchial blockers can overcome many of the previously discussed disadvantages and contraindications of DLT use.

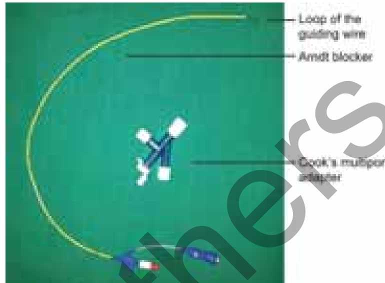


Fig. 6: Arndt endobronchial blocker

Technique of Insertion

Coaxial Placement

In the classically described method, first intubate the trachea with a single lumen tube, and confirm the placement by auscultation and capnography. Introduce the EBB through the lumen of the ETT. Insert the FOB with external diameter of 4.00 mm or less (depending on size of ETT) along the EBB through the endotracheal tube and then place EBB under vision into the main stem bronchus of the lung to be collapsed. This is called coaxial placement (Fig. 8). Inflate the balloon with 4–5 mL of air under direct vision. When EBB is correctly positioned, FOB examination will show that the proximal or outer surface of the inflated balloon is located just below the tracheal carina, usually around 5 mm inside the desired bronchus. Once adequate initial placement is achieved, the balloon of the EBB should be deflated before turning patient into lateral decubitus to prevent dislodgement (inflated EBB balloon can easily pop out of bronchus while changing position), except when indication for lung isolation is

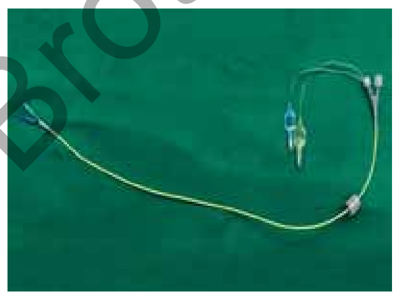
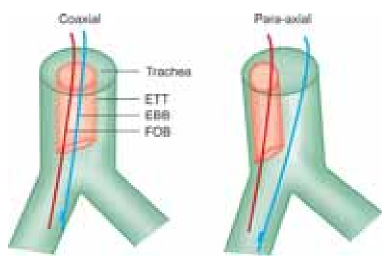


Fig. 7: E-Z Endobronchial Blocker

Fig. 5: Coopdech endobronchial blocke



ETT, endotracheal tube; EBB, endobronchial blocker; FOB, fiberoptic bronchoscope.

Fig. 8: Types of placement of endobronchial blockers

protecting normal lung from getting contaminated, in which case balloon should be kept inflated while giving position.

Paraxial Placement

Alternately, blockers can also be inserted along the side of single lumen tube (paraxial placement) which can be done with patient awake or under anesthesia. In awake technique, EBB is inserted through the vocal cords under FOB guidance and placed in desired bronchus followed by either awake intubation or intubation under anesthesia. Alternately, patients can be anesthetized first, followed by insertion of blocker through cords under vision up to the carina (approximately 26–28 cm in adults), followed by intubation with single lumen tube. Final position of the EBB can be adjusted by using FOB through ETT. Pediatric sized FOB is required for coaxial placement needs of EBB; but paraxial positioning of EBB can be done using adult FOB with outer diameter of 6–6.5 mm in adult (Fig. 8).

The coaxial insertion is preferred as the blocker remains well anchored through the ETT and the chances of its free movement and mucosal injuries are less. Because of small airway size, coaxial placement of a blocker may not be always possible in small children. Thus, paraxial placement of Arndt EBB or Fogarty is often practiced in children.[14]

Advantages of Blockers

- Unlike double lumen tubes, EBB adds no further complexity to intubation
- Offers a distinct advantage in the intubation of difficult upper airways
- Useful in pediatric patients in whom the tracheobronchial size may not accommodate even the smallest double lumen tube
- Lung isolation in distorted neck (e.g. burns contracture, post radiation) and tracheobronchial anatomy (by extraluminal tumors or thoracic aortic aneurysm etc.), where positioning of DLT is difficult or impossible
- EBB can be inserted through DLT intraoperatively as a rescue method in case of failed lung isolation using DLT
- Repositioning is possible in lateral decubitus, if the blocker is mal positioned after giving position for thoracotomy
- Rupture of the tracheal cuff during intubation is not an uncommon problem when using DLTs, which, on occasion, requires the use of multiple DLT tubes. This problem is not seen with the use of EBB
- EBB can be used when ETT is already in place (oral, nasal, tracheostomy)
- Not necessary to change ETT if postoperative ventilation required
- Allows selective lobar blockade
- Useful for patients requiring nasotracheal intubation.

Disadvantages of Blockers

- Tedious final placement after intubation
- Final placement to achieve adequate lung isolation takes little longer than DLT insertion and requires bronchoscopic guidance
- Difficult to place when bronchoscopic visualization is limited by massive hemoptysis
- EBBs cannot be used when the side of the bleeding is unknown in case of intrapulmonary hemorrhage
- Dislodgement is more common with bronchial blockers than in DLTs during positioning and surgical manipulation of lung
- By blocking up the pathological side, it is difficult to monitor continued bleeding or secretions
- Lung collapse is slower though final quality of surgical exposure is similar with both DLTs and EBBs
- Inclusion of bronchial blocker or distal wire loop of Arndt blocker in stapler during lung surgery has been reported and requires good communication between the surgeon and anesthetist
- Inflated balloon may slip in trachea causing blockade of ETT and obstruction to ventilation
- Due to very narrow suction channel suctioning of blood or thick secretions is difficult
- Bronchial blockers present the potential risk of perforating a bronchus or lung parenchyma
- Sizes not available for children less than 1 year.

Fogarty Endovascular Catheter

It is available in 2–9 Fr sizes. It has a high-pressure, low-volume balloon and does not have a lumen for suction or application of CPAP. Though they are not designed for bronchial blockade they are traditionally used. The placement is difficult as there is no guiding mechanism but only a stylet.

In children for coaxial placement; the smallest tracheal tube recommended is 4.5 mm ID for using 5 Fr Fogarty catheter and 4 mm internal diameter (ID) ETT for 2 Fr and 3 Fr Fogarty catheters with a fiberscope of less than 2 mm external diameter. Before the availability of Marraro DLT, this was the only possible method of lung isolation in infants. In adults, the 8 Fr catheter can be placed through 7 mm or 8 ID ETT using a fiberscope of 3.4/3.7 mm external diameter. For coaxial placement, Fogarty catheter needs to be inserted through the Cook's multiport adapter so that patient can be ventilated.

Arndt Wire-Guided Endobronchial Blocker

This is the first independent bronchial blocker. It is available in 5 Fr and 7 Fr with high volume-low pressure spherical cuff and 9 Fr with spherical and elliptical cuffs (Table 1). Spherical balloon is designed for right main stem bronchus to avoid the blockade of the opening of right upper lobe to ensure complete deflation of right bronchus. It is also used for selective lobar blockade. Elliptically shaped cuff fits better into the left main-stem bronchus because of its elongated shape. The catheter has 1.4 mm central channel which contains a nylon guide wire with loop that projects out from the distal tip. The Arndt blocker with fully deflated cuff and the FOB are introduced through the multiport connector. The mechanical ventilation can be continued throughout the placement, using a breathing circuit attached to the third (horizontal) port of the adapter. The wire-loop of the Arndt blocker is coupled with the FOB and serves as

TABLE 1 Characteristics of commonly used endobronchial blockers

	Arndt	Coopdech	EZ	Fogarty
Size (French)	5, 7, 9	9	7	2–9 Fr
Balloon shape and colour	• 5, 7—spherical • 9—spherical and elliptical • All cuffs blue	• Small spindle-shaped, blue • Rectangular, blue	• Spherical • One cuff green and other blue	• Spherical, transparent
Cuff characteristic	High volume-low pressure	High volume-low pressure	High volume-low pressure	Low volume-high pressure
Murphy eye	Present in 9 Fr	Absent	Absent	Absent
Center channel	Present	Present	Present	Present
Smallest ETT for coaxial use	• 4.5 (5 Fr) using FOB <2 mm • 7.0 (7 Fr) using FOB <3 mm • 8.0 (9 Fr) using FOB 3.4 mm	• 7.0 (9 Fr) using FOB <3 mm • 8.0 (9 Fr) using • FOB 3.4 mm/3.7 mm	• 7.0 (7 Fr) using FOB <3 mm	• 4 (2 and 3 Fr) and • 4.5 (5 Fr) using FOB <2 mm
Guidance mechanism	Nylon wire-loop coupled with FOB	Preformed bend at tip	Natural curve at bifurcation	Stylet

ETT, endotracheal tube; FOB, fiberoptic bronchoscope; Fr, french..

Fig. 9: Arndt blocker

Fig. 10: Coopdech endobronchial blocker tube

a guide to introduce the blocker into desired bronchus. (Fig. 9) Once the deflated cuff is below the entrance of the bronchus, the FOB is withdrawn, and the cuff is fully inflated with 2–3 mL of air for selective lobar, or 5–8 mL of air for bronchial blockade. After the patient is turned to the lateral decubitus position, bronchoscopic confirmation of the position is mandatory. Refer to video 6.3 for Arndt blocker insertion.

In case after changing the patient position, one needs to reposition blocker, the guide-wire loop cannot be reinserted in 5 Fr and 7 Fr. Hence it is advisable not to withdraw the wire loop till the blocker position is reconfirmed after patient positioning.

Coopdech Blocker

The blocker kit contains blocker and the joint connector incorporated with blocker; which is functionally same to Cook's multiport connector (Fig. 10). It is a 9 Fr, 60 cm blocker; available in two types: (i) type A (without auto inflator) and (ii) type B (with auto inflator device). Each type is available in rectangular and spindle-shaped cuffs. In type B Coopdech blocker; air is injected in the auto inflator balloon in advance before introducing the blocker through ETT. Once the blocker tip reaches the target place; the operator presses the auto inflator button which features a one touch structure. The valve opens by pressing the button and directs the accumulated air from the auto inflator to the pilot balloon.

Thus, operator can inflate the balloon by pressing the auto inflate button while still performing bronchoscopy. Refer to video 6.4 for insertion of Coopdech blocker. The FOB and the Coopdech blocker are inserted through multiport connecter till carina is seen. Then the blocker is advanced in to the desired bronchus and the cuff is inflated (Fig. 11).

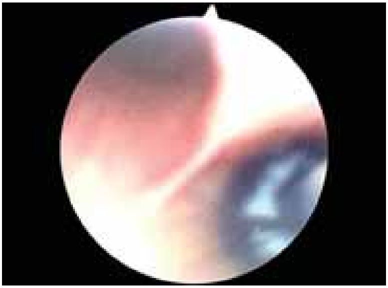


Fig. 11: Bronchial blocker in right main bronchus

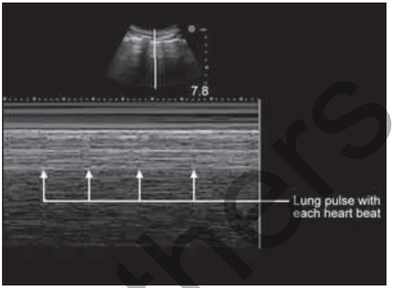


Fig. 12: Lung pulse

After placement of any of the EBB, disconnect the ETT from the anesthesia circuit and apply continuous suction to the blocker channel to deflate the lungs. Then inflate cuff of the blocker and resume ventilation through the ETT. This ensures adequate deflation of the nonventilated lung.

EZ Blocker

It is a 7 Fr 75 cm catheter, has a bifurcation at its distal end. It has green cuff on one limb and blue on another. (Fig.7) Intubate as usual with an endotracheal tube (ET) size 7.0 mm or larger attach the EZ-Multiport Adaptor to the machine end of ETT. And confirm depth of intubation leaving 4 cm between distal tip of the ET tube and the carina using FOB, to allow sufficient space for the deployment of the bifurcated tips. Now insert EZ blocker through the adapter into the ETT. As the blocker emerges through the distal end of the endotracheal tube, the bifurcated cuffs separate and are naturally directed into the left and right main stem bronchi. Confirm blocker placement and orientation by inflating and deflating individual cuffs using FOB. The advantage is cuff inflation can be performed on the side desired to be collapsed, just before lung isolation, which minimizes the need to manipulate the catheter after placement and reduces the potential for the cuffs to become dislodged.

Method of Sterilization

All EBBs are disposable; recommended for single use.

ROLE OF ULTRASONOGRAPHY IN LUNG ISOLATION

After positioning of DLT or EBB, ultrasound of the chest can be done to assess collapse of the lung. In the absence of lung inflation there is no movement between parietal and visceral pleura (lung slide). Hence absent lung slide confirms absent air entry on the nonventilated side and thus correct lung isolation. However, in presence of adhesions between parietal and visceral pleura, the nonventilated lung may not collapse despite achieving good isolation. Therefore, absence of lung slide confirms the isolation; but may not guarantee complete collapse of the nonventilated lung.

The "lung pulse" (Fig. 12) is a dynamic ultrasound sign described as the association of absent lung sliding along with heart rhythm perception at pleural line; it is used in early diagnosis of complete atelectasis.

LUNG ISOLATION IN PEDIATRIC PATIENTS

The lung isolation in children is challenging owing to their small airway size and unavailability of very small DLT, and therefore, endobronchial intubation with single lumen tube was the commonly practiced method in children. The Fogarty embolectomy catheter was often used in very small children for lung isolation in children until Arndt blocker was introduced.

Marraro Pediatric Bilumen Tube (Fig. 13)[15]

It is a DLT specially designed for infants and neonates. It is a single use PVC tube made of two separate uncuffed tubes of different lengths fused together. The tracheal tube is shorter and is attached to the longer bronchial tube along its whole length. It is a thin walled, kink resistant, light weight, thermosensitive tube, which confers to the child's trachea-bronchial anatomy. The bronchial tube has an oval opening "Murphy's eye" to prevent exclusion of the upper right lobar bronchus in case of selective right bronchial intubation. Both the lumens are circular in cross-section along the whole length to facilitate the introduction of a suctioning catheter and to perform bronchial aspiration. There is a radio-opaque line running along the entire length of the tube. A disposable metal stylet (of the length of the longer tube) is used to intubate to maintain the shape of the bi-lumen tube. The tube has universal connectors so that it is easily linked to anesthesia

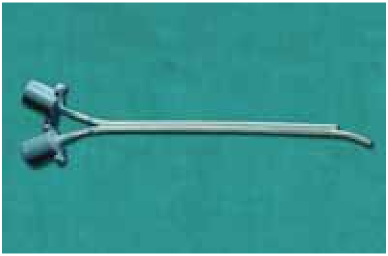


Fig. 13: Marraro Bilumen Tube

TABLE 2 Marraro pediatric bilumen tube

Age	Calibre suggested
Premature baby (1400–2500 g)	2 + 2
New-born (2500–4000 g)	2.5 + 2/2.5 + 2.5
1 month	2.5 + 2.5
6 months	3 + 2.5
12 months	3.5 + 3

machine or ventilators. Since the transverse diameter of the tube is larger than AP diameter, it is positioned perpendicular to the vocal cords.

The caliber suggested for Marraro Pediatric Bilumen tube are described in table 2.

Disadvantages of Marraro Tube

- Tracheal, carinal and bronchial trauma can occur while introduction of the tube
- It can be easily obstructed due to secretions, due to its narrow caliber
- Dislocation of the tube is easy
- It offers more resistance to airflow due to its long and narrow lumen.

Other various possible options available in pediatric patients are described in table 3.

Airway Trauma during Use of Double Lumen Endotracheal Tube or Bronchial Blocker

The recent meta-analysis showed that the incidence of sore throat was significantly more with DLTs. The incidence and severity of airway injury was significantly less in EBB which included bronchial and vocal cord redness, edema, and hematoma, vocal cord thickening, erythema, and granuloma. The frequency of mal positioning was associated more with EBB. The quality of lung collapse and time taken for collapse were comparable with both DLT and EBB.[17]

The incidence of sore throat and vocal cord injuries were reduced by thermal softening of DLTs by dipping them in saline at 40° C for 10 minutes.[18]

WHAT TO USE WHEN

The decision to use which technique for lung isolation depends on clinical setting as no technique is perfect as we have seen above. Surgery on patients with massive intrapulmonary hemorrhage or drainage of copious secretions will be best managed with DLT; whereas lung isolation for patients with difficult airway, patients requiring naso tracheal intubation or for surgeries like

TABLE 3 Other methods of pediatric lung isolation

Method	Remarks
Arndt 5 Fr blocker	• Smallest tracheal tube recommended for use with this pediatric bronchial blocker is 4.5 mm ID, which requires a fibre optic scope of less than 2.0 mm coaxial placement for limiting the use of this technique in infants[16] • 2.2 mm or 2.8 mm scope may be used with larger tracheal tubes
DLT	• Smallest size available 26 Fr. corresponds to 8.7 mm outer diameter. Therefore, limits the use in children more than 8-year-old or more than 30 kg in weight
Univent blocker	• The smallest univent tube has a large outer diameter (8 mm OD) and narrow inner diameter (3.5 mm ID) limiting its use to an older age group.
Fogarty endovascular catheter	• Size 2, 3, 5 Fr are used in children • Smallest tracheal tube possible is 4.5 mm ID for using 5 Fr Fogarty catheter and 4 mm ID ETT for 2 Fr and 3 Fr Fogarty catheters with a fiberscope of less than 2 mm external diameter
Endobronchial intubation with single lumen tube	• May provide partial lung isolation if uncuffed tube is advanced in the contralateral bronchus • Intraoperative suction of the surgical lung is not possible

DLT, double lumen tube; OD, outer diameter; ETT, endotracheal tube; ID, internal diameter; Fr, french.

esophagectomies where indication is just lung separation, as well as in small children, EBB would be a technique of choice.

CONCLUSION

Double lumen endotracheal tubes and bronchial blockers have been found to be clinically equivalent in terms of performance in providing lung collapse for patients with normal airways. Until recently, use of DLTs had been the method of choice for separating the lungs in most adult patients, however with familiarity of bronchial blockers use of blockers is increasing steadily. Each device provides advantages depending upon the case, such as absolute lung separation with a double-lumen endotracheal tube or the use of a bronchial blocker in a difficult airway for a patient requiring lung isolation. No matter what method of separating the lungs is chosen, there is a real need for the immediate availability of a small-diameter fiber optic bronchoscope with a suction port to confirm correct position of device and rule out malposition which can occur anytime during surgical procedure.

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