LUNG ISOLATION TECHNIQUES

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INTRODUCTION

We are often required, either electively or urgently to isolate and selectively ventilate a single lung for several reasons. Optimal conditions for the surgeon, are a fully collapsed lung with minimal ‘motion’ of the surgical field. Failure to achieve successful lung isolation can result in disastrous consequences. Therefore it is the responsibility of the anaesthetist to have a good knowledge of the current lung isolation devices and techniques of lung isolation.

INDICATIONS FOR LUNG ISOLATION

There are widely accepted indications for lung isolation, including:-

1. To facilitate surgical exposure :-
   - in thoracic surgery, thoracoscopy, lobectomy, pneumonectomy, lung transplantation, cardiac surgery(i.e. in minimally invasive surgery)
   - surgery of the descending thoracic aorta
   - esophageal surgery
   - other surgical procedures, such as thoracic approach to the spine;

2. Facilitate gas exchange :
   -surgery on the bronchus (i.e. bronchopleural fistula and intraluminal tumors), facilitate gas exchange to the other bronchus

3. Prevent contamination to the contralateral lung (i.e. abscess, hemorrhage due to trauma, rupture of the pulmonary artery, or bronchopulmonary lavage);

4. During the use of differential lung ventilation and positive end-expiratory pressure ventilation.¹

Knowledge of tracheobronchial anatomy, coupled with recognition of this anatomy through a flexible fiberoptic bronchoscope are key factors for successful placement of lung isolation devices.
The trachea is a cartilaginous and fibromuscular tubular structure that extends from the inferior aspect of the cricoid cartilage to the level of the carina. The adult trachea is, on average, 15 cm long. The trachea is composed of 16–22 C-shaped cartilages. The cartilages compose the anterior and lateral walls of the trachea and are connected posteriorly by the membranous wall of the trachea, which lacks cartilage and is supported by the trachealis muscle.
The average diameter in a normal trachea is 22 mm in men and 19 mm in women. In men, the coronal diameter ranges from 13 to 25 mm and the sagittal diameter ranges from 13 to 27 mm. In women, the average coronal diameter is 10–21 mm and the sagittal diameter is 10–23 mm²⁻³.

The tracheal wall is about 3 mm in thickness in both men and women, with a tracheal lumen that is often ovoid in shape. The trachea is located in the midline position, but often can be deviated to the right at the level of the aortic arch, with a greater degree of displacement in the setting of an atherosclerotic aorta, advanced age, or in the presence of severe chronic obstructive pulmonary disease (COPD).⁴

The cricoid cartilage is the narrowest part of the trachea with an average diameter of 17 mm in men and 13 mm in women. The trachea bifurcates at the carina into the right and left mainstem bronchus. An important fact is that the tracheal lumen narrows slightly as it progresses towards the carina. The tracheal bifurcation is located at the level of the sternal angle anteriorly and the 5th thoracic vertebra posteriorly.

The right mainstem bronchus lies in a more vertical orientation relative to the trachea (25° angle), whereas the left mainstem bronchus lies in a more horizontal plane(45°angle). The right mainstem bronchus continues as the bronchus intermedius after the take-off of the right upper lobe bronchus.⁵ See Figure 1

In men, the distance from the tracheal carina to the take-off of the right upper lobe bronchus is an average of 2.0 cm, whereas it is approximately 1.5 cm in women. One in every 250 individuals (incidence 0.1–3%) from the general population may have an abnormal take-off of the right upper lobe bronchus emerging from above the tracheal carina on the right side.⁶,⁷

The diameter of the right mainstem bronchus is an average of 17.5 mm in men and 14 mm in women. The trifurcation of the right upper lobe bronchus consists of the apical, anterior, and posterior division. This is a very important landmark to identify while performing fiberoptic bronchoscopy in order to distinguish the right from the left mainstem bronchus.⁸

Also, a bifurcated or quadrivial patterns in the right upper lobe, two with vertical keels and two with horizontal keels, have been reported. This quadrivial pattern is more predominant in males and its incidence is reported to be 2.9%.⁹ The bronchus intermedius gives rise to the middle lobe bronchus, with its medial and lateral divisions and the lower lobe bronchus. The segmental bronchi of the right lower lobe consist of the superior, anterior basal, medial basal, lateral basal, and posterior divisions.
The distance from the tracheal carina to the bifurcation of the left upper and left lower lobe is approximately 5.0 cm in men and 4.5 cm in women. The left mainstem bronchus is longer than the right mainstem bronchus, and it divides into the left upper and the left lower lobe bronchus. The left upper lobe bronchus has a superior and inferior division (also known as the lingular bronchus). The segmental bronchi of the superior division of the left upper lobe consist of the apicoposterior and anterior segments. The segmental bronchi of the lingular bronchus are the superior and inferior segments.

The left lower lobe consists of the superior, anterior medial basal, lateral basal, and posterior basal segmental bronchi.5

Figure 2 depicts labelled bronchial divisions.
Basic fibreoptic bronchoscopic views of trachea and bronchus

Figure 3. Bronchoscopic View of the Trachea and Bronchus

(A) Tracheal carina. At 12 o’clock there is a cartilage ring (anterior wall) and at 6 o’clock there is the membranous portion of the trachea. In addition, the longitudinal folds are seen (posterior wall). Also, the entrance of the right mainstem bronchus is seen towards the right, and the entrance of the left mainstem bronchus is seen towards the left. (B, upper) Bronchial carina. To the right, the entrance of the right upper lobe bronchus can be seen, and towards the left the bronchus intermedius is seen. (B, lower) Entrance of the right upper lobe bronchus with three orifices (B-1 apical, B-2 anterior, and B-3 posterior segments). (C) Right middle lobe bronchus at 11 o’clock (resembles the letter D), and right lower lobe bronchus downward. (D) A clear view of the left upper lobe bronchus and lingula bronchus to the right and the left lower lobe bronchus towards the left.

Campos JH. Current Opinion anaesthesiol 2009;22:4-10

OPTIONS FOR LUNG ISOLATION

Currently lung isolation can be achieved by

1. **Double Lumen Technology** (Left and Right-Sided double lumen endotracheal tubes)

2. **Bronchial Blocking Technology**. This involves blockade by the brochial blockers of a mainstem bronchus to allow lung collapse distal to the occlusion

Double lumen technology

The first DLT was designed by Carlens’ in the 1950s. Although it enabled anaesthesiologists to achieve reliable lung isolation, its narrow lumen resulted in high flow resistance and the carinal hook made it difficult to pass in some patients. In the 1960s Robertshaw modified this design, by introducing DLTs without carinal hooks, larger lumens and left and right DLTs. The 1980s saw the...
designed DLTs being manufactured in disposable polyvinylchloride instead of rubber. Further improvements to the DLTs include\textsuperscript{11}, radiographic markers near the endotracheal and endobronchial cuffs, and a radiographic marker surrounding the ventilation slot for the right upper lobe bronchus for the right sided DLT version. Bright blue, low volume, low pressure endobronchial cuffs are incorporated for easier visualisation during fibreoptic bronchoscopy.

![A. Carlens Tube](image)

![B. Placement at the Carina](image)

Figure 4: Compares the design and correct placement of the Carlens and Robertshaw DLTs respectively

Lung isolation is most commonly achieved with a double lumen tube (DLT). The DLT is a bifurcated tube with both an endotracheal and an endobronchial lumen and can be used to achieve isolation of either right or the left lung.\textsuperscript{11}

All DLTs share the following characteristics:

1. A longer bronchial lumen that enters either the right or left main bronchus and another shorter tracheal lumen that remains in the lower trachea
2. A preformed curve that allows preferential entry into either bronchus
3. A bronchial cuff
4. A tracheal cuff

Ventilation can be delivered to only 1 lung by clamping either the bronchial or tracheal lumen with both cuffs inflated; opening the port on the appropriate connector allows the ipsilateral lung to collapse.
Table 1 lists the different sizes of DLTs, the appropriate fibreoptic bronchoscope sizes to be used, and the comparable diameters of SLTs.

Table 1 -- Comparative Diameters of Single- and Double-Lumen Tubes

<table>
<thead>
<tr>
<th>Single-Lumen Tubes</th>
<th>Double-Lumen Tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Diameter (mm)</strong></td>
<td><strong>External Diameter (mm)</strong></td>
</tr>
<tr>
<td>6.5</td>
<td>8.9</td>
</tr>
<tr>
<td>7.0</td>
<td>9.5</td>
</tr>
<tr>
<td>8.0</td>
<td>10.8</td>
</tr>
<tr>
<td>8.5</td>
<td>11.4</td>
</tr>
<tr>
<td>9.0</td>
<td>12.1</td>
</tr>
<tr>
<td>9.5</td>
<td>12.8</td>
</tr>
<tr>
<td>10.0</td>
<td>13.5</td>
</tr>
</tbody>
</table>

* The approximate external diameter of the double-lumen portion of the tube
† FOB, fiberoptic bronchoscope. The maximal diameter of FOB that will pass through both lumens of a given size of double-lumen tube. Miller’s Anaesthesia 7th Edition

Left and right sided DLTs are available to pass into the left and right bronchus respectively, this is due to the difference in anatomy between the two main bronchi. Left DLTs are used more frequently than right DLTs. In an article describing their clinical experience of Left DLTs in 1170 patients, Brodsky and Lemmens refer a L DLT for both right- and left-sided procedures.

Reasons cited is that the right bronchus is much shorter than the left bronchus so there is a greater risk of upper-lobe obstruction with a right DLT. Because the right upper-lobe bronchus originates at the carina or even the trachea in as many as 3% of the population, a right DLT may be difficult to safely position in some patients.'
LEFT SIDED DOUBLE LUMEN TUBE

Selecting the ‘ideal’ size left DLT

A properly sized DLT is one in which the main body of the tube passes without resistance through the glottis and advances easily within the trachea, and in which the bronchial component passes into the intended bronchus without difficulty.\textsuperscript{10}

Various methods have been described to select the proper L sided DLT size. Generally, size of DLT is chosen on patient height and gender. The study by Brodsky et al\textsuperscript{13} found that, for most men in their patient population, despite height or weight, a 41 Fr DLT could be used. For women gender, height and weight were not reliable guides in predicting airway dimensions.

Table 2 -- Selection of Double-Lumen Tube Size Based on Adult Patients’ Sex and Height

<table>
<thead>
<tr>
<th>Sex</th>
<th>Height (cm)</th>
<th>Size (Fr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>&lt;160 (63 in.)\textsuperscript{*}</td>
<td>35</td>
</tr>
<tr>
<td>Female</td>
<td>&gt;160</td>
<td>37</td>
</tr>
<tr>
<td>Male</td>
<td>&lt;170 (67 in.)\textsuperscript{†}</td>
<td>39</td>
</tr>
<tr>
<td>Male</td>
<td>&gt;170</td>
<td>41</td>
</tr>
</tbody>
</table>

\textsuperscript{*} For females of short stature (< 152 cm or 60 in.), examine bronchial diameter on CT scan and consider 32 Fr.

\textsuperscript{†} For males of short stature (<160 cm or 63 in.), consider 37 Fr.

A later study by Brodsky et al\textsuperscript{15} suggested a more accurate method for selecting Left DLTs based on the tracheal diameter. They found a significant correlation between tracheal size and bronchial diameter. Using a ratio of left bronchial diameter to tracheal diameter of 0.68, the bronchial width could thus be calculated from the measured tracheal width. They devised a guide to choosing the correct Left DLT by measuring the tracheal width at the level of the clavicles on a pre-op P-A CXR. Using tracheal width as a guideline, they placed 41 Fr tubes in 10 of the 32 women included in the study. Their subsequent preference is to use large DLTs, citing reasons that: \textsuperscript{15}

1. most intra-operative malpositioning occur from small DLTs, which can easily advance too deep into the bronchus and obstruct the upper lobe orifice
2. the bronchial cuff of small DLTs must be inflated with large volumes of air that can cause airway rupture or cuff herniation into the carina.
3. If the cuff is underinflated, the lung will fail to collapse and/or the opposite lung will not be isolated or protected from contamination
4. The lumen of a smaller DLT offers more resistance to airflow during one-lung ventilation and makes it more difficult to advance a fiberoptic bronchoscope or suction catheter.

**Table 3 -- Guidelines for Choice of Left DLTs**

<table>
<thead>
<tr>
<th>Measured Tracheal width (mm)</th>
<th>Predicted Left bronchus width (mm)</th>
<th>DLT size</th>
<th>Outside diameter (mm)</th>
<th>Outside diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;= 18</td>
<td>&gt;= 12.2</td>
<td>41 Fr</td>
<td>14-15</td>
<td>10.6</td>
</tr>
<tr>
<td>&gt;= 16</td>
<td>&gt;= 10.9</td>
<td>39 Fr</td>
<td>13-14</td>
<td>10.1</td>
</tr>
<tr>
<td>&gt;= 15</td>
<td>&gt;= 10.2</td>
<td>37 Fr</td>
<td>13-14</td>
<td>10.0</td>
</tr>
<tr>
<td>&lt;= 14</td>
<td>&lt;= 9.5</td>
<td>35 Fr</td>
<td>12-13</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Tracheal width (in mm) measured from chest radiograph.
Predicted left bronchus = tracheal width (mm) x 0.68
DLT = nonbeveled, left BronchoCath (Mallinckrodt Medical, Inc, St. Louis, MO)
Outside diameter (in mm) for the main body of the DLT and for the left lumen of the DLT.

Miller’s Anaesthesia 7th Edition

Chow et al found that by using the method by Brodsky et al described above, seems more accurate when selecting larger sizes of DLTs (39Fr/41 Fr) for a patient, but is not reliable when predicting smaller DLT sizes (35Fr/37 Fr). Their study, conducted with an Asian patient population, showed that the use of tracheal width method of determining DLT size was limited in patients of short stature (<155cm) and suggested an alternative method of predicting DLT size based on direct measurement of the left main bronchus from a CT Scan of the chest. Although useful, this method is impractical as, a CT Scan is a limited resource and an experienced radiologist is required to determine the airway sizes.

Controversy about DLT size is compounded by a study by Amar et al who concluded that use of a smaller DLT (35Fr/37 Fr left sided DLT) rather than a larger DLT (39Fr/41Fr) was not associated with any difference in clinical intra-operative outcome, regardless of patient size or gender in 300 patients undergoing thoracic surgery requiring OLV. However in this study only the majority of patients (65%) who received 35Fr DLTs were female, who are more likely to be intubated with 35Fr LDTs in most cases.

The salient points from these studies are that pre-operative chest radiological investigations i.e. the PA chest radiograph and CT Scan of the chest can provide valuable information of the patients tracheobronchial anatomy and lung pathology.
that might make intubation difficult, and should therefore be reviewed prior to selecting DLT size.

**Methods of Placement of Left-Sided Double–Lumen Endotracheal Tubes**

There are 2 recognised methods for placement of the left sided DLT
1. A 'blind' technique
2. A fibreoptic guided technique

**Blind Technique**

A left DLT is passed by direct laryngoscopy beyond the vocal cords with a stylette in place (endobronchial lumen), the stylette is then withdrawn and the tube rotated 90° counterclockwise and advanced until slight resistance is felt, which usually indicates that the endobronchial lumen of the DLT has entered the bronchus.

![Figure 5: The blind method technique for placing a left-sided DLT](image)

A: The DLT is passed with direct laryngoscopy beyond the vocal cords.
B: The DLT is rotated 90 degrees to the left.
C: The DLT is advanced until moderate resistance is felt, indicating that the endobronchial lumen of the DLT has entered the bronchus (in general 27 cm marks the level of the teeth).  
SAJAA 2008; 14(1): 22-26
Fibreoptic-Directed Method

Again, the Left DLT is passed by direct laryngoscopy. Once the endobronchial tip of the DLT has passed the vocal cords, the fibrescope is passed down the endobronchial lumen, and the tip of the DLT is then guided over the fibrescope into the left main bronchus.

![Figure 6: The fibreoptic bronchoscopy guidance technique for placing a left-sided DLT](image)

A: The DLT is passed with direct laryngoscopy beyond the vocal cords.
B: The fibreoptic bronchoscope is advanced through the endobronchial lumen. The tracheal carina and left mainstem bronchus are visualised.
C: The DLT is rotated 90 degrees to the left and, with the aid of the fibreoptic bronchoscope, the tube is advanced into the left mainstem bronchus. *SAJAA 2008; 14(1): 22-26*

Auscultation and/or fibreoptic bronchoscopy are current methods to confirm DLT placement. Full inflation of both the endotracheal and endobronchial cuffs are required to achieve a good seal. An airtight endobronchial cuff is necessary to allow ventilation or to protect against contamination no leaks should be present with a maximum of 3ml air.

When the endobronchial lumen adapter is clamped, you should not hear breath sounds or observe chest movement on the left side of the chest. When the endotracheal lumen adapter is clamped is, chest movement and breath sounds should be absent on the right side.
(A) Shows an unobstructed view of the entrance of the right mainstem bronchus when the fiberscope 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) Shows the take-off of the right-upper bronchus with the three segments (apical, anterior and posterior); this is a landmark to reconfirm a right bronchus.

(C) Shows an unobstructed view of the left-upper and left-lower bronchus when the fiberoptic bronchoscope is advanced through the endobronchial lumen.

In average sized adult, the height of the patient can be used to assess the optimal depth of insertion. In adults, depth, measured at the teeth, for a properly positioned DLT will be approximately 12+\text{\text{patient height/10}} \text{cm}. This formula is less reliable in patients with short stature\text{(<155cm)}. The depth of insertion for a DLT should be between 27 and 29cm at the marking of the incisors for a subject who is 170 cm tall.( For every 10 cm in height greater or less than 170 cm, the DLT should be advanced or retreated 1 cm deeper from the incisors.)

It is crucial to recheck the position of the tube once the patient is re-positioned as it is often found that that the turning the patient lateral results in apparent movement of the tube more proximal into the trachea.

Evidence suggests that auscultation alone is unreliable for confirmation of proper DLT placement. This is shown in a study involving 200 patients who were
intubated using the blind method with confirmation of placement by auscultation. The position of the DLT, as confirmed by FOB by a second anaesthetist with expertise in FOB, required re-positioning in more than a third of cases. However, in a study by Brodsky et al reporting clinical experience with use of left sided DLTs in 1,164 patients, successful lung isolation was achieved in 98% of cases—the DLTs were placed in this case by experienced thoracic anaesthetists.

The use of fibreoptic bronchoscopy has several benefits, which include, being able to confirm and correct malpositioned tubes, detect airway injuries, suction and jet ventilate through the available ports. However, fibreoptic bronchoscopy can only be beneficial in experienced hands. In a study involving anaesthetists with limited experience in lung isolation techniques, it was found that although fibreoptic bronchoscopy was used to place the devices, malpositions were not recognised in up to 38% of cases. Possible reasons for this, were lack of skill with fibreoptic bronchoscopy and lack of the recognition of the airway anatomy.

In his review of lung separation techniques, Campos is of the opinion that positioning a DLT with fibreoptic bronchoscopy guidance is an essential adjunct to correct lung isolation. He concedes that anaesthetists inexperienced in anomalous tracheobronchial anatomy and FOB, may wish to increase their chances of successful DLT placement by also using the blind technique with confirmation by auscultation.

The relative ease of placement and ability to isolate and/or ventilate either lungs, makes the left-sided DLT the choice for most thoracic cases. However there are situations where the right sided DLT can be used as an alternative.

**RIGHT-SIDED DOUBLE LUMEN ENDOTRACHEAL TUBES**

Although the left-sided DLT is used for lung isolation in most cases due to the greater margin of safety it provides, the right sided DLT is recommended in certain situations. Studies on lung isolation techniques favour the use of the L DLT in most cases.

The main reason preventing the use of the R DLT is the higher incidence of right upper lobe collapse and obstruction due to the shorter mainstem bronchus and higher takeoff of the right upper lobe bronchus.

**Recommendations for a Right-Sided DLT**

- Distorted anatomy at the entrance of left mainstem bronchus by an intrabronchial or external compression
- Compression at the entrance of the left mainstem bronchus due to a descending thoracic aortic aneurysm
- Left –sided pneumonectomy
- Left-sided single-lung transplantation
- Left-sided sleeve resection
- Any contra-indication to place a left-sided DLT

Although recommended, a L sided DLT or bronchial blocker can be used for most left pneumonectomies, the device is withdrawn before stapling of the left mainstem bronchus.

The right sided DLT is designed according to the differing right bronchial anatomy described above and thus has a modified cuff, or slot, on the endobronchial side that allows ventilation for the right upper lobe. 1 in 250 people have an anomalous right upper lobe take-off from the trachea, which is a contra-indication for use of the R-sided DLT.

![Figure 8](image)

(A) Displays a fibreoptic bronchoscopy view of the tracheal carina (B) displays fiberoptic bronchoscopy view of the take-off of the right upper bronchus to the right and bronchus intermedius to the left (C) shows a fiberoptic bronchoscopy view of the apical, anterior and posterior segments of the right upper bronchus (a landmark to identify right bronchus) (D) displays the Mallinckrodt® right-sided DLT and (E) displays the Sher-I-dan® rightsided DLT with two endobronchial cuffs.

Update on lung separation techniques: Double Lumen Tubes and Bronchial Blockers Campos JH june2011

The Right Sided DLT is placed under fibre-optic guidance, the optimal position being, one that provides good alignment between the opening slot of the endobronchial lumen and the right upper lobe bronchus and distally a clear view of the bronchus intermedius and the right lower lobe bronchus seen from the endobronchial lumen. The fibre-optic view through the endotracheal lumen would show a clear view of the left mainstem bronchus, and the edge of the fully inflated endobronchial cuff below the tracheal carina in the right bronchus. A rotational
movement might aid alignment of the slot of the tube with the right upper lobe bronchus.

**COMPLICATIONS OF DOUBLE LUMEN TUBE PLACEMENT**

**Malposition**

The danger of a malpositioned tube is that the lung will fail to collapse resulting in gas trapping during positive pressure ventilation, or it may compress the dependent or ventilated lung resulting in hypoxaemia. Causes of malposition include, an overinflated cuff, extension of head and neck in the lateral decubitus position and surgical manipulation of the bronchus. Fibreoptic bronchoscopy is the recommended method to diagnose and correct intra-operative malpositions.

**Airway Trauma**

Airway trauma can occur from an oversized DLT or from an undersized DLT that has migrated into the bronchus causing the tracheal part of the tube to enter the bronchus producing lacerations and possible airway rupture. Airway trauma can present as an unexpected air leak, subcutaneous emphysema, massive airway bleeding into the lumen of the DLT, or protrusion of the endobronchial or endotracheal cuffs into the surgical field. In these instances, bronchoscopy and surgical repair is indicated. DLTs are also associated with an increased incidence of minor airway injuries i.e. postoperative hoarseness and sore throat than bronchial blockers.

**BRONCHIAL BLOCKERS**

Although lung isolation is most commonly achieved with DLTs, bronchial blockers are an alternative method of achieving lung isolation and is the preferred device in certain situations.

Specific indications for Bronchial blockers

- difficult airways
- limited mouth opening
- Nasotracheal intubation
- awake orotracheal intubation
- selective lobar blockade
- already intubated patient requiring lung isolation
- potential for mechanical ventilation in the post op period

The indications for bronchial blockers infer its advantages, In patients with an anticipated or unanticipated difficult airway, placement of a DLT with direct laryngoscopy could be difficult.
This includes patients with cervical spine injuries and/or pathology. In this situation, placement of a single-lumen ETT is easier and often necessary, requiring the need for a bronchial blocker for subsequent lung isolation. Placing a DLT in patients with distorted tracheobronchial anatomy is often difficult and at times, contraindicated, this difficulty is compounded by the larger size of the DLT compared to a single lumen ETT. Use of a bronchial blocker, in this situation, is more often successful and safe.

Patients already intubated may present for surgery requiring OLV, some of these patients may be nasally intubated. Furthermore, some of these patients may not tolerate periods of apnea. Some bronchial blockers can be placed during continuous ventilation.

CPAP can be applied through several bronchial blockers, as well. Additionally, bronchial blockers can provide selective blockade of a specific lobe. This is particularly useful in the patient with an isolated air leak, hemorrhage, or infection in one lobe, thereby allowing ventilation of more lung units. Finally, bronchial blockers are useful in patients who have had a prior pneumonectomy and now present for a selective lobectomy.

Bronchial blocker technology has progressed since its introduction by Magill in 1936, with several devices currently available.

These devices can be used independently by passing it within the lumen of conventional single lumen tube, these are;
- Arndt wire- guided endobronchial blocker
- Cohen tip-deflecting endobronchial blocker
- Fuji Uniblocker
- Fogarty venous embolectomy catheter

Or are incorporated within a modified single lumen tube:
- torque control blocker (Univent)
Figure 9 shows the independent bronchial blockers. Anesth-analg.org

The table below describes characteristics of the current independent bronchial blockers. The smallest internal diameter (ID) of an ETT that will allow passage of both a bronchial blocker and a fiberoptic bronchoscope depends on the diameters of the bronchoscope and the blocker. For standard adult 9Fr blockers, an ETT ≥ 7.0mm ID can be used with a bronchoscope <4.0mm in diameter. Larger bronchoscopes will require an ETT >7.5mmID.

**Table 4 -- Characteristics of the Cohen, Arndt, and Fuji Bronchial Blockers**

<table>
<thead>
<tr>
<th></th>
<th>Cohen Blocker</th>
<th>Arndt Blocker</th>
<th>Fuji Uniblocker</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>9 Fr</td>
<td>5 Fr, 7 Fr, and 9 Fr</td>
<td>5 Fr, 9 Fr</td>
</tr>
<tr>
<td><strong>Balloon shape</strong></td>
<td>Spherical</td>
<td>Spherical or elliptical</td>
<td>Spherical</td>
</tr>
<tr>
<td><strong>Guidance mechanism</strong></td>
<td>Wheel device to deflect the tip</td>
<td>Nylon wire loop that is coupled with the fiberoptic bronchoscope</td>
<td>None, preshaped tip</td>
</tr>
<tr>
<td><strong>Smallest recommended ETT for coaxial use</strong></td>
<td>9 Fr (8.0 ETT)</td>
<td>5 Fr (4.5 ETT), 7 Fr (7.0 ETT), 9 Fr (8.0 ETT)</td>
<td>9 Fr (8.0 ETT)</td>
</tr>
<tr>
<td><strong>Murphy eye</strong></td>
<td>Present</td>
<td>Present in 9 Fr</td>
<td>Not present</td>
</tr>
<tr>
<td><strong>Center channel</strong></td>
<td>1.6 mm ID</td>
<td>1.4 mm ID</td>
<td>2.0 mm ID</td>
</tr>
</tbody>
</table>


ETT, single endotracheal tube; ID, internal diameter.

**THE ARNDT® BLOCKER**¹⁷,¹⁸

Used for wire-guided endobronchial blockade of the left or right lung for procedures which require one-lung ventilation. The set consists of an endobronchial blocker catheter, the Arndt Multi-Port Airway Adapter and a CPAP adapter.

The blocker is placed coaxially through a conventional endotracheal tube using a pediatric bronchoscope. The Arndt blocker’s required usage of a single-lumen endotracheal tube eliminates potential loss of the airway, commonly posed during the extubation-reintubation of a double-lumen tube. Low-pressure, high-volume balloon creates excellent surface area contact with the inner bronchial wall, while minimizing potential trauma to the bronchus.

The unique, adjustable guide-loop couples with a paediatric fibrescope, enabling precise placement. The 9 Fr blocker guide-loop is replaceable once removed.

The Arndt Multi-Port Airway Adapter permits simultaneous bronchoscopy,
ventilation and blocker placement. Included suction adapter facilitates lung deflation.

The Arndt® Blocker, a wire-guided endobronchial blocker is an independent blocker that is passed through an existing SLT. The spherical shaped blocker is used for right sided mainstem bronchial intubation whilst the elliptical shaped blocker is for intubation of the left mainstem bronchus. For ease of insertion though the endotracheal tube, the blocker and the fibre-optic bronchoscope are lubricated.

The placement of the Arndt Blocker involves placing the endobronchial blocker through the endotracheal tube and using the fibre-optic bronchoscope and wire guide to direct the blocker into a mainstem bronchus. The fibreoptic bronchoscope has to be advanced distally enough so that the Arndt® blocker so that enters the bronchus while it is being advanced. When the deflated cuff is beyond the entrance of the bronchus, the scope is withdrawn, and the cuff fully inflated with 4-8ml of air under fibre-optic view with 4-8ml of air to obtain total bronchial blockade. Optimal position of the Arndt blocker in the left or right bronchus is achieved when the proximal edge of the fully inflated cuff is approximately 5-10mm below the trachea carina.

Placement of the blocker into the right mainstem bronchus can be performed without the wire loop under fibre-optic visualisation.

It is important to remove the wire loop to avoid inclusion in the stapling line of the bronchus.

COHEN® ENDOBRONCHIAL BLOCKER

Used for tip-deflecting, wire-guided endobronchial blockade of the left or right lung for procedures which require one-lung ventilation. Balloon is low-pressure, high volume. A manually torqued device with a high-traction silicone grip on the introducer shaft for precise placement into the desired airway.

The unique deflecting tip provides a wide range of adjustments to precisely direct the blocker under bronchoscopic guidance. An indicator arrow on the turning wheel shows which direction the tip deflects, ensuring fail-safe access to the desired lung.

Markings on the introducer show how far the Cohen blocker has been advanced. The small outer diameter preserves maximum airway volume for enhanced patient ventilation during thoracic procedures. The set consists of an endobronchial blocker catheter, the Arndt Multi-Port Airway Adapter and a CPAP adapter.
Included suction adapter facilitates lung deflation
The blocker should be lubricated prior to placement, cuff fully deflated. Optimal position in the right main bronchus is one that that on fiberoptic bronchoscopy shows a fully inflated balloon (4-8ml of air) at least 5mm below the tracheal carina on the right mainstem bronchus.
Optimal placement in the left mainstem bronchus is when blocker balloon’s outer service is seen with fibreoptic bronchoscope at least 5mm below the trachea carina inside the left mainstem bronchus.

FUJI UNIBLOCKER®

The FUJI uniblocker, once lubricated is passed through the single lumen endotracheal tube. Its distal end is angulated to facilitate insertion under fiberoptic guidance into the desired main-stem bronchus. Optimal position of the fully inflated cuff (4-8ml of air), as seen with fibre-optic bronchoscope is at least 5-10mm below the tracheal carina inside left main-stem bronchus and at least 5mm below the tracheal carina on the right main-stem bronchus.

FOGARTY EMBOLECTOMY CATHETER AS BRONCHIAL BLOCKER 17

The Fogarty embolectomy catheter, a device used in vascular surgery can also be used to provide lung isolation. The occlusion balloon of the Fogarty catheter is considered to high pressure, low volume, requires 0,5-10ml of air to achieve bronchial occlusion. The catheter also has a stylet which can be used to mould the distal end of the catheter prior to insertion.

Although the Fogarty catheter can provide reliable lung isolation especially as a rescue device when passed through a DLT that cannot be properly positioned, it has several disadvantages. It is designed to be a vascular device, not a bronchial blocker, it has no channel for suction or jet ventilation, an air leak from the breathing circuit is common.

The potential for inclusion in the stapling line exists especially if the device is used to isolate a lobe.

TORQUE CONTROL BLOCKER (UNIVENT) 17

This bronchial blocker is enclosed into a single lumen endotracheal tube—the original Univent®. Within the Univent® unit there is a channel enclosing a moveable bronchial blocker that can be used to block the left, right or any specific bronchi. Before use, both the bronchial blocker and the endotrachal cuff are lubricated for ease of insertion. The enclosed bronchial blocker is retracted into the standard
lumen of the tube. Once conventional tracheal intubation is performed, a fibreoptic bronchoscope is passed and the enclosed bronchial blocker is directed into the bronchus to be isolated. Advantages of this device is its use to achieve lung isolation in patients with difficult airways.

**COMPLICATIONS RELATED TO BRONCHIAL BLOCKERS**

- Inclusion of the bronchial blocker or the distal wire loop of the Arndt Blocker into the stapling line: the device should be pulled back a few centimetres before the stapling.
- movement of the bronchial blocker from the bronchus into the traches which can lead to failure to ventilate and hypoxia.

The advantages and disadvantages of double lumen tubes and bronchial blockers are summarised in the table below:

**Table 5 -- Options for Lung isolation**

<table>
<thead>
<tr>
<th>Options</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Double-lumen tube</strong></td>
<td>☑ Quickest to place successfully ☑ Repositioning rarely required ☑ Bronchoscopy to isolated lung ☑ Suction to isolated lung ☑ CPAP easily added ☑ Can alternate OLV to either lung easily ☑ Placement still possible if bronchoscopy not available</td>
<td>☑ Size selection more difficult ☑ Difficult to place in patients with difficult airways or abnormal tracheas ☑ Not optimal for postoperative ventilation ☑ Potential laryngeal trauma ☑ Potential bronchial trauma</td>
</tr>
<tr>
<td>1. Direct laryngoscopy</td>
<td>☑ Size selection rarely an issue ☑ Easily added to regular ETT ☑ Allows ventilation during placement ☑ Easier placement in patients with difficult airways and in children ☑ Postoperative two-lung ventilation by withdrawing blocker ☑ Selective lobar lung isolation possible ☑ CPAP to isolated lung possible</td>
<td>☑ More time needed for positioning ☑ Repositioning needed more often ☑ Bronchoscope essential for positioning ☑ Nonoptimal right lung isolation due to RUL anatomy ☑ Bronchoscopy to isolated lung impossible ☑ Minimal suction to isolated lung ☑ Difficult to alternate OLV to either lung</td>
</tr>
<tr>
<td>2. Via tube exchanger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fiberoptically</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bronchial blockers (BB)</strong></td>
<td>☑ Same as BBs Less repositioning compared with BBs</td>
<td>☑ Same as for BBs ☑ ETT portion has higher air flow resistance than regular ETT ☑ ETT portion has larger diameter than regular ETT</td>
</tr>
<tr>
<td>Arndt</td>
<td></td>
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<tr>
<td>Cohen</td>
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<td>Fuji</td>
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</table>
DOUBLE LUMEN TUBE VS BRONCHIAL BLOCKERS

In a recent randomised trial comparing lung isolation achieved by 3 bronchial blockers (Arndt wire-guided BB, Cohen Flexi-tip BB or Fuji Uniblocker) versus double lumen tubes it was concluded that the three bronchial blockers provided equivalent surgical exposure to left-sided DLTs during left-sided open or video-assisted thoracoscopic surgery thoracic procedures. BBs required longer to position and required intra-operative repositioning more often. Arndt BB needed to be repositioned more often than the other BBs.

An earlier study by Campos and Kerstine had similar findings: that time taken for DLT placement was less than time taken for placement of the TCBU or the Arndt Blocker. Although lung collapse was achieved faster with DLT, once one lung ventilation was achieved with either bronchial blocker or DLT, surgical exposure was clinically equivalent among the 3 groups.

It is important to bear in mind that in these studies, placement of the lung isolation devices were by experienced thoracic anaesthetists in a limited number of patients.

In a prospective randomised trial, designed to determine the success and time required for proper placement of the left-sided double lumen tube, univent tube and the Arndt Blocker by anaesthetists who usually performed less than two lung isolation cases per month. Variables recorded included:

1. Successful placement (as determined by an independent observer
2. Time taken to place the isolation device
3. Number of times the fibre-optic bronchoscope was used.

The results were that participants failed to place or position their assigned device in 25 of 66 patients. The failure did not differ among the 3 devices (P=0.65). The median (35th-75th percentile) times to complete the placement procedures were as follows: 1. Double-lumen tube: 6.1 min (4.6-9.5min), 2. Univent tube: 6.7 min (4.9-8.8 min) and 3. Arndt Blocker 8.6min (5.8-17.5min) (P=0.45 comparing all devices). After device malposition, it took 1min or less for the investigating anaesthetist (experienced in thoracic anaesthesia) to achieve optimal position.

The authors concluded that anaesthetists with limited experience in thoracic anaesthesia frequently fail to successfully place lung isolation devices. They surmised that from the nature of the malpositions the most critical factor in successful placement was the anaesthetist’s knowledge of endoscopic bronchial anatomy.

Overall, each device provides advantages depending upon the nature of 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. The onus is upon the anaesthetist to have knowledge of the tracheobronchial anatomy and bronchoscopic views of the airway to aid successful placement.

THE EZ® BLOCKER: A NEW BRONCHIAL BLOCKING DEVICE

![Figure 10. Schematic drawing of the EZ® Blocker](From: bja.oxfordjournals.org)

Patented in 2006, the EZ-Blocker® is an endobronchial blocker (AnaesthetIQ BV, Rotterdam, The Netherlands), intended for use through a single lumen ETT. It consists of a 7 Fr polyurethane catheter containing four lumina. Two of these lumina are for inflation of the cuffs; the other two can be used for additional O₂ supply to the non-inflated lung, or suctioning. The distal part of the BB ends in a Y shape, consisting of two 4 cm long distal extensions, each with a polyurethane spherically shaped cuff.

The extensions are fully symmetrical and coloured differently (blue and yellow) for identification purposes. The EZ-Blocker® is supplied with an adaptor, the EZ-Multiport Adaptor® (AnaesthetIQ BV), which is designed for connection to ventilation devices, introduction of the EZ-Blocker® and a fiberoptic- or video bronchoscope, or a suction catheter. The blocker is introduced and positioned under direct vision using a bronchoscope. Recommended ETT size 8 for females and size 9 for men. When a paediatric scope (max. 3mm) is used size 7.5 ETT can be used.

The symmetrical design facilitates introduction and positioning of the device with the extensions in both main stem bronchi. When the proper position is reached, the cuff in the main stem bronchus of the non-ventilated lung can be inflated and lung isolation is achieved. Owing to its Y shape, the blocker remains in position.

The first clinical trial²¹ using this device in human subjects were reported by Mungroop et al in 2010. They used the EZ Blocker in 11 consecutive patients undergoing elective thoracic surgery. The procedures included wedge resection, lobectomy, chest wall resection and pericardial fenestration and were performed
both on the right and left side. Successful positioning was reached in all patients
easily, and mean time from start of advancement through the TT to the right
position of both distal extensions in the left and right main stem bronchus was
about 1 min and 10 s. After the patient was repositioned in the right or left lateral
decubitus position, the blocker was checked with the bronchoscope. In all
patients, the blocker remained in position throughout the surgical procedure.
Deflation of the isolated lung was good and provided optimal surgical exposure. At
the end of surgery, the cuff of the blocker was deflated, the isolated lung
expanded, and the blocker was removed. All procedures were uneventful and the
patients were extubated at the end of surgery.

They concluded that the new Y-shaped BB device for lung isolation was easy to
introduce and position through a conventional TT and good surgical exposure was
obtained in all patients.

The results of a further clinical trial\(^{22}\), published in April 2011, comparing the
double-lumen tube and EZ blocker for single lung ventilation found that although
time for intubation was longer with the EZ blocker, the device proved to be an
efficient and easy-to-use device. The authors suggested that EZ blocker is a
valuable alternative device to conventional DLT.

The studies so far, although few, shows promise that EZ Blocker's use might
become more common owing to the ease of placement and ability to adequately
provide lung isolation. Further studies, conducted on more subjects are needed.

**CONCLUSION**

Anaesthetists are frequently requested to provide lung isolation. Lung isolation is
indicated most commonly, for surgical exposure, to protect a contralateral lung
from contamination by bleeding or pus and to provide differential lung ventilation.
There are multiple lung isolation devices available, each with advantages and
disadvantages. It is the responsibility of the anaesthetist to have knowledge of the
tracheobronchial anatomy with recognition of the anatomy on pre-operative chest
radiograph, be familiar with the available lung isolation devices and be skilled in
performing fibre-optic bronchoscopy. These factors have proved to increase the
chance of successful lung isolation.
REFERENCES

18. Cook® Medical Website product information
