

# An Update on Bronchial Blockers During Lung Separation Techniques in Adults

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Techniques for one-lung ventilation (OLV) can be accomplished in two different ways. The first involves the use of a double-lumen endotracheal tube (DLT). The second method involves blockade of a mainstem bronchus to allow lung collapse distal to the occlusion (bronchial blockers) (1–3). In 1936, Magill (4) achieved bronchial blockade using a long tube with an inflatable cuff at its distal end that was advanced alongside a single-lumen endotracheal tube. Since then, more devices have been introduced including: 1) the Fogarty vascular embolectomy catheter (5) [Edwards Lifesciences, Irvine, CA]; 2) a Wiruthan bronchial blocker (6) [Willy Rusch AG, Kernen, Germany]; 3) a single-lumen endotracheal tube with an enclosed bronchial blocker (Torque Control Blocker Univent<sup>®</sup>) [Vitaid Lewinston, NY] (7); and 4) the wire-guided endobronchial blocker [Arndt blocker; Cook<sup>®</sup> Critical Care, Bloomington, IN] (8).

Although DLTs are still the most common device used during lung separation techniques (9), bronchial blockade technology is on the increase, and in some specific clinical situations it can offer more advantages over the DLTs. This review addresses current concepts on the use of bronchial blockers as an alternative to achieve lung separation in adults.

## Use of the Fogarty Embolectomy Catheter as a Bronchial Blocker

The Fogarty occlusion embolectomy catheter (5) is a device designed specifically to be used as a vascular tool; however, there are well documented reports of its use in successful bronchial blockade to achieve lung isolation. Common sizes of the Fogarty occlusion

catheter used in adults for bronchial blockade include: number 6.0, 8/14, or 8/22 French (F) catheter, which has a length of 80 cm. The number 8 refers to the catheter size and the numbers 14 and 22 correspond to the inflated balloon diameter in millimeters. The occlusion balloon of the Fogarty catheter is considered a high-pressure, low-volume cuff, that requires between 0.5 to 10 mL of air to achieve occlusion of a bronchus.

The Fogarty catheter has an incorporated stylet that can be preshaped at the distal end to facilitate its guidance into the left mainstem bronchus. The Fogarty occlusion catheter has the following advantages: 1) it can be advanced through the lumen of an existing single-lumen endotracheal tube; 2) it can be used as a rescue device when difficulties to position a right- or left-sided DLT are encountered in patients who are already intubated with a DLT and are in the lateral decubitus position. By advancing the Fogarty catheter inside the endobronchial or endotracheal lumen of a DLT, lung isolation can be obtained (10,11). 3) Fogarty catheters have been used as a selective lobar bronchial blocker in patients with bronchopleural fistula where placement of this device along with a DLT reduced the amount of leakage and led to improvement of gas exchange (12). 4) Fogarty catheters also have been used as a double endobronchial blocker to collapse the right lung with two independent Fogarty catheters to facilitate a right-sided lung isolation during selective lobar blockade (13). 5) Fogarty catheters have been used in patients with tracheostomies requiring OLV. 6) Finally, they can be used nasotracheally if oral airway anatomy is distorted and OLV is required.

The disadvantages of the Fogarty occlusion catheter for use as a bronchial blocker are: 1) the Fogarty catheter is a vascular device, and not designed as a bronchial blocker; 2) the Fogarty catheter is made of natural rubber latex, which is contraindicated in patients with latex allergy; 3) there is a lack of a communicating channel in the center, therefore suction or oxygen insufflation is not possible; 4) there is a lack of guidewire device. Although its stylet facilitates insertion into a bronchus, it cannot be coupled with a

This study was supported by the Department of Anesthesia, University of Iowa Health Care.

Accepted for publication June 19, 2003.

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DOI: 10.1213/01.ANE.0000085301.87286.59

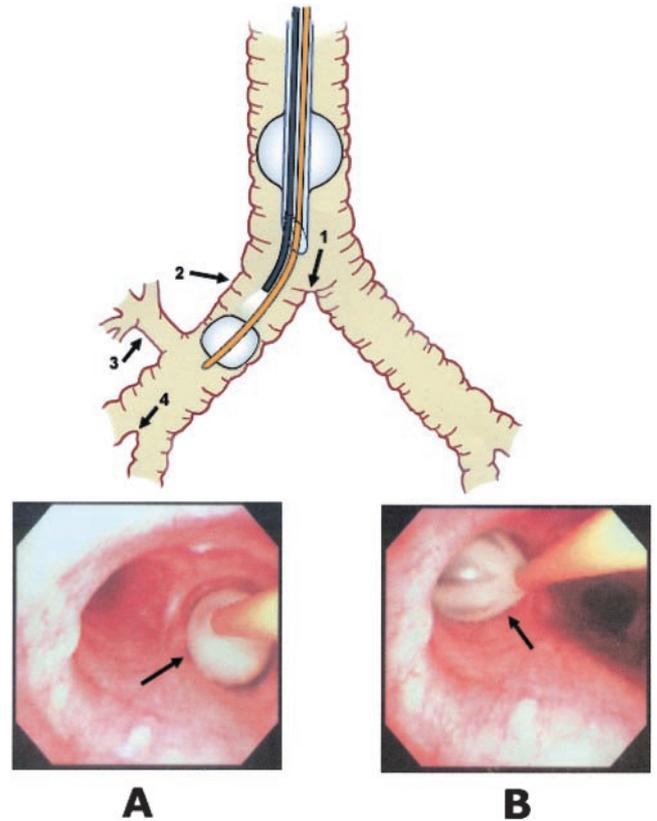
fiberoptic bronchoscope; 5) an air leak from the breathing circuit can be a common problem, specifically when the Fogarty catheter is placed inside the single-lumen endotracheal tube. However, this problem can be prevented when the Fogarty is placed externally to the endotracheal tube.

Although clinical reports of comparison with other blockers are lacking, there is a large series of >200 cases by a single author in which the Fogarty occlusion catheter was preferentially used for a left-sided thoracic surgery with apparently positive results (5). There are also some isolated reports of use in patients with difficult airways requiring OLV (10-13).

### Placement and Positioning of Fogarty Occlusion Catheters

The Fogarty occlusion catheter (8/14F) can be lubricated with silicone spray (use with caution because it can become highly flammable) or lubricating jelly and then passed through a single-lumen endotracheal tube. Its guidance is facilitated while advancing the fiberoptic bronchoscope next to it. Another alternative when placing a Fogarty catheter is to use it as an independent device, passed during direct laryngoscopy as a separate device externally to the single-lumen endotracheal tube. Once the Fogarty catheter is introduced into the targeted bronchus, the stylet is removed and the catheter balloon is inflated under direct vision with the fiberoptic bronchoscope. The optimal position of the Fogarty occlusion catheter is one that allows complete blockade of the bronchus without any detectable air leak.

When the Fogarty occlusion catheter is placed in the left mainstem bronchus, it is in the ideal position so that the outer surface of the cuff is located approximately 10 mm below the tracheal carina inside the left bronchus. In most circumstances, for a right-sided mainstem bronchus occlusion, blocker cuff inflation should include the right-upper lobe. This approach is depicted in Figure 1A. Once the Fogarty occlusion catheter is in its optimal position, confirmation of placement with the fiberoptic bronchoscope must be done in the supine and lateral decubitus positions. Figure 1, A and B shows the optimal position of the Fogarty occlusion catheter. After placement and positioning is completed, to prevent an air leak between the connector of a single-lumen endotracheal tube and the elbow connector of the breathing circuit, a modified 9F arrow-Flex sheath connected with a twist-lock device makes a perfect airtight seal when used with the diaphragm of the Portex bronchoscope swivel connector (14) (Portex Inc., Keene, NH). In addition, two different alternatives can be used to prevent an air leak between the breathing circuit and the endotracheal tube with the Fogarty catheter passing through



**Figure 1.** A, Fogarty occlusion catheter; the optimal position of the Fogarty in the right, and (B) the left mainstem bronchus. The arrow indicates the outer surface of the inflated balloon (A and B). 1 = tracheal carina, 2 = right mainstem bronchus, 3 = right upper lobe bronchus, and 4 = bronchus intermedius.

the endotracheal tube: 1) the cap of the diaphragm on a Portex swivel adaptor is perforated allowing passage of the Fogarty catheter. Once the Fogarty catheter is correctly positioned in the bronchus, the cap is advanced over the Fogarty and inserted into its slot in the swivel adaptor thereby providing an airtight seal; 2) the use of the Arndt multiport adaptor permits independent passage of any blocker and fiberoptic bronchoscope. The multiport adaptor from the Arndt blocker can be obtained separately from its manufacturer (Cook® Critical Care).

### Complications of the Fogarty Occlusion Catheter

Because of the uncommon use of the Fogarty catheter as a bronchial blocker, there are no reported complications with the Fogarty occlusion catheter in adults. The tip of the Fogarty catheter is very soft because the wire stylet terminates at least 1 cm proximal to the end of the catheter. Therefore, airway rupture with the Fogarty catheter is very unlikely especially if the catheter is advanced under direct fiberoptic visualization.

However, forcing the introduction of a Fogarty with the stylet in place can carry the risk of airway rupture. Also, the potential for inclusion in the stapling line exists, especially when this device is used as a selective lobar blocker.

## Single-Lumen Endotracheal Tube with an Enclosed Bronchial Blocker (Univent<sup>®</sup>) and the Torque Control Blocker (Univent<sup>®</sup>)

In 1982, Inoue et al. (15) introduced a new device for OLV. They used a single-lumen endotracheal tube with an incorporated bronchial blocker (the original Univent<sup>®</sup>) so that when OLV is no longer needed the tube can be left *in situ* (for postoperative mechanical ventilation). The Univent<sup>®</sup> and its newest version, the Torque Control Blocker Univent<sup>®</sup> (TCBU), introduced in 2001, have a shape similar to that of a standard endotracheal tube. Within the Univent<sup>®</sup> unit, there is a channel enclosing a moveable bronchial blocker that can be used to block the left, the right, or any specific secondary bronchi. The enclosed bronchial blocker is made of flexible nonlatex material, and has a flexible shaft (TCBU) which is easier to guide into a bronchus. It has a high-pressure, low-volume cuff that requires approximately 2 mL of air to produce an airtight seal if selective lobar blockade is used (16–18), or 4–8 mL of air if total blockade of the bronchus is desired (19,20). The resting volume and diameter of the bronchial blocker cuff of the Univent<sup>®</sup> is 2 mL and 5 mm, respectively (19), and for the TCBU, the resting volume is 3 mL (personal communication from the manufacturer). The bronchial blocker has a small lumen for suctioning and should be closed before insertion.

Current sizes available for the TCBU in adults range from 6.0 to 9.0 mm inner diameter. Because of the oval shape of the airway lumen, the effective internal radius is reduced. Also, the channel that encloses the bronchial blocker has a diameter of 2 mm but increases the anterior-posterior external diameter of the Univent<sup>®</sup>, which makes it larger than a single-lumen endotracheal tube of corresponding internal diameter (ID). Table 1 depicts the sizes available for Univent<sup>®</sup> tubes and compares those to a single-lumen endotracheal tube and DLTs. An advantage of the Univent<sup>®</sup> is its utility in patients in whom the airway is considered difficult for direct laryngoscopy (21–26), and during unanticipated difficult endotracheal intubation (27). The Univent<sup>®</sup> has been used in tracheostomy patients who require OLV (28,29).

Other features of the Univent<sup>®</sup> tube are its efficacy as a selective lobar blocker to improve oxygenation (16–18). Because of its relative ease of placement, the Univent<sup>®</sup> has been used in patients with hemoptysis

or bleeding diathesis, and can be used during rapid sequence induction during OLV (30,31). The Univent<sup>®</sup> tube has been effective with different modalities of ventilation including jet ventilation during sleeve pneumonectomy (34,35). It can be converted to a conventional single-lumen endotracheal tube by deflating and withdrawing the bronchial blocker.

## Placement and Positioning of the TCBU

The TCBU has two compartments, a large lumen for air/oxygen passage through the anesthesia breathing circuit, and a small lumen in the middle of the enclosed and movable bronchial blocker. The inner diameter of the bronchial blocker is 2 mm. This blocker can be advanced >10 cm beyond the main body.

Before use, the bronchial blocker of the Univent<sup>®</sup> is lubricated to facilitate passage; the endotracheal cuff should also be lubricated. The enclosed bronchial blocker must be retracted into the standard lumen of the tube. Conventional endotracheal tube placement is performed, and then a fiberoptic bronchoscope is passed. Under direct vision, the enclosed bronchial blocker is advanced into the targeted bronchus. When a Univent<sup>®</sup> tube is used, the enclosed bronchial blocker must be directed into the bronchus of the surgical side, where the lung collapse occurs.

The optimal position for the Univent<sup>®</sup> tube in either the right- or left-side bronchus is when the bronchial blocker cuff is fully inflated with no air leaks detected. Fiberoptic bronchoscopic examination will show that the proximal or outer surface of the cuff is located just below the tracheal carina, usually  $\geq 5$  mm inside the desired bronchus. The end of the Univent<sup>®</sup> tube should be at least 1–2 cm above the tracheal carina. Figure 2, A and B show the TCBU and its optimal position for a right or left bronchus seen through the fiberoptic bronchoscope. Because of the relatively short distance between the tracheal carina and the right upper bronchus, the Univent<sup>®</sup> can be used as a selective blocker by advancing it into the bronchus intermedius and thereby selectively collapsing the right-middle and right-lower lobes (16–18), specifically in case of hemorrhage of these lung segments.

## Ventilation Modalities that Apply to the TCBU

During OLV, hypoxemia can occur, and one way to improve oxygenation is by applying continuous positive pressure ventilation (CPAP). CPAP can be easily applied to the Univent<sup>®</sup> tube when the suction cap of the enclosed bronchial blocker is open and a small

**Table 1.** Comparison of Outer Diameter (OD) and Internal Diameter (ID) of Single-Lumen, Univent<sup>®</sup>, and Double-Lumen Endotracheal Tubes

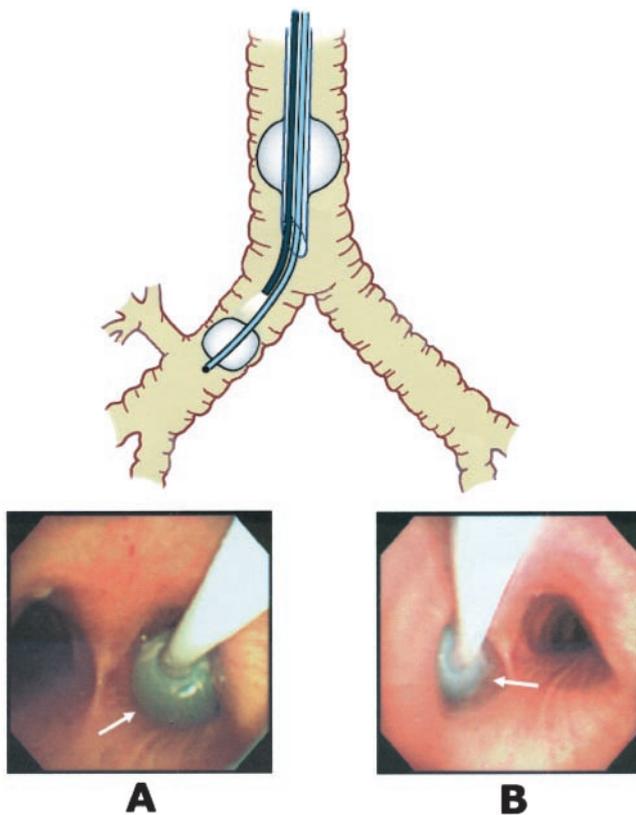
Single-lumen endotracheal tube <sup>a</sup>		Univent <sup>®</sup> tube		Double-lumen endotracheal tube <sup>c</sup>			
ID	OD	ID	OD <sup>b</sup>	French	OD	Bronchial ID	Tracheal ID
6.0	8.2	6.0	9.7/11.5	26	8.7	3.5	3.5
6.5	8.9	6.5	10.2/12.0	28	9.3	3.2	3.1
7.0	9.6	7.0	10.7/12.5	32	10.7	3.4	3.5
7.5	10.2	7.5	11.2/13.0	35	11.7	4.3	4.5
8.0	10.9	8.0	11.7/13.5	37	12.3	4.5	4.7
8.5	11.5	8.5	12.2/14.0	39	13.0	4.9	4.9
9.0	12.1	9.0	12.7/14.5	41	13.7	5.4	5.4
10.0	13.5						

Sizes are given in millimeters.

<sup>a</sup> Sheridan Hudson Respiratory Care, Inc., Temecula, CA.

<sup>b</sup> Two OD measures are given because of the oval shape of the tube.

<sup>c</sup> Rüsch (Duluth, GA) (26), Sheridan (Argyle, NY) (32), Mallinckrodt (St. Louis, MO) (28, 35, 37, 39, 41).



**Figure 2.** A, Torque Control Blocker Univent<sup>®</sup>; the optimal position of the Univent<sup>®</sup> in the right, and (B) the left mainstem bronchus. The arrow indicates the outer surface of the inflated blocker cuff.

4.5-mm connector of a single-lumen endotracheal tube is attached, and then a standard CPAP system is connected (32,33). The Univent<sup>®</sup> tube has also been successfully used during high-frequency jet ventilation (HFJV) in a patient with a tracheal carina resection by using the enclosed bronchial blocker lumen to assist with the HFJV repair of the trachea (34,35). Thus,

different alternatives for selective ventilation with CPAP or HFJV can be adapted to the Univent<sup>®</sup> tube.

### Complications and Pitfalls with the TCBU

A variety of complications have been reported with the original version of the Univent<sup>®</sup>. Fragments torn from the inner wall when the connector was reattached to the tube resulted in aspiration of silicone material into the bronchus (36-38). Also, a structural complication in the TCBU has been reported in which a fracture of the blocker cap connector occurred in 2 of the first 50 tubes used (39).

Failure to achieve lung separation because of abnormal anatomy or lack of seal within the bronchus has also been reported (40,41). Inclusion of the enclosed bronchial blocker into the stapling line has been reported during a right upper lobectomy (42). Therefore, communication with the surgical team regarding the presence of a bronchial blocker in the surgical side is crucial. One potential and dangerous complication with the bronchial blocker cuff of the Univent<sup>®</sup> was reported: the cuff of the bronchial blocker was mistakenly inflated near the tracheal lumen producing a respiratory arrest (43).

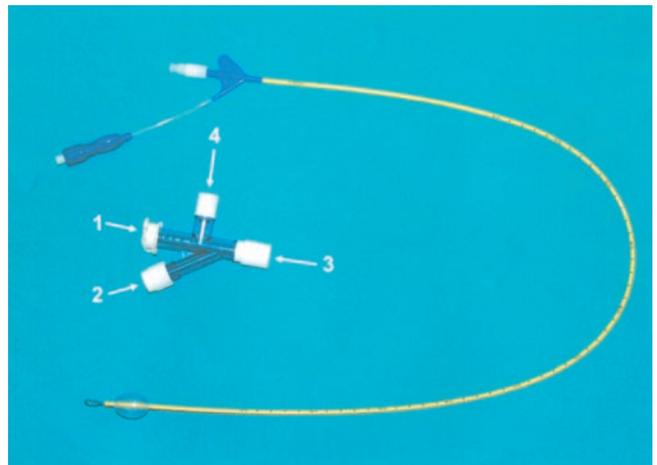
Development of severe hypoxemia with the potential risk of negative-pressure pulmonary edema has been reported after continuous suctioning of the non-dependent lung by the bronchial blocker (44). Therefore, if suction is used to facilitate lung collapse, it should be done for a few seconds, at intervals, and with low-pressure suctioning. Another complication reported with the Univent<sup>®</sup> involved blind insertion of the blocker, passing it distally beyond the left bronchial carina, causing lung rupture and pneumothorax (45). Therefore, all Univents<sup>®</sup> require fiberoptic bronchoscopy guidance during placement of the bronchial blocker.

Another common problem with the Univent<sup>®</sup> can be malposition and dislodgement of the bronchial blocker while turning the patient from a supine to a lateral decubitus position. Therefore, I recommend cuff deflation of the Univent<sup>®</sup> bronchial blocker after the original placement and before turning the patient into a lateral decubitus position. After the patient is in the lateral decubitus position, then reinflation of the bronchial blocker is established. Also, malpositions can occur during surgery while surgical manipulation of the bronchus occurs (46). Therefore, fiberoptic bronchoscopy is the method of choice to achieve optimal position of the Univent<sup>®</sup> as well as to correct intraoperative malpositions. Although malpositions with the Univent<sup>®</sup> occur more frequently when compared with left-sided DLT (46), one study (47) demonstrated that when the Univent<sup>®</sup> was used for a right-sided thoracic surgery, it was comparable to right-sided DLT with respect to malpositions.

Total malpositions occurred in 3 of 20 patients studied in the right-sided DLT group versus 5 of 20 patients who received right-sided Univent<sup>®</sup>. Therefore, clinical evidence suggests that Univents<sup>®</sup> can be used for right-sided bronchus intubations with minimal problems if fiberoptic bronchoscopy is used while positioning this device.

### Wire-Guided Endobronchial Blocker (Arndt Blocker)

Another technique to achieve lung separation is the Arndt blocker (8), which is considered an independent bronchial blocker. The Arndt blocker is attached to a 7 or 9F catheter that is available in 65- and 78-cm lengths with an inner lumen measuring 1.4 mm of diameter. Near the distal end of the catheter, there are side holes (Murphy eye) incorporated to facilitate lung deflation. These side holes are present only in the 9F Arndt blocker version. This bronchial blocker has a high-volume, low-pressure cuff with either an elliptical or spherical shape. Changes in the cuff from elliptical to spherical shape were necessary to facilitate its use for the right mainstem bronchus blockade. By using the spherical-shape cuff on the right bronchus, complete blockade can be achieved without inclusion of the right upper bronchus, whereas the elongated and elliptical-shape cuff does not block the right bronchus properly. The inner lumen contains a flexible nylon wire passing through the proximal end of the catheter and extending to the distal end and then it exits as a small flexible wire-loop. Figure 3 displays the Arndt blocker and its multiport connector. The wire-loop of the Arndt blocker is coupled with the fiberoptic bronchoscope and serves as a guidewire to introduce the blocker into a bronchus. For the Arndt blocker to function properly and allow manipulation with the



**Figure 3.** The wire-guided endobronchial blocker (Arndt blocker) and the multiport connector. 1 = Fiberoptic bronchoscope port, 2 = blocker port, 3 = endotracheal tube connector port, and 4 = ventilation port.

adult fiberoptic bronchoscope, the proper endotracheal tube should be used: for a 7F blocker, use a 7.0-mm ID single-lumen endotracheal tube, and for the larger Arndt blocker 9F, use at least a 8.0-mm ID single-lumen endotracheal tube.

There are advantages to using the Arndt blocker over the DLTs or TCBU in patients who are already tracheally intubated (48), who present a difficult airway (49), or require OLV during acute trauma to the chest (50). Another advantage of the Arndt blocker is that it can be passed through a nasotracheal tube in patients who require nasal intubation and OLV, in patients with airway abnormalities, or in patients with previous tracheostomy and OLV (51,52). Also, it can be used as a selective lobar blocker in patients with previous pneumonectomy who require selective one-lobe ventilation (51,53) or as a selective blocker during severe pulmonary bleeding (54). Because the Arndt blocker requires a single-lumen endotracheal tube, it maximizes the cross-sectional diameter, and eliminates the need for tube exchange if mechanical ventilation is contemplated in the postoperative period. Another advantage of the Arndt blocker is its capability to allow CPAP ventilation through the inner channel, by connecting a 3.0-mm ID of a single-lumen endotracheal tube connector with the Mallinckrodt CPAP delivery system [Mallinckrodt Inc., St. Louis, MO] during OLV (55).

Limitations with the use of the Arndt blocker include the fact that it is difficult to use when a 9F blocker is passed over a <7.0-mm ID single-lumen endotracheal tube. Another limitation is with the wire-guided loop; once it is removed, it cannot be reinserted and thus intraoperative repositioning of the blocker can be difficult especially during left mainstem bronchus intubation, unless a new Arndt blocker

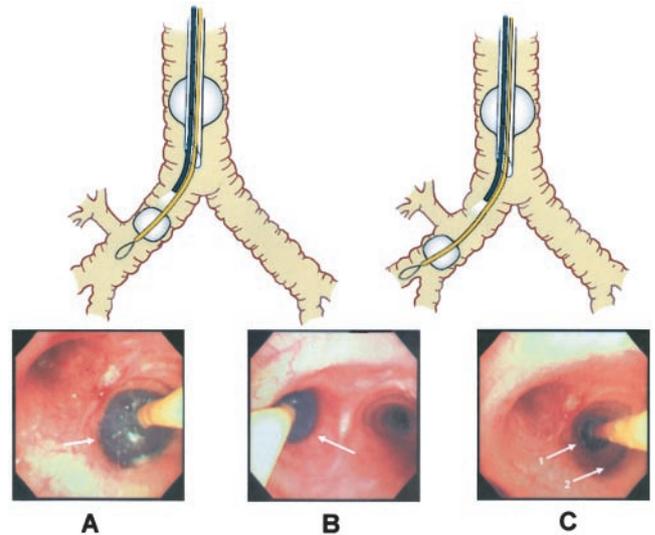
is used. Also, the small diameter of the suction channel increases the time required for the lung to collapse, when compared with the TCBU (7).

## Placement and Positioning of the Wire-Guided Endobronchial Blocker

The Arndt blocker is a single unit that is passed through a single-lumen endotracheal tube. Before insertion, the blocker balloon is tested then fully deflated. The whole unit is lubricated with silicone spray or lubricating jelly. It is my opinion that the spherical shape fits better for a right-sided mainstem bronchus intubation or wherever a selective lobar blockade is needed, and the elliptically shaped cuff should be limited to left-sided mainstem intubations because its elongated shape fits better into the left bronchus. To prevent damage of the blocker cuff after insertion through the multiport adaptor, the balloon must be fully deflated before insertion through the blocker port. Also, the blocker port should be fully opened before insertion of the balloon.

The placement of the Arndt blocker involves placing the endobronchial blocker through the endotracheal tube and using the fiberoptic bronchoscope and wire-guide loop to direct the blocker into a mainstem bronchus. The fiberoptic bronchoscope has to be advanced far enough so that the Arndt blocker will enter the bronchus while it is being advanced. Once the deflated cuff is below the entrance of the bronchus, the fiberoptic bronchoscope is withdrawn, and the cuff is fully inflated with 2–3 mL of air, if selective lobar blockade is attempted, or 5–8 mL of air if total bronchial blockade is pursued to obtain proper sealing of the target bronchus. For a right mainstem bronchus blockade, the Arndt blocker can be advanced independent of the wire-loop, observing its entrance into the right main bronchus under fiberoptic visualization. After the patient is turned to the lateral decubitus position, bronchoscopic confirmation is necessary to ensure that the cuff of the Arndt blocker is still properly positioned.

Based on a recent study (7), once the optimal position of the Arndt blocker is achieved in the supine position, the cuff should be deflated, the blocker advanced approximately 1 cm to avoid dislodgment toward the trachea during changing the patient's position, and then placement again confirmed in the lateral decubitus position. The wire-loop can then be withdrawn to convert the 1.4-mm channel into a suction port to expedite lung collapse. It is important to remove the wire-loop to avoid inclusion during the stapling line of the bronchus. The optimal position of the Arndt blocker in the left or in the right bronchus is achieved when the blocker balloon outer surface is seen with the fiberoptic bronchoscope at least 5 mm below the tracheal carina on the targeted



**Figure 4.** A, Wire-guided endobronchial blocker (Arndt blocker), the optimal position of the Arndt blocker in the right, (B) the left mainstem bronchus; and (C) as a selective lobar blocker when positioned into the bronchus intermedius. 1, The arrow indicates the outer surface of the inflated Arndt blocker cuff; 2, a free entrance of the right upper lobe bronchus.

bronchus and the proper seal is obtained. (Fig. 4, A and B show the proper position of the Arndt blocker in the right or left mainstem bronchus. Fig. 4C shows a selective lobar blockade with the Arndt blocker when positioned into the bronchus intermedius.)

## Complications and Pitfalls with the Wire-Guided Endobronchial Blocker (Arndt Blocker)

Because of its relatively recent introduction (1999) (8), there are not many reports of complications with the Arndt blocker. There is a recent report (56) of sheared balloon of the Arndt blocker that occurred when the blocker was removed through the multiport blocker side. Fortunately, this piece was retrieved from the single-lumen endotracheal tube before dislodgment into the patient's trachea. In fact, the label instructions from the manufacturer (Cook<sup>®</sup> Critical Care) clearly states that upon completion of use, the Arndt blocker cuff must be deflated and the blocker withdrawn along with the multiport connector and not through the unlocked blocker port.

A common pitfall with the Arndt blocker is a reported more frequent incidence of malpositions when compared with the TCBU (7). In fact, when compared with other blockers, it was shown that despite obtaining an optimal position in the supine position, the Arndt blocker was more prone to dislodgment after turning the patient into a lateral position regardless of whether a right or left mainstem bronchus blocker was used.

**Table 2.** Indications of Bronchial Blockers

Device	Advantage	Disadvantage	Ventilation mode (can be applied)
Fogarty catheter (6.0, 8/14, and 8/22F sizes)	<ul style="list-style-type: none"> <li>• Critically ill intubated patients who require OLV</li> <li>• Small bronchus</li> <li>• Nasotracheal intubation</li> <li>• Tracheostomized patients who require OLV</li> </ul>	<ul style="list-style-type: none"> <li>• Not designed as a bronchial blocker</li> <li>• No communicating channel in the center</li> <li>• Difficult to seal an air leak with the single-lumen endotracheal tube connector</li> <li>• No guidewire device</li> <li>• Potential for inclusion in stapling line</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>
Torque Control Blocker Univent® (6.0, 6.5, 7.0, 7.5, 8.0, 8.5, and 9.0 mm ID sizes)	<ul style="list-style-type: none"> <li>• Difficult airways requiring OLV</li> <li>• Selective lobar blockade</li> <li>• Tracheostomized patients requiring OLV</li> <li>• Rapid sequence induction that requires OLV</li> <li>• Robotic (cardiac, thoracic, or esophageal surgery)</li> </ul>	<ul style="list-style-type: none"> <li>• #8.5-9.0 tied fit to pass through vocal cords</li> <li>• Enclosed channel of 2.0 mm (not enough lumen to aspirate secretions)</li> <li>• More expensive (\$137.00)</li> <li>• Potential for inclusion in the stapling line</li> </ul>	<ul style="list-style-type: none"> <li>• CPAP</li> <li>• HFJV</li> </ul>
Arndt blocker (7.0 and 9.0F sizes)	<ul style="list-style-type: none"> <li>• Critically ill intubated patients who require OLV</li> <li>• Selective lobar blockade</li> <li>• Difficult airways and OLV (oral or nasotracheal)</li> <li>• Tracheostomized patients</li> <li>• Robotic (cardiac, thoracic, or esophageal surgery)</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a large single-lumen endotracheal tube &gt;7.5-mm ID</li> <li>• Opening center channel of 1.4 mm (not enough to aspirate)</li> <li>• Longer time to collapse the lung</li> <li>• Potential for inclusion in the stapling line</li> </ul>	<ul style="list-style-type: none"> <li>• CPAP</li> </ul>

CPAP = continuous positive airway pressure, HFJV = high-frequency jet ventilation, OLV = one-lung ventilation.

### Air-Flow Resistances of a Single-Lumen Endotracheal Tube and the Univent® Tube

In theory, one of the advantages of a single-lumen endotracheal tube and the Univent® blocker is that they do not have to be replaced at the end of thoracic surgery because doing so can increase airway trauma or potential risk for losing the airway. However, some considerations have to be reviewed when leaving a tube in the patient's trachea after OLV is no longer needed, including: the ID of the tube, the outer diameter, and air-flow resistances. In a study by Slinger and Lesiuk (57), the external circumference of each tube was measured on the main body of the tube (single-lumen endotracheal tubes 6.0-, 7.5-, 8.0-, and 9.0-mm ID and Univent® tube sizes 6.0-, 7.5-, 8.0-, and 9.0-mm ID) at the point of the distal attachment of the tracheal cuff. Their results showed that tube circumference had a significant effect on the coefficients of resistance K1 and K2 for all tubes studied. Only the 9.0-mm single-lumen endotracheal tube had an external circumference equivalent to any Univent® tubes studied. Also, they reported that the

circumference of Univent® tubes was larger when compared with single-lumen endotracheal tubes with corresponding equally ID numbers (Table 1). Although the diameters of 6.5 and 7.0 Univent® tubes are much larger than those of 6.0- and 7.5-mm ID single-lumen endotracheal tubes, the flow resistance was roughly equivalent. Therefore, the smaller sizes of Univent® tubes (such as 6.0- to 7.5-mm ID) have a high-flow resistance and should be replaced with an appropriate single-lumen endotracheal tube if postoperative mechanical ventilation is contemplated.

### Are Bronchial Blockers a Substitute for a DLT During Lung Separation Techniques?

After reviewing the important aspects and characteristics of each bronchial blocker, some conclusions can be drawn. Lung separation is mainly used: 1) to facilitate surgical exposure in thoracic, esophageal, mediastinal, vascular, and robotic surgery involving the chest; 2) to facilitate gas exchange to the other bronchus as with a bronchopleural fistula; 3) to prevent

contamination to the contralateral lung (e.g., abscess, hemorrhage); or 4) during the use of specific modes of lung ventilation (e.g., CPAP or HFJV). All of this can be managed with bronchial blockers. Yet, DLTs are continuously used in most cases that require OLV (9). In many cases, a DLT placement can be difficult, including difficulties in selecting the proper tube size, the potential for tearing the tracheal cuff during intubation requiring multiple DLTs, and difficulties in placement or positioning. Therefore, a bronchial blocker could be an alternative. Perhaps when difficulties are encountered predicting a DLT size, such as in a patient of short stature, a bronchial blocker might be preferred over DLT. Table 2 depicts a summary of specific indications in which a bronchial blocker can be advantageous.

To distinguish the advantages that a bronchial blocker can offer over a DLT, some facts have to be considered. In a recent study, Campos and Kernstine (7) showed that left-sided DLT takes less time to place (an average of 2:08 min, when compared with the TCBU, 2:38 min, or the Arndt blocker, 3:34 min). That study also showed that lung collapse is faster with the DLT compared with the TCBU or the Arndt blocker. Also, the majority of the patients who received a bronchial blocker required assisted suction to expedite lung collapse. In another study (6), the frequency of malpositions was increased when the Wiruthan bronchial blocker was compared with the left-sided DLT during thoracoscopic surgery. The number of bronchoscopies needed to place a DLT or a bronchial blocker averages two (one in supine and one in decubitus position) (7).

The most important issue is the effectiveness of the surgical exposure. In the Campos and Kernstine study (7), after OLV was achieved either with a DLT or bronchial blocker, surgical exposure was clinically equivalent among the three groups studied during elective thoracic surgery. During re-expansion of the lung to check for any air leaks, no contamination with secretions to the contralateral lung occurred. No difficulties recollapsing the lung were encountered in the bronchial blocker group. Therefore, it is my opinion that bronchial blockers can be used in many cases that require OLV, taking into consideration that: 1) bronchial blockers might require longer time for placement, 2) assisted suction to expedite lung collapse might be required, and 3) the use of fiberoptic bronchoscope in the event that dislodgement of the blocker occurs.

Anesthesiologists should become familiar with this technology and be skilled enough to use it when appropriate (i.e., management of a difficult airway during OLV or selective lobar blockade). In the case of absolute lung separation, e.g., bronchopulmonary lavage or presence of contamination to the other lung with massive bleeding or pus where a large suction

lumen is needed, then use of a DLT should be the first-line intervention for lung separation.

Although Fogarty, Univent<sup>®</sup>, and Arndt blockers have performed well, specifically in patients with difficult airways that require OLV, there is still room for improvement. Perhaps the ideal bronchial blocker should have a center channel with a diameter large enough to allow secretions to be aspirated without difficulty and without compromising the cross-sectional area of the single-lumen endotracheal tube. Currently, the manufacturer of the TCBU has made the bronchial blocker available as a separate device, and it can be used independently through a single-lumen endotracheal tube. This unit comes with its own multiport adaptor. Also Cook<sup>®</sup> Critical Care has developed a new independent blocker similar to the Arndt blocker without the need for wire-guidance. Unfortunately, neither of these devices have been studied.

The current use of bronchial blocker technology, supported by scientific clinical evidence, dictates that bronchial blockers should be available in any service that performs lung separation techniques. Finally, it is important to emphasize that positioning and intraoperative correction of malpositions of bronchial blockers are managed best with the use of fiberoptic bronchoscopy in a supine, then lateral decubitus position, or whenever an intraoperative malposition occurs. In addition, the applications and use of bronchial blockers in the pediatric population might be different, and are not the focus of this review.

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