

Lung separation in adult thoracic anesthesia

ABSTRACT

Thoracic anesthesia is mainly the world of OLV during anesthesia. The indications for OLV, classified as absolute or relative are more representative of the new concepts in OLV: It includes either the separation or the isolation of the lungs. Modern DLTs are most widely employed worldwide to perform OLV including the concept of one lung separation. Endobronchial blockers are a valid alternative to DLTs, and they are mandatory in the education of lung separation and in case of predicted difficult airways as they are the safest approach (with an awake intubation with an SLT through a FOB). Every general anesthesiologist should know how to insert a left-sided DLT, but he/she should also have in his technical luggage and toolbox, basic knowledge and minimal expertise with BBs, this option being considered a suitable alternative, particularly in emergency situation where the patient is already intubated and/or in case of difficult airways. One should keep in mind that extubation or re-intubation after DLT might be difficult too, and additional intubation tools are necessary for the safety conditions.

Key words: Bronchial blocker; double-lumen tube; lung isolation; lung separation; one-lung ventilation

Introduction

Selective bronchial intubation combined with positive pressure ventilation was for the first time used in practice in 1931, as a solution to the deadly pneumothorax problem associated with chest opening.^[1] Various types of catheters with an inflatable distal balloon (e.g., urinary catheter, Fogarty embolectomy catheter or Swan-Ganz catheter) were inserted within the bronchial divisions to exclude the ventilation of the distal lung parenchyma. These techniques, however, were hazardous as the shape of the balloon is not designed for the airway blockade.

Over the next decades, different techniques for securing the airways and selectively ventilating the lungs have largely contributed to the development of intrathoracic surgery. With the recent advances in video technology, endoscopic instruments, and mini-invasive approaches, the demand for one-lung ventilation (OLV) has increased not only in thoracic surgery but also for various cardiac, oesophageal, orthopedic and neurosurgical procedures.

Currently, two main techniques are available to achieve selective OLV coupled with the exclusion of the opposite

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Website: www.saudija.org	Quick Response Code 
DOI: 10.4103/sja.sja_78_21	

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How to cite this article: Huybrechts I, Tuna T, Szegedi LL. Lung separation in adult thoracic anesthesia. Saudi J Anaesth 2021;15:272-9.

ISABELLE HUYBRECHTS, TURGAY TUNA¹, LASZLO L. SZEGEDI²

Consulting Anesthesiologist, Service d'Anesthésiologie-Réanimation, C.U.B. Hôpital Erasme, Université Libre de Bruxelles (U.L.B.),
¹Chair of the Medical Council, Service d'Anesthésiologie-Réanimation, C.U.B. Hôpital Erasme, Université Libre de Bruxelles (U.L.B.),
²Clinical Director, Past-Chairman and Member of the Thoracic Scientific Subcommittee and Member of the Educational Committee of the European Society of Cardiothoracic Anesthesiologists (EACTA), Service d'Anesthésiologie-Réanimation, C.U.B. Hôpital Erasme, Université Libre de Bruxelles (U.L.B.), Brussels, Belgium

Address for correspondence: Prof. Laszlo L. Szegedi, Service d'Anesthésiologie-Réanimation, C.U.B. Hôpital Erasme, Université Libre de Bruxelles (U.L.B.), Route de Lennik 808, 1070 Bruxelles, Brussels, Belgium. E-mail: laszlo.szegedi@skynet.be

Submitted: 25-Jan-2021, **Accepted:** 26-Jan-2021, **Published:** 19-Jun-2021

lung: The double-lumen tubes (DLTs) or the endobronchial blockers (BBs). The ultimate choice between DLTs and BBs depends on the clinical settings, the specific properties of these devices and the operator's personal preferences. In emergency conditions and in pediatric patients, a standard single lumen tube can also be advanced into a main bronchus stem or a Fogarty catheter can be inserted along the single lumen tube to prevent soiling of the ventilated lung and/or to facilitate transient collapse of the lung according to the tracheobronchial anatomy.

Some recent surveys in the United Kingdom, Italy the Middle East and a survey conducted by the European Association of Cardiothoracic Anesthesiologists suggest that DLTs are preferred by a large majority of thoracic anesthesiologists (more than 90%).^[2-4] Interestingly, although most of these experts declare being familiar with BBs, up to 30% acknowledge never using BBs.

Thorough knowledge of tracheobronchial anatomy, expertise in fiber-optic bronchoscopy (FOB), and familiarity with specific lung isolation devices are essential conditions for the successful placement of BBs and DLTs as well as for safe management of OLV.^[5] Anaesthesiologists with limited exposure to thoracic surgery should develop basic knowledge and practical skills with anesthesia simulator training, computer-based programs, and continuous education via thoracic anesthesia workshops.^[6-8]

Indications and difference between isolation and separation of the lungs

Selective lung ventilation techniques have three main purposes: 1. preventing contamination of a healthy lung with pus, blood or other fluids from the contralateral lung, 2. facilitating exposure of intrathoracic anatomic structures for diagnostic and therapeutic procedures, and 3. providing differential ventilation and securing the airways in unilateral thoracic disorders (e.g., bronchopleural fistula, giant bulla, lung contusion).^[9]

The purpose of OLV is to provide a good surgical exposure of a collapsed lung while ensuring adequate gas exchange with the other. Currently, DLTs or BBs are used to achieve these goals. The separation of the lungs today means a completed "anatomical" sealing with a DLT, and the isolation of the lung means a "functional" sealing with a BB.^[9,10] In the first case, there are some absolute indications in which a protective strategy for the contralateral lung is needed, including potentially life-threatening conditions such as massive pulmonary bleeding, pneumonia with pus, broncho-pleural and broncho-cutaneous fistulas, as well as giant unilateral bullae. Maintenance of adequate gas exchange, prevention of

soiling/flooding the other lung with contaminated material/blood and avoidance of barotrauma are best achieved with DLTs in these situations. Some surgical interventions as sleeve pneumonectomy, or bronchopulmonary lavage for alveolar proteinosis or cystic fibrosis require lung separation with a DLT. In all the other situations, in which lung separation is a relative indication, lung isolation can be considered, as shown in Table 1.^[9,11-14]

Overall, the DLT remains the gold standard technique in various surgical procedures requiring lung separation/isolation and are favored by most thoracic anesthesiologists.^[15] The BBs offer the advantage of being placed through a conventional SLT. In emergencies, securing the airways is a priority and this is performed easier and faster with an SLT for all anesthesiologists. Moreover, in patients with abnormal airway anatomy (post-laryngeal/pharyngeal surgery, tracheotomy), predicted difficult intubation or at risk of vocal cord injuries (e.g., singers) as well as in children, BBs are most suitable for lung separation as far as the chest wall and lung compliance is normal. Likewise, if postoperative ventilation is needed, the use of a BB is a good choice, avoiding the (risky) replacement of the DLT by an SLT with an airway exchange catheter.^[16,17] Finally, BBs remains the sole option in children and in patients who have undergone pneumonectomy and those requiring selective lobar exclusion (e.g., severe lung disease).

In modern practice, DLTs are most widely employed. The DLTs available in the recent years, have a fixed curvature and do not have a carinal hook, in order to avoid tracheal laceration and reduce the likelihood of kinking. Numerous manufacturers produce clear disposable Robertshaw design DLTs, which are available for adults in French sizes from 35 to 41^[18] [Figure 1].

Essentially, they all have similar features but modified cuff shape and location. A colored bronchial cuff, commonly blue, permits its easy identification by fiber-optic bronchoscopy. The right endobronchial cuff is donut-shaped and allows the right upper lobe ventilation slots to ride over the right upper lobe orifice. Most authors refrain from using right-sided DLT simply to avoid potential obstacles. Instead of its extensive use, one of the major challenges for a DLT is the lack of an objective method and guideline for selecting the proper size and its optimal depth. The most accurate method to select a left-sided DLT size is to measure the left bronchus width and the outer diameter of the endobronchial lumen of the DLT, then the largest tube that safely fits that bronchus can be selected.^[19] For a right-sided DLTs, there is no study available that addresses the issue of optimal size for a determined

Table 1: Indications for lung isolation technique

		Indications for lung isolation technique		
		Indication	Main goal	Recommendation
Absolute indications		Unilateral lung abscess or cyst	Contralateral lung protection	DLT
Unilateral hemorrhage				
Bronchoalveolar lavage for alveolar proteinosis		Contralateral lung protection	DLT	
Bronchopulmonary fistulae or tricho-bronchial tree injury		Contralateral lung protection	DLT	
Giant unilateral emphysematous bulla		Secure the airways and gas exchange	DLT	
Lung transplantation		Differential ventilation	DLT	
		Secure the airways differential ventilation	DLT	
Relative indications	High priority	Pneumectomy, sleeve resection, tumor obstructing the main bronchial stem	Surgical exposure	DLT
		Thoracic aneurysm	Surgical exposure	DLT > BB
		Lobectomy (any surgical approach)	Surgical exposure	DLT = BB
	Low priority	Interventions on the pleura and mediastinal structures	Surgical exposure	DLT = BB
		Oesophagectomy	Surgical exposure	DLT = BB
		Orthopedic surgery on the chest, spine surgery	Surgical exposure	DLT = BB
		Minimally invasive cardiac surgery	Surgical exposure	DLT = BB
		Sympathectomy	Surgical exposure	DLT < BB

DLT – Double-lumen Tube, BB – Bronchial Blocker

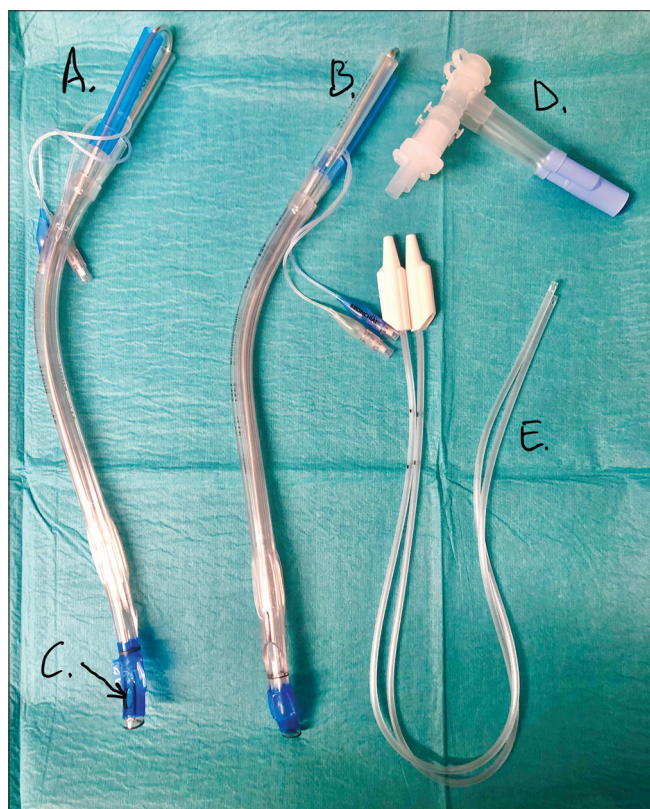


Figure 1: Double-lumen endobronchial tubes (Shiley™, Medtronic) (a) Right-sided (b) Left-sided (c) Side-opening of the right sided double-lumen tube for the right upper-lobe bronchus (d) Connection port (e) Endobronchial suction catheters Please note the slightly curved bronchial tip for position placement. There are X-ray opaque markers at the distal tip, above the bronchial cuff and at the tracheal opening to aid location and verification of the tube position Either left or right sided, the tube features two cuffs: A blue colored cuff at the distal end for the bronchus, with a blue proximal lumen, blue pilot balloon for easy identification and a clear, polyurethane cuff for positioning within the bronchus

patient. In general, a 37 Fr DLT can be used in most of the adult females, while 39 Fr can be used in the average adult male. Undersized or oversized DLTs could lead to serious airway complications, including tracheo-bronchial rupture. The optimal depth of insertion for a left-sided DLT is strongly correlated to the patient's height. In general, the depth of the insertion for a DLT should be between 27 and 29 cm at the marking of the incisors.^[20,21] An inadvertent deep insertion of a DLT could lead to rupture of the left mainstem bronchus or unilobar ventilation. Three other sizes (26 and 28 Fr for pediatrics and 32 Fr for small adults) have recently been introduced in the market.

When a conventional laryngoscopy reveals a grade III view (only the epiglottis) or a grade IV view (only the soft palate) in the Cormack-Lehane scale, the airway may be termed difficult.^[22] When the separation of the lung is strictly indicated, the use of tubes such as DLT or Univent, which are inherently difficult to insert, cannot be recommended.^[11,23,24] If the patient has a recognized difficult airway, awake intubation with fiber-optic bronchoscopy (FOB) can be attempted using an SLT. The same approach may be used for the patient with an unrecognized difficult airway. However, thoracic anesthesiologists' expertise and propensity with a DLT rather than a BB and vice versa, and their knowledge in fiber-optic tracheobronchial anatomy, plays an important role in that choice. On the other hand, for the occasional thoracic anesthesiologist, DLTs and BBs are difficult to use and none of these devices provide any advantage over the other.^[25] In modern clinical practice, this instrument has been replaced

by three different types of 9 Fr BBs with a steering mechanism and a patent 1.6 mm lumen to facilitate the collapse of the lung and/or oxygen insufflation through continuous positive airway pressure (CPAP) to the nondependent lung.^[12] Of these three devices, the Arndt blocker is available in 7 and 5 Fr for small adults and pediatrics; it uses a wire-guided mechanism.^[13] The Cohen blocker possesses a rotating wheel that allows it to flex the tip of the blocker.^[11] Both blockers use a multiport adapter. The Uniblocker which has a fixed curve similar to a hockey stick has been recently introduced in clinical practice. It is essentially the same blocker as the one incorporated in Univent tube, but now available as an independent blocker.^[14]

Performances and Limitations of DLTs and BBs

Several randomised controlled trials have compared DLTs versus BBs^[12,25-35] [Table 2]. The time needed for the initial insertion and for lung collapse as well as the success rate for proper position and the quality of surgical exposure have been rated quite similarly with both techniques. The major drawback was related to more frequent displacements of the EBB when the surgeon manipulates the lung and the difficulties encountered to reposition the blocker with FOB while the patient lies on his side. Transient symptoms such as sore throat (10–45%), voice hoarseness (15–25%) and irritative cough have been more frequently reported postoperatively with DLTs than with SLTs combined with BBs.^[28,33] Likewise, a higher incidence of mucosal damage and hematoma has been observed within the larynx and the tracheobronchial tree following the utilization of DLTs versus BBs.^[27,28] Anecdotal cases of rupture of the tracheobronchial membrane have been related to the placement of an oversized DLT or keeping the stylet in place whilst attempting to guide the endobronchial tip into the mainstem bronchus.^[36-38] In the

rare case of tracheal bronchus (prevalence ranging from 0.1% to 1%), the use of left (or right) sided DLT will fail to achieve satisfactory lung isolation or may result in lobar atelectasis.^[39,40] Successful lung isolation can be achieved by using one (or two simultaneous) BBs. On the other hand, inadvertent resection of the guide wire and stapling the distal tip of the BB have been reported that required surgical re-exploration. Near-fatal hypoxic complications may also result from dislodgment of the inflated BB balloon into the trachea, leading to complete airway obstruction or severe gas trapping into the lung (s) associated with cardiovascular collapse.

Double-Lumen Tubes

Following intubation, the tracheal cuff should be inflated first, and then the tube's correct position should be confirmed. To avoid mucosal damage from excessive pressure applied by the bronchial cuff, the cuff is inflated with incremental volumes until air leaks disappear. Inflation of the bronchial cuff seldom requires more than 2 ml of air. If the cuff needs less than 1 ml to obtain a correct seal means that the DLT is too big, if the inflation volume of the bronchial cuff exceeds 3 ml means that the DLT is too small for that patient. Bilateral breath sounds should be rechecked to confirm that the bronchial cuff is not herniating over the carina, impeding the ventilation of the lung. An important step is to verify that the tip of the bronchial lumen is located in the designated bronchus. One simple way to check this is to first clamp the tracheal lumen, then observe and auscultate. Usually, inspection will reveal unilateral ascent of the ventilated hemithorax. Following proper auscultation, the bronchial lumen is clamped to ventilate the tracheal lumen. Each time a right-sided DLT is used, appropriate ventilation of the right upper lobe should be ensured. This can be accomplished

Table 2: Advantages and disadvantages of double-lumen tubes and bronchial blockers

	DLT	BB
Advantages	Suctioning of blood, pus, secretions Secure damaged airways (operated, open) Lesser risk of displacement Easier to correct position under FOB Lesser interference with surgical manipulation Conversion from TLV to OLV and vice versa CPAP to nondependent lung Differential lung ventilation Blind insertion if FOB not available (however, not recommended)	Difficult airway, abnormal anatomy, no DLT possible Nasal intubation Lesser risk of laryngeal injuries Lesser risk of tracheal cuff damage CPAP to nondependent lung
Disadvantages	Difficulty of placement in case of abnormal airways, previous lung surgery, children Laryngeal and tracheo-bronchial injuries, sore throat Appropriate size selection difficult Damage to tracheal and/or bronchial cuffs	Postoperative ventilation without reintubation Difficult suction for fluids, impossible in case of EZ Blocker Intraoperative displacement and difficult repositioning Impossibility of differential lung ventilation FOB mandatory

DLT – Double-lumen Tube, BB – Bronchial Blocker, FOB – Fibre-optic bronchoscopy

by a careful auscultation over the right upper lung field or more accurately by a fiber-optic bronchoscope.^[41,42] When a left-sided DLT is used, the risk of occluding the left upper lobe bronchus by the bronchial tip advanced too far into the left main bronchus should always be kept in mind. If the peak airway pressure is 20 cmH₂O during two-lung ventilation, for the same tidal volume that pressure should not exceed 40 cmH₂O on OLV.

Two techniques for DLT insertions are currently recommended: (1) a “blind” insertion, associated or not, with fiber-optic control and (2) the fiber-optic-guided approach,^[43] but there is no consensus about the correct insertion method. Fiber-optic bronchoscopy may reveal a malposition in 20–48% of the DLTs thought to be correctly positioned by inspection and auscultation only. The simplest method to evaluate proper positioning of a left-sided DLT is bronchoscopy via the tracheal lumen. The carina is then visualized, while only the proximal edge of the endobronchial cuff is visualized just below the tracheal carina. Herniation of the bronchial cuff over the carina to partially occlude the ipsilateral main bronchus should be excluded. Bronchoscopy should then be performed via the bronchial lumen to identify the patent left upper lobe orifice.^[5] When using a right-sided DLT, the carina is visualized through the tracheal lumen. More importantly, the right upper lobe bronchial orifice must be identified while the bronchoscope is passed through the right upper lobe ventilating slot. This is somewhat complex to accomplish and requires a relatively skilled endoscopist. Moreover, anatomically, the margin of safety for positioning right-sided DLTs is much narrower than left-sided ones, given the distance from the carina to the splitting of the upper-lobe bronchus. In the left lung this is about 5 cm, while at the right side just about 2.5 cm, and sometimes the right upper lobe bronchus emerges above the level of the carina, so it's impossible to insert a right-sided DLT.

Several sizes of bronchoscope are available for clinical use: 5.6, 4.9, 3.9 and 2.2 mm of external diameter. The 3.9 mm-diameter bronchoscope can easily pass through a 37 Fr or larger tube, while it is a tight fit through a 35 Fr tube and cannot be used for smaller DLTs.^[5,41-43]

Bronchial Blockers

BBs allow for the blocking of one main bronchus (or a lobar bronchus in case of selective lobar blockqde) in order to achieve the collapse of lung (or lobe) distal to the obstruction. Generally, the advantages of BBs are the disadvantages of the DLT: Use through a single-lumen tube in case of difficult intubation, in case of difficult extubation, suctioning relative

more difficult, but still possible, higher price, availability in some regions, countries.

An important advantage of BBs inserted through a tracheal tube is that this technique allows removal of the BB at the end of surgery without changing the tube. This is very important during prolonged thoracic or oesophageal surgery. In many cases, these patients present a swollen respiratory tract towards the end of the surgical procedure. It is also indicated the use of BBs in patients already intubated with orotracheal tubes for any other reason. Patients with a patent tracheostomy orifice are an indication of the use of BBs. The impossibility of using DLTs for some pediatric patients implies the need to use pulmonary isolation with BBs.

There are two types of BBs [Figure 2], the first and most used nowadays being an independent BB that is introduced through a standard endotracheal tube, and the second which is attached to a single-lumen tube, such as the Univent tube.

In 1982 Inoue^[44] described an endotracheal tube with a side channel that included a BB, known as the Univent® (Fuji Systems Corporation, Tokyo, Japan). Most recently, because anesthesiologists, didn't like the tube, but they appreciated the BB, so the company commercialized an independent BB derived from this Univent tube, the Uniblocker (Fuji-BB, Fuji Systems Corp., Tokyo, Japan). Available since 1999, the Arndt Endobronchial Blocker Set (Cook Critical Care, Ireland) is using a characteristic nylon loop protruding from the distal lumen that is coupled with an appropriate-sized fiber-optic bronchoscope to enable precise placement. The low-pressure, high-volume cuff reduces risk to injury of the bronchial wall mucosa. The BB has a lumen that allows via an adapter suctioning to accelerate deflation of the lung. Several sizes, including pediatric ones are available.

More recently, the Cohen Tip Deflecting Endobronchial Blocker (Cook Critical Care, Ireland) has also appeared on the market, which has the advantage that its placement is done under direct visualization by fibro-scope.^[11] The deflecting tip provides a quite wide range of motion which helps to position the BB to the respective mainstem bronchus. This BB is available only in a 9 Fr size. All these BBs have a small lumen that allows suctioning of air and secretions from the non-ventilated lung (or lobe).

Eventually, the most recent to appear is the Rusch® EZ® blocker (Teleflex Medical Europe Ltd., Athlone, Ireland) presenting a Y-shaped end with an inflatable balloon on each side^[45] which opens when released from the tube above the carina and which positions instantaneously in the mainstem

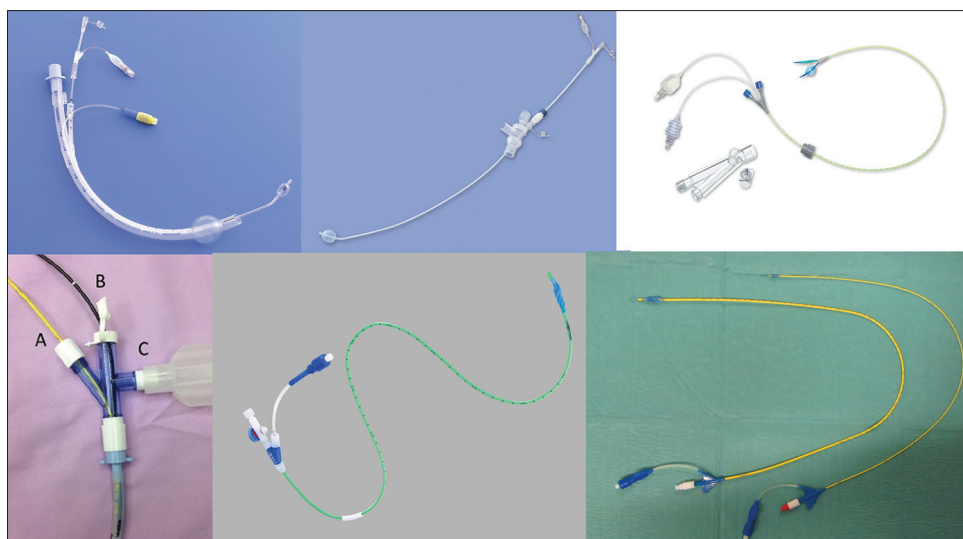


Figure 2: Different types of bronchial blockers From left to right: Upper: Univent Fuji® tube with blocker, the Uniblocker® - independent blocker derived from the first one, the EZ® blocker, one of the last blockers on the market, without lumen, but with possibility of sequential lung ventilation. Lower: Multiport airway adapter from Cook® with (A) Blocker port, (B) FOB port, (C) Ventilation port, Arndt endobronchial blocker from Cook®, and Cook® Cohen Tip deflecting Endobronchial Blocker

bronchi. Its major disadvantage is impossibility to suction the air or secretions, because the absence of lumen.

In recent years clinical practice has begun to use new types of tubes, including single-lumen (VivaSight-SL®, AMBU, Denmark) and double-lumen (VivaSight-DL®, AMBU, Denmark) aided using miniature HD cameras on the distal tip. This facilitates orotracheal intubation using the camera (for SL) or endobronchial intubation (for DL), without the need for a fiberscope to guide the device, even in cases of tracheal stenosis. The VivaSight-SL® can thus achieve lung isolation and one-lung ventilation with the use of any BB that could be inserted into a bronchus guided through the camera of the orotracheal tube during the procedure.

Terminating Surgery and Reintubating the Patient

The vast majority of patients undergoing thoracic surgery are extubated at the end of surgery. However, after complicated or prolonged surgery, some patients require postoperative ventilation. Either the DLT is pulled back with the bronchial tip above the carina and the patient is ventilated via the DLT further, or the DLT is replaced by an SLT. However, after ventilating a patient via a DLT, airway edema may occur and re-intubating the patient may be difficult, so airway guides or exchange catheters should be used for facilitating this procedure. The airway guide may be used for inserting an SLT over a DLT and vice versa, or simply inserting a difficult tube. Several tube exchangers are available. All of these airway guides are commercially made, depth is marked in cm, the tip is atraumatic, are available in a wide range of

sizes, and are easily adapted for either oxygen insufflation or jet ventilation. Critical details to keep in mind to maximize benefit and minimize risk of airway injuries are as follows: First, the size of the airway guide and the size of the difficult tube must be determined and should be tested *in vitro* before the use of the airway guide. Second, the airway guide should never be inserted against resistance; the clinician must always be aware of the depth of insertion. Two reported perforations of the tracheobronchial tree have occurred.^[46,47] Third, a jet ventilator should be immediately available in case the new tube does not follow the airway guide into the trachea, and the jet ventilator should be preset at 25 psi by the use of an additional in-line regulator.^[48] Finally, when passing any tube over an airway guide, a laryngoscope should be used to facilitate the passage of the tube over the airway guide past the supraglottic tissues. Because of the potential injury to the bronchial tree from the stiff tip of the tube exchanger, a new catheter has been designed with a soft tip to reduce the risk of trauma. In case of BBs, there is no extubation problem after surgery and anesthesia, the BB is simply pulled out and the single-lumen tube left in place to ventilate the patient.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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