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REVIEW

Isolation of the lung: Double-lumen tubes and endobronchial blockers

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SUMMARY

Over the past decades, indications for one-lung ventilation (OLV) have largely increased in cardiothoracic, orthopedic and spinal surgery along with the advances in minimally invasive techniques. Lung isolation is currently achieved with a double-lumen endotracheal tube (DLT) or an endobronchial blocker (EBB). Expertises in videolaryngoscopy and fiberoptic bronchoscopy (FOB) are valuable assets for safe management of the upper airways and correct placement of DLTs and BBs. This review will focus on a rationale application of either of these lung isolation devices, discussing their specificities, indications and limitations which are relevant for thoracic and non-thoracic anesthesiologists.

1. Introduction

First described in anesthetic practice in 1931, selective endobronchial intubation combined with positive pressure ventilation was the long awaited solution to the deadly pneumothorax problem associated with chest opening.[1] Whilst providing positive pressure ventilation, various types of catheters with an inflatable distal balloon (e.g., urinary catheter, Fogarty embolectomy catheter or Swan-Ganz catheter) were inserted in bronchial divisions to exclude ventilation of the distal lung parenchyma.[2]

Over the next decades, different techniques for securing the airways and selectively ventilating the lungs have largely contributed to the development of intrathoracic surgery.[3] Nowadays, along the recent advances in video technology, endoscopic instruments, and mini-invasive approaches, the demand for lung separation methods has increased not only in thoracic surgery but also for various cardiac, orthopedic and neurological procedures.[4–7]

Lung isolation 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).[8]

In the vast majority of procedures requiring one-lung ventilation (OLV), two techniques are available: the double-lumen tubes (DLTs) or the endobronchial blockers (EBBs). Satisfactory lung separation can be achieved with both techniques, the ultimate choice depending on the clinical settings, the specific properties of these devices and the operator's personal preferences.[8] In emergency conditions and in pediatric patients, a standard single lumen tube (SLT) can also be advanced into a main bronchus stem or a Fogarty catheter can be inserted along the SLT, to prevent soiling of the ventilated lung and/or to facilitate transient collapse of the lung.

According to recent surveys in the United Kingdom, Italy and the Middle East, DLTs are preferred by a large majority of thoracic anesthesiologists (more than 90%).[9–11] Interestingly, although most of these experts declare being familiar with EBBs, up to 30% acknowledges never using EBBs.

A working knowledge of tracheobronchial anatomy, expertise in fiberoptic bronchoscopy (FOB) and familiarity with specific lung isolation devices are essential conditions for successful placement of EBBs and DLTs as well as for safe management of OLV.[12] Anesthesiologists with limited exposure to thoracic surgery should develop basic knowledge and practical skills with anesthesia simulator training, computer-based DVD programs and continuous education via thoracic anesthesia workshops.[13–15]

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Table 1 summarizes the common indications, goals of isolating the lung with DLTs or BBs.

2. Double-lumen tubes (DLTs)

2.1. Characteristics of DLTs

All DLTs contain two catheters bonded together, one shorter ending in the trachea and the other extending further into the left or right mainstem bronchus. These devices have evolved from the rubber Carlens and Robertshaw tubes to silicone and polyvinyl chloride tubes, with larger internal to external diameter ratios (D-shaped lumen), and specific features facilitating the insertion through the upper airways into the right or left mainstem bronchus.[1] The transparent wall facilitates the detection of exhaled water vapor, blood and secretions. The balloon cuffs are color-coded, white for tracheal and blue for bronchial. Inflation with 2–3 ml of air into the highly compliant bronchial balloon is sufficient to seal off the airway, the pressure applied against the bronchial mucosa remaining well below the critical ischemic threshold (25 mmHg) (Table 2).[16]

On the proximal part of the shaft, graduations (in cm) are useful to gauge the depth of insertion (with annular markings at the bottom of the tracheal cuff, above and/or below the bronchial cuff) and to facilitate fiberoptic guidance and radiographic localization. Some DLTs have a radiopaque line running all along their whole length.

At least five manufacturers provide disposable DLTs in various sizes (26, 28, 32, 35, 37, 39 and 41 French [Fr]) and configurations (right and left; tracheostomy).[17] Each sterile package contains a DLT, a stylet, a ventilating connector, and several suction catheters. Smaller DLTs (28 Fr and 32 Fr) are specifically designed for children (>120 cm) or small adults. Some DLTs have a carinal hook to prevent tube displacement although they may cause airway trauma, interfere with bronchial closure during pneumonectomy or even break off in the bronchia.[18,19]

2.2. Choice of a DLT

2.2.1. Right or left DLT

Right and left-sided DLTs are specifically designed to the anatomic differences of the major conducting airways.[20] As illustrated in Fig. 1, the right mainstem bronchus is straighter (10°–15° angle) and shorter than the left mainstem bronchus. Accordingly, a cylindrical or balloon-shaped cuff covers the endobronchial part of the left-sided DLT whereas the right-sided DLT incorporates an oblique, donut-shaped cuff or two bronchial cuffs with a median slot to allow ventilation of the right upper lobe (RUL) (Fig. 2). The Cliny, a right-sided DLT (Create Medic Co. Ltd, Yokohama, Japan), has a long bronchial cuff with two ventilation slots for the RUL. The Silbroncho, a left-sided DLT (Fuji Systems), features a shorter, silicone wire-reinforced endobronchial tip with a bronchial cuff of reduced size. For patients bearing a tracheostomy, a shorter left-sided DLT (37 Fr and 39 Fr) has been designed with the tracheal and bronchial cuffs being placed closer to each other.

Table 2
Outer and inner diameters of double-lumen tubes.

Size	OD mm	Bronchus mm ID	Trachea mm ID	Length mm	FOB
26	8.7–9.3	3.0	3.0	280	2.4
28	9.3–10.2	3.2	3.1	280	2.4
32	10.5–11.2	3.4	3.5	300	3.1
35	12.0–13.5	4.3	4.5	300–310	3.5–4.2
37	13.3–14.0	4.5	4.7	310–320	3.5–4.2
39	13.8–14.3	4.9	4.9	330–340	3.5–4.2
41	13.7–14.9	5.4	5.4	340–350	3.5–4.2

OD, outer diameter; ID, inner diameter; and FOB, fiberoptic bronchoscopy.

The length of the tracheobronchial tree over which the endobronchial segment can move without obstructing a bronchial division (toward the upper, lower or middle bronchial lobe) has been coined the "margin of safety".[21] Left-sided DLTs have a greater margin of safety than right-sided DLTs due to the longer distance from the tracheal carina to the takeoff of the upper lobe. Accordingly, left DLTs are much more commonly used than right DLTs owing to the easiness of positioning and safer intraoperative management (lesser need for repositioning or risk of bronchial obstruction) in patients undergoing right and left thoracic procedures. Intraoperatively, particularly during lung transplantation or left pneumonectomy, verbal communication between the surgeon and the anesthesiologist is very important as the left-sided DLT often needs to be withdrawn before clamping the left mainstem bronchus.

The use of right-sided DLTs is mandatory in patients bearing a tumor obstructing the left main bronchial stem and is recommended in those with distorted airway anatomy or external compression of the left mainstem bronchus by an aortic aneurysm or lymph nodes.[22] In some thoracic centers, the operated side always dictates the selection of the opposite sided DLT. Hence, a

Table 1
Indications for lung isolation technique.

		Indications	Main goal	Suggestion
Absolute indications		Unilateral lung abscess or cyst	Contralateral Lung protection	DLT
		Unilateral lung hemorrhage (e.g., thromboembolism, aneurysm)	Contralateral Lung protection	DLT
		Bronchoalveolar lavage with saline to treat alveolar proteinosis	Contralateral Lung protection	DLT
		Bronchopulmonary fistula, trachea-bronchial injury	Secure the airways and gas exchange	DLT
		Severe unilateral disease (giant emphysematous bullae)	Differential lung ventilation	DLT
		Lung transplantation	Secure the airways and differential ventilation	DLT
Relative indications	High priority	Pneumonectomy, sleeve resection on the bronchial mainstem Tumor obstructing the main bronchial stem	Surgical exposure	DLT
		Thoracic aneurysm with cardiopulmonary bypass	Surgical exposure	DLT (>EBB)
		Lobectomy and lesser lung resection (any surgical approach[a])	Surgical exposure	DLT = EBB
	Low priority	Interventions on the pleura and mediastinal structures	Surgical exposure	DLT = EBB
		Oesophagectomy	Surgical exposure	DLT = EBB
		Orthopedic surgery on the chest, thoracic spine surgery	Surgical exposure	DLT = EBB
		Minimally invasive cardiac surgery	Surgical exposure	DLT = EBB
		Bilateral cervical sympathectomy	Surgical exposure	EBB (>DLT)

[a] Video-assisted thoracoscopy, robotic surgery or open thoracotomy; DLT, double-lumen tube; EBB, bronchial blocker.