ONE LUNG VENTILATION

A Practical Guide - Javier Lasala, MD

Ambu

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Disclaimer
The information presented here is for general knowledge.
It is recommended to review the relevant Manufacturer's Manual(s) for instructions, warnings and cautions.

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INTRODUCTION

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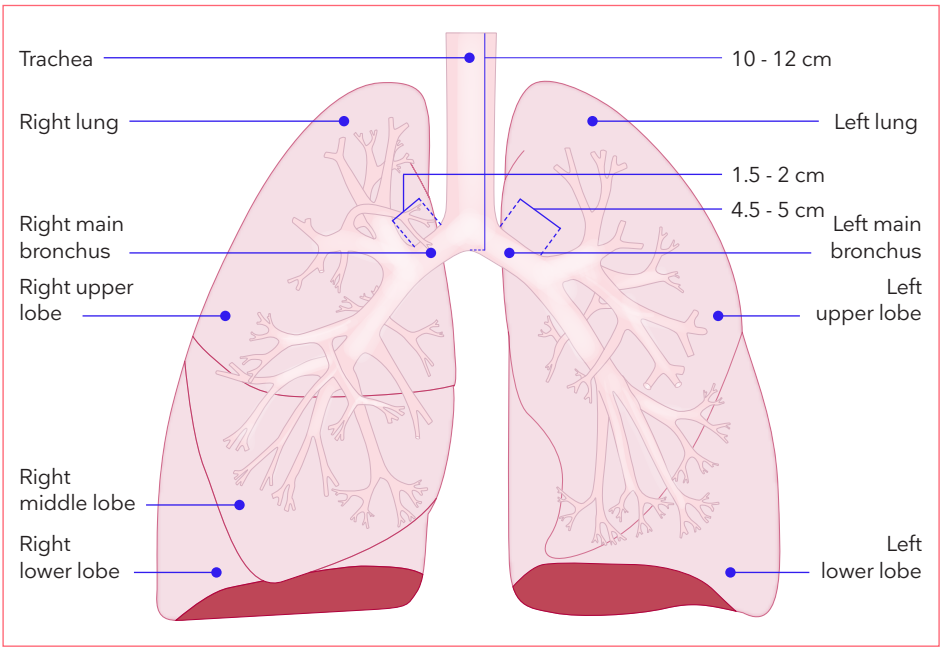
One lung ventilation (OLV) is the separation of the lungs to allow single lung ventilation of either the right or left lung[1]. OLV is implemented for surgical exposure in cardiac, pulmonary, esophageal, spinal surgery, or it may be used to isolate a diseased lung from a healthy lung to prevent soiling or to implement differential ventilation. OLV has evolved recently with the development of video capable single and double lumen endotracheal tubes, which now allow real time visualization[2-4]. This booklet is intended to provide a summary of the tools available for OLV and the techniques for using these.

ANATOMY

The trachea divides into right and left main bronchi at the carina. Identification of the carina is critical for OLV. Each lung is separated into lobes with three lobes on the right side and two lobes on the left. The right main bronchus is much shorter (average length 1.5 - 2 cm), than the left main bronchus (average length 4.5 - 5.0 cm) and the diversion angle on the right is much smaller than that of the left (25 degrees vs an angle of 45 degrees on the left). The smaller angle of diversion of the right main bronchus is important for OLV because lung isolation devices are more likely to travel into the right main bronchus[5]. An anatomical abnormality called “bronchus suis” may be present in up to 2 % of the population where the right main bronchus originates directly from the supra-carinal trachea[6].



The human anatomy is asymmetric. The right main bronchus is much shorter (average 1.5 – 2 cm), than the left main bronchus (average 4.5 - 5.0 cm).

PHYSIOLOGY

The lungs facilitate the transfer of oxygen into the blood and the removal of carbon dioxide from it. This function depends on a number of processes: ventilation (bringing gas into the alveolar spaces), the diffusion of gases across the alveolar membrane (and the reaction between oxygen and haemoglobin) and the perfusion of the alveoli with deoxygenated blood. Successful OLV requires the management of these processes[5]. The main physiological effect of OLV is the development of a right to left shunt. This occurs where there is no ventilation, but lung perfusion still occurs. This shunt may be reduced by hypoxic pulmonary vasoconstriction whereby the pulmonary arteries constrict in the presence of hypoxia, redirecting blood flow to the dependent ventilated lung[7-9].

INDICATIONS FOR
One Lung Ventilation (OLV)

OLV is used in Thoracic Surgery (including lung resection procedures, video assisted thoracoscopic surgery[VATS]), decortication, diaphragmatic hernia repair and single lung transplantation). It is also used in minimally invasive cardiac surgery, thoracic aortic surgery, esophageal surgery, thoracic spinal surgery, cervical sympathectomy, thymectomy and pericardial surgery[5]. In these procedures, OLV is essential for surgical manipulation and exposure of the operative field.

OLV may also be used in non-surgical procedures including pulmonary lavage, differential lung ventilation, the management of pulmonary haemorrhage, bronchopleural and bronchocutaneous fistulae and isolation of infection[13].

CHOOSING THE RIGHT EQUIPMENT

OLV can be performed by two primary methods: Double Lumen Tube (DLT) and Endobronchial Blocker (EBB). Suggestions on when to choose a DLT and when to choose an EBB are described below.

a) DOUBLE LUMEN TUBE (DLT)

A DLT is essentially two tubes stuck together. One tube opens in the trachea. The other tube is longer and opens in the left or right main bronchus. Both tubes have a cuff to prevent the gases from mixing between the two tubes. Each tube has a separate proximal connector so that they may be ventilated independently. There are two types of DLTs - right and left sided - corresponding to the main bronchus they enter[1].

DOUBLE LUMEN TUBE

Advantages	Disadvantages
• Effective lung protection with full isolation	• Selecting the correct size can be difficult
• Less likely to dislodge than EBB	• Difficult to place during laryngoscopy
• Conversion from two to one lung ventilation is easy	• More frequent injuries
• Deflation and re-inflation of collapsed lung is possible during the procedure	• Tube exchange to an SLT is necessary in cases where mechanical ventilation is needed post-operatively.
• Effective suction	• Placement can be difficult in patients with abnormal anatomy or in patients with difficult airways
• Continuous Positive Airway Pressure (CPAP) application to the collapsed lung during OLV	
• Independent ventilation of each lung	
• Possible to ventilate lungs independently using different modalities	

Table 1: Advantages and disadvantages of DLT

INDICATION FOR THE USE OF DLT

Left-sided DLT	Right-sided DLT
Used for both left and right sided surgery Left sided DLT is the most commonly used DLT[15]	Used in special cases such as: • Central surgery on the left side • Obstruction/disruption of the left main bronchus • Left single-lung transplantation • Left main stem sleeve resection • Left main stem compression • Aortic Aneurysm surgery • Mediastinal Mass

Table 2: Indication for the use of DLT

Sizing

Larger DLTs offer less resistance to airflow during OLV and allow easier introduction of a suction catheter or a bronchoscope. There is no accurate method for selecting the correct size DLT, but the following table can be used as a guide.

Women		Men	
< 160 cm	35 Fr	< 170 cm	39 Fr
> 160 cm	37 Fr	> 170 cm	41 Fr

Table 3: DLT Size Selection[5]

i. LEFT-SIDED DLT

1. Conventional left-sided DLT

Left-sided DLTs are most commonly used due to the long left main stem bronchus[15]. As a result, it is less likely to occlude the upper lobe when correctly placed than a right-sided DLT. The length of the left main bronchus also ensures that the left-sided DLT is less likely to dislodge during surgery.

The left-sided DLT can be used for both left and right sided surgery. Refer to Table 2.

With the real-time video image transmitted to the displaying unit, VivaSight 2 DLT allows immediate detection and correction of malpositioning and dislocation.

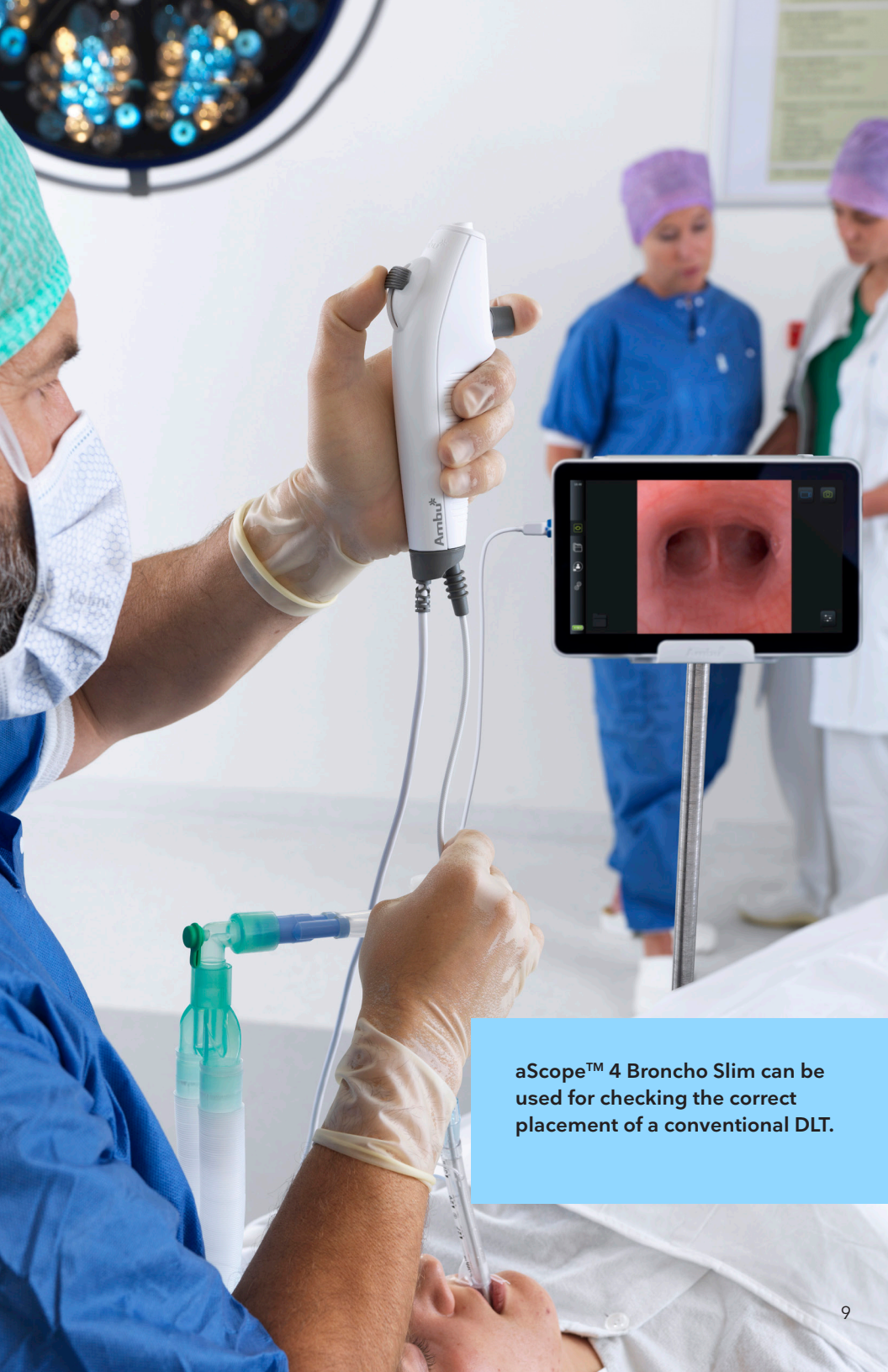
2. VivaSight 2 DLT

The VivaSight 2 DLT is a single-use, left-sided double lumen tube based on a similar design to the conventional DLT. The VivaSight 2 DLT has an integrated camera and light source at the tip of the tracheal lumen. It also has a flush port that may be used for cleaning the camera lens with air or saline. The VivaSight 2 DLT offers uninterrupted visualization for tube placement and continuous monitoring throughout the procedure. Thus malpositioning and dislocation may be immediately detected with the real-time video image transmitted to the displaying unit. For the vast majority of procedures, the use of bronchoscopy for intubation and confirmation of tube positioning is not necessary when using the VivaSight 2 DLT compared to conventional DLTs[2,3,22].

ii. RIGHT-SIDED DLT

1. Conventional right-sided DLT

The right-sided DLT is used in special cases when performing surgery on the left side (Refer to Table 2). The bronchial lumen is curved to fit the right main bronchus. It also has special shaped endobronchial cuff (with an orifice for the right upper lobe bronchus – the 'Murphy eye') - to maintain ventilation of the right upper lobe. Sizing is the same as for left-sided DLTs.



aScope™ 4 Broncho Slim can be used for checking the correct placement of a conventional DLT.

b) ENDOBRONCHIAL BLOCKER (EBB)

An EBB is a thin catheter that is placed alongside or through a single-lumen endotracheal tube. The inflatable balloon at the tip of the catheter is placed into either the left or right main stem bronchus to isolate and deflate the lung.

ENDOBRONCHIAL BLOCKER

Advantages	Disadvantages
• Easy to select size • Easy to insert at correct depth • Very few and less serious complications • Suitable for patients with difficult airways or cervical spine injuries • Tube exchange is not needed for patients already intubated with an SLT or in need of mechanical ventilation postoperatively • Can facilitate isolation of a single lobe rather than the entire lung	• Slow collapse of the desired lung • EBBs are more easily dislodged • Continuous positive airway pressure (CPAP) cannot easily be applied to the non-ventilated lung • Whilst in place, it may be difficult to suction bronchial secretions without removing the EBB • Risk of bronchial perforation and pneumothorax

Table 4: Advantages and disadvantages of EBB[16]

INDICATION FOR THE USE OF AN EBB

EBBs are often used in the following clinical scenarios
• Where the size of the patient's trachea would not allow placement of a DLT • Patients with difficult airways or cervical spine injuries • Patients already intubated with an SLT or where there is a need for postoperative mechanical ventilation • Single lobe isolation rather than entire lung isolation

Table 5: Indication for the use of EBB

An endobronchial blocker with an inflated balloon at the tip of the catheter. In this figure, the UNIBLOCKER™ from Fuji is shown

i. Endobronchial Blocker with an endotracheal tube (ETT)

An EBB can be placed through an ETT with the assistance of a bronchoscope. The most common sizes of EBBs are 9 Fr and 7 Fr. An adult patient of average stature generally needs a 9 Fr EBB that is compatible with an SLT OD 8.0 mm. The EBB and the bronchoscope need to be tested for compatibility prior to insertion[5].

VivaSight 2 SLT connected to the displaying unit

Endobronchial Blocker Tube

ii. Endobronchial Blocker used with VivaSight 2 SLT

An EBB can also be used with an SLT with integrated camera like the VivaSight 2 SLT that decreases the need of a bronchoscope.

VivaSight 2 SLT is a sterile, single-use endotracheal tube. It is intended to be used as a temporary artificial airway in adults requiring mechanical ventilation and for general inspection of the airways and for visualization during oral intubation procedures. The Endobronchial Blocker Tube is a single-use endobronchial blocker, which consists of a curved tipped balloon catheter that can be directed under vision with the VivaSight 2 SLT camera to a selected bronchial segment to affect balloon blockage of the distal airway. The blocker can be placed in either the right or left main stem bronchus for operations on the right or left lung, respectively.

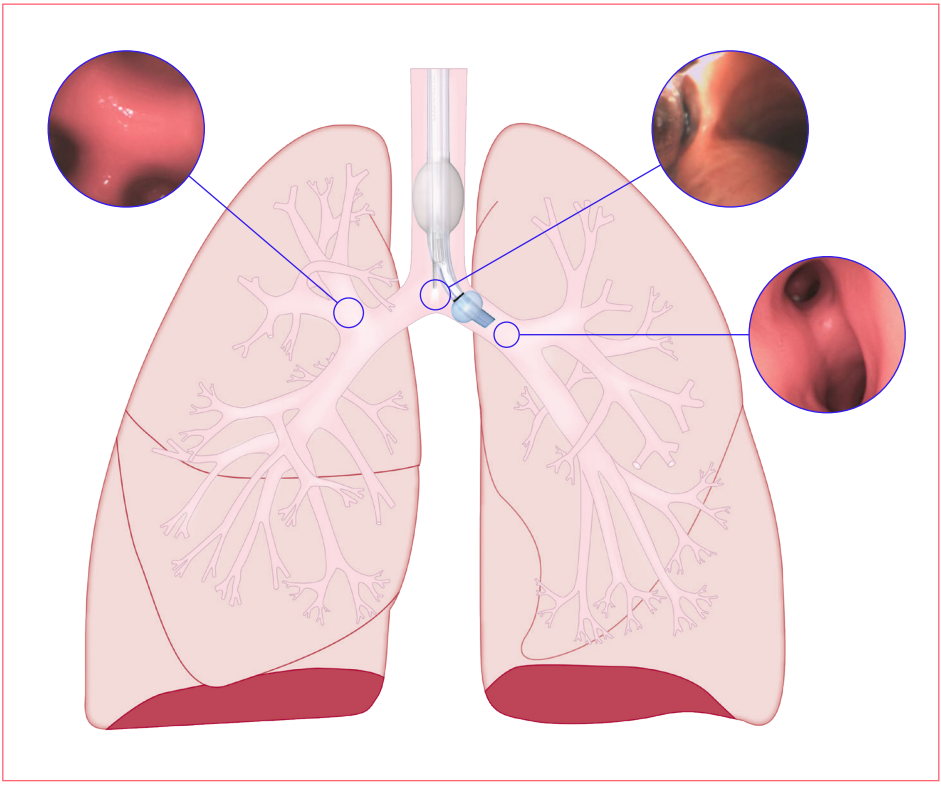
TECHNIQUES – HOW TO USE THE EQUIPMENT

a) CONVENTIONAL LEFT-SIDED DLT INSERTION AND CONFIRMATION OF PLACEMENT

1. The stylet in the bronchial lumen may be bent to a “hockey stick” shape.
2. A conventional DLT is placed under direct laryngoscopy or video laryngoscopy with the bronchial lumen pointing upward.
3. After passing the vocal cords with the bronchial cuff, the stylet is removed, the tube is rotated approximately 90° degrees towards the left side, and advanced until resistance is felt.
4. The flexible bronchoscope (e.g. aScope™ 4 Broncho Slim) can also be used as a ‘guidewire’ to place the DLT. If direct laryngoscopy is anticipated to be difficult, the DLT can be advanced directly over the flexible scope.
5. After insertion, the tracheal cuff is inflated and tube placement is checked.
6. Auscultation alone is an unreliable method for confirmation of proper DLT placement – visual inspection is usually required[20].
7. Flexible bronchoscopy (e.g. using aScope™ 4 Broncho Slim) is required each time a traditional DLT is placed and again when the patient is repositioned.
8. To confirm DLT position with the use of a bronchoscope, the scope should be inserted down the tracheal lumen first, and then the bronchial lumen. The tip of the bronchial lumen should be seen entering the left main bronchus, and the cuff, when inflated, should fill the orifice.

Lung isolation

Lung isolation is achieved by clamping the limb of the Y-connector to the required lung and opening the cap of the Y-connector. This allows the lung to passively deflate and the bronchial cuff is inflated until there is an absence of leak through the cap. A suction catheter can be used to accelerate deflation of the lung, but the lowest effective suction should be used to avoid atelectasis (collapse of the lung tissue).



Bronchoscopy for confirmation of optimal position of left-sided DLT. The bronchoscope (e.g. aScope™ 4 Broncho Slim) is advanced through the tracheal lumen and shows an unobstructed view of the entrance of the right main stem bronchus and the edge of the fully inflated endobronchial cuff is below the carina in the left bronchus. Further down, it shows the take-off of the right-upper bronchus with the three segments. When the bronchoscope is advanced through the bronchial lumen, it shows an unobstructed view of the left-upper and left-lower bronchus.

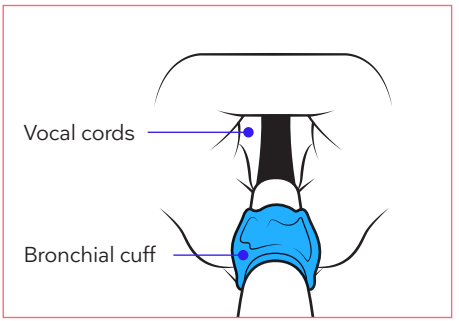
b) VivaSight 2 DLT

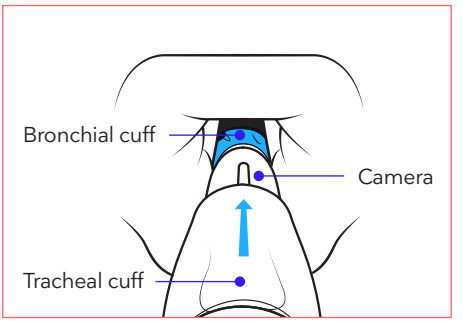
Insertion and confirmation of placement

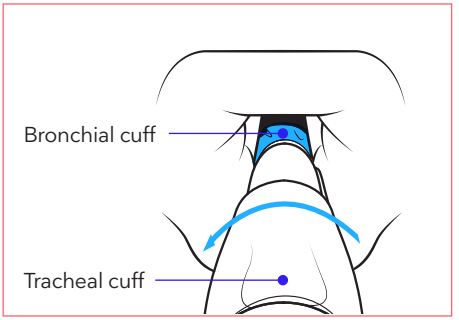
The VivaSight 2 DLT has a camera at the side of the tracheal lumen, which allows insertion under direct visualization.

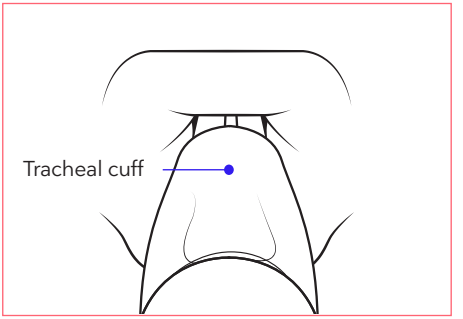
1. In order to maintain good visualization with the VivaSight 2 camera, it is recommended that a defogging solution be applied to the camera prior to insertion[2,3]. The camera cable should be connected to the displaying unit to confirm a good image prior to insertion. Test the cuffs for integrity by inflating and deflating. Lubricate the tube if needed, avoiding the area around the camera lens.

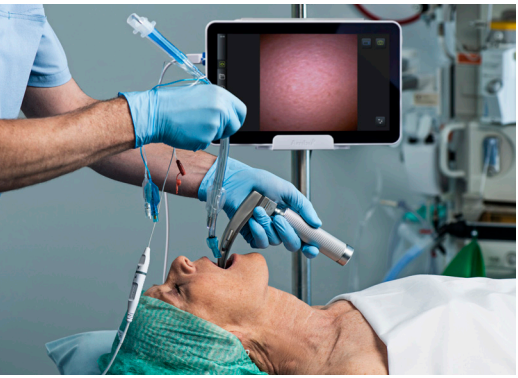
2. Before insertion, the oral cavity should be suctioned thoroughly to remove secretions, which may collect on the camera lens during insertion. An anti-sialagogue may be considered for some patients to help diminish secretions.











3 The tube is usually inserted with the assistance of a conventional laryngoscope or video laryngoscope; it is imperative that the camera does not touch any mucosa on insertion in order for the image quality to remain pristine.

4 Once the bronchial cuff has passed the vocal cords, the stylet is removed, and the tube is rotated 90° degrees until the camera of the VivaSight 2 DLT is pointing upwards (at 12 o'clock).

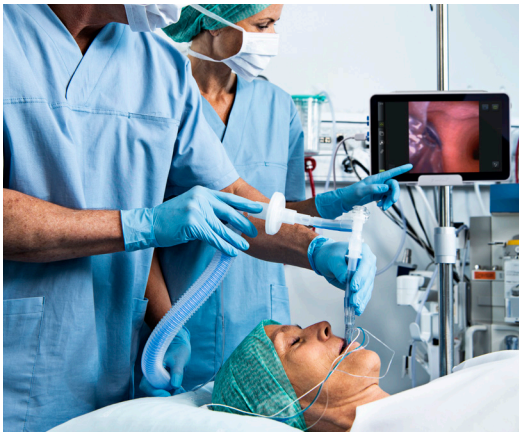
5 With the camera upwards, the goal is to advance it through the cords without any contact to maintain image quality.

6 The risk of damaging the mucosa while passing the vocal cords is minimized by orientating the camera at 12 o'clock.

7 Once the camera has passed the vocal cords, the insertion is guided by the view on the displaying unit. It is recommended to keep the laryngoscope in place until final positioning as this helps with DLT manipulation.

8 The tube is then advanced slowly with a slight clockwise rotation applied during advancement as to align the camera correctly after vocal cord passage. The tube is advanced until the bronchial cuff is in the desired position in the left main stem bronchus.

9 Insertion is completed when VivaSight 2 DLT is visualizing the carina and the bronchial leg is in the left bronchus with a clear view of the right main stem bronchus.



10 The position of the VivaSight 2 DLT can continuously be checked by looking at the image displayed on the displaying unit.

11 If the tube is dislodged as a result of aggressive manipulation of the lung, it can be repositioned immediately under visual guidance which significantly reduces the need for a bronchoscope.

Lung Isolation

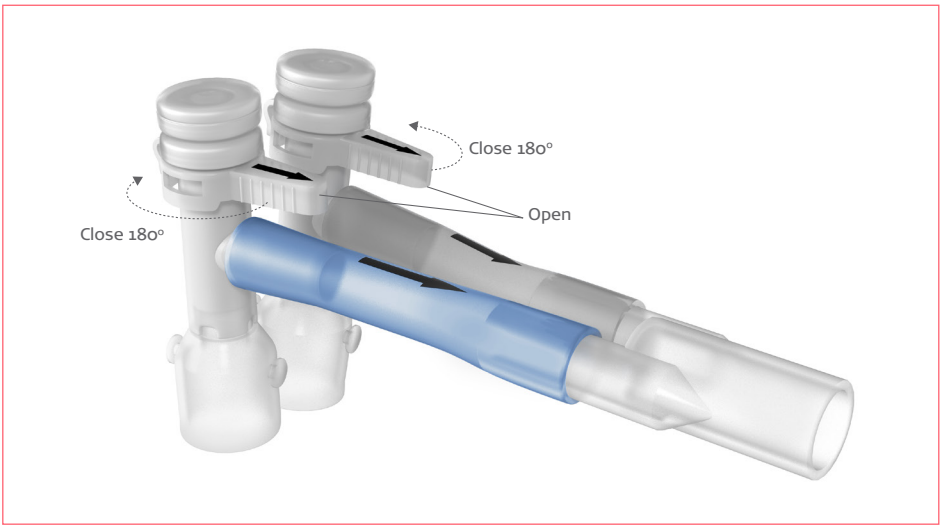
1. Isolation of one lung using VivaSight 2 DLT is also done by inflating both cuffs, but with VivaSight 2 DLT, the Y-Connector has a rotator that enables the blockage of airflow.

2. The lumen is closed for ventilation when the rotator is turned 180° degrees opposite the direction of the arrow on the lumen. The cap on the top valve is opened on the occluded side and air can escape and deflate the lung.

3. The tracheal cuff pressure needs to be 22-32 cm H_2O (<30 cm H_2O according to the VivaSight 2 DLT IFU) and should be generated with an inflation volume of approx. 5-10 ml [17, 18].

4. The bronchial cuff requires less air to obtain a seal; if an appropriate large tube is chosen, a volume of < 3 ml of air is required achieving an average cuff pressure of approx. 20 cm H_2O [17, 18].

	Cuff volume (ml)	Cuff pressure (cm H_2O)
Tracheal cuff	5 - 10	< 30
Bronchial cuff	< 3	Approx. 20



Operation of the VivaSight 2 DLT Y-connector. In the illustration, both lumens are open for ventilation

Secretion Management

Once positioned if secretions develop on the camera lens, there are two ways of clearing them either by using the flush port on the tube or using the provided suction catheters.

1. A syringe can be connected to the flush port on the camera lens and either air or saline can be injected to attempt to clear condensation or secretions from the camera lens.

2. We recommend using air first to try and clear the camera as excessive use of saline flushing may disperse thick secretions and worsen the problem.

3. When using saline to flush the camera, we suggest using a very small quantity and trying to aspirate the saline immediately after flushing to avoid leaving a saline droplet on the lens.

4. The angled suction catheter can also be used to clear any secretions around the camera lens. The angled suction catheter should be inserted via the tracheal tube and if a partial view is present on the camera, the tip of the suction catheter can be directed under visual monitoring to the area with the secretions.

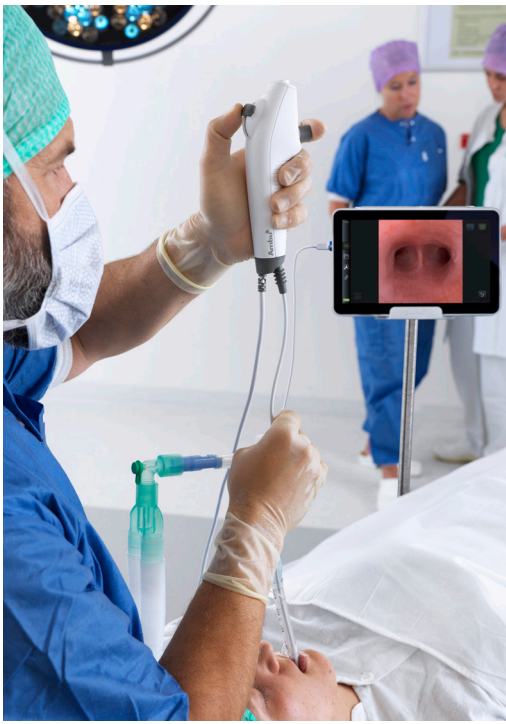
Disposal

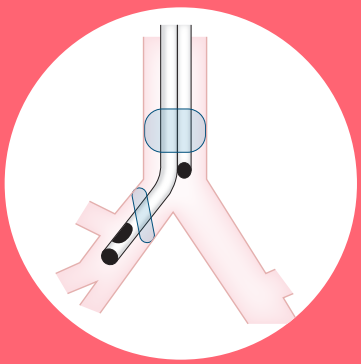
Discard the single-use VivaSight 2 DLT, Y-connector, stylet, suction catheters and adapter cable in a suitable biohazard receptacle in accordance with local regulations.

c) CONVENTIONAL RIGHT-SIDED DLT
Insertion and confirmation of placement

1. Technique for the insertion of right-sided DLT devices are essentially the same as for conventional left-sided DLT devices. The only difference is that, as mentioned, the right-sided DLT has a special orifice (Murphy eye) that is to be placed at the take-off of the right upper lobe bronchus.

2. Confirmation of correct placement of the right-sided DLT involves bronchoscopy via the tracheal lumen (just as for a left-sided DLT) to check positioning of the bronchial tube at the carina and again through the bronchial lumen to visualize the Murphy eye being correctly positioned at the opening of the right upper lobe bronchus. This will ensure that the right upper lobe bronchus is not obstructed.





The right-sided DLT is correctly placed when the tracheal cuff is below the vocal cords and the bronchial cuff is placed in the right main bronchus below the carina and with the Murphy eye aligned with the entrance to the right upper lobe.

d) ENDOBRONCHIAL BLOCKER USED WITH AN ENDOTRACHEAL TUBE (ETT)

Insertion and confirmation of placement

1. EBBs placed through a conventional SLT must be checked by performing a flexible bronchoscopy (e.g. using aScope™ 4 Broncho Slim).

2. The bronchoscope is introduced in the SLT next to the EBB and advanced to the trachea above the carina. Knowledge of the bronchial anatomy on both sides is necessary to check correct placement.

3. The method of positioning the EBB will vary according to the manufacturer – some will attach to the bronchoscope and others can be directed by rotation. It is recommended to refer to the manufacturer's instructions for placement of these devices.

4. After the EBB position has been visually confirmed, the blocker cuff is inflated (according to the manufacturer's recommendations) under direct visual monitoring to fill the main bronchus.

5. The lumen port is opened so the air can escape and hence the lung can be deflated. Deflation occurs more slowly with an EBB rather than a DLT. This is because the lumen of the EBB is very small, and the channel is very long compared to a DLT. This process will be even more delayed in patients with Chronic Obstructive Pulmonary Disease (COPD). If deflation occurs too slowly, controlled suction can be applied to speed up the process. Adequate isolation is checked by visual checks, auscultation and airway compliance changes.

6. Another alternative for lung deflation is the disconnection technique[21]. Prior to inflation of the blocker cuff, the ventilator is turned off to allow both lungs to deflate. The blocker cuff is then inflated and OLV is resumed. This technique, although effective, may result in contamination of the dependent lung by blood or secretions from the non-dependent lung.

7. Compared to a DLT, the EBB is more likely to become dislodged during repositioning of the patient and as a result of manipulation during surgery. It is therefore important to check that the isolation is adequate once the patient is correctly positioned for the surgery.

e) ENDOBRONCHIAL BLOCKER USED WITH VivaSight 2 SLT

Insertion and confirmation of placement VivaSight 2 SLT

1. For the preparation of VivaSight 2 SLT, the same process of preparation as for the VivaSight 2 DLT is recommeded. (Refer to page 16.)

2. As with conventional SLTs, the VivaSight 2 SLT is placed under direct laryngoscopy, with an emphasis on proper care of the camera and avoiding mucosal contact.

3. After passing the vocal cords, the stylet (if used) is removed. The tube is advanced under direct visual monitoring and correct placement is confirmed by visualizing the carina.

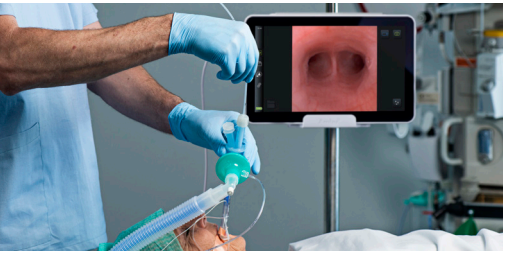
4. The tracheal cuff is inflated until a seal is obtained. The cuff pressure should not exceed 30 cm H_2O (According to VivaSight 2 SLT IFU).

5. Once the patient has been intubated with VivaSight 2 SLT and the position of the tube is confirmed (above the carina), the insertion of the Endobronchial Blocker can begin.

Insertion and confirmation of placement of Endobronchial Blocker Tube and VivaSight 2 SLT.

(1) Endobronchial Blocker Tube is inserted into the VivaSight 2 SLT and the tip can be directed into the target bronchus by rotating the EBB left or right.

(2) While the patient is in supine position, the EBB is advanced to the main stem bronchus where lung deflation is required.



(3) Once correctly positioned, the cuff of the EBB is inflated under direct visual monitoring to fill the main bronchus. The cuff pressure should not exceed 20 cm H_2O (According to Endobronchial Blocker Tube IFU). Adequate isolation is confirmed by visual checks, auscultation and airway compliance changes.

(4) Once the patient is in the optimal surgical position, the EBB position is checked again with the VivaSight 2 SLT camera on the displaying unit.

(5) By using VivaSight 2 SLT, the need to employ flexible bronchoscopy for placement and confirmation of EBB position is avoided in the majority of cases, which saves time.

Secretion Management

The options for managing secretions obscuring the camera view are the same as for the VivaSight 2 DLT, although caution should be taken when using suction catheter and EBB in the VivaSight 2 SLT at the same time.

Disposal

Discard the single-use VivaSight 2 SLT and/or Endobronchial Blocker Tube, stylet and adapter cable in a suitable biohazard receptacle in accordance with local regulations.

COMPLICATIONS ASSOCIATED WITH THE USE OF DOUBLE LUMEN TUBES AND ENDOBRONCHIAL BLOCKERS[1,5,16]

Double Lumen Tube	Endobronchial Blocker
• Incorrect placement or malposition of a DLT prevents deflation of the selected lung and may affect the ventilated lung leading to hypoxemia. The most common causes of incorrect placement and failure to maintain OLV are over inflation of the bronchial cuff, surgical manipulation of the lung, and extension or flexion of the head and neck during patient positioning. • Airway trauma and damage to the tissue in the trachea or main bronchus continue to be associated with the use of DLTs. This complication can be developed at any time while the DLT is in position or during extubation.	• The most common complications related to the use of an EBB are failure to achieve adequate lung isolation and/or separation due to dislodgement. • This may be due to abnormal bronchial anatomy and repositioning of patient. • More commonly, the cuff is not inflated or positioned properly, leading to inadequate sealing of the bronchus.

CONCLUSIONS

DLTs and EBBs are essential tools for OLV. The specific device to be used should be selected based on the specific case and patient needs[16]. Both DLTs and EBBs are safe and effective in performing lung separation. It is ultimately the level of familiarity and comfort of the anaesthesiologist and surgeon that determine what is best for the management of the patient. VivaSight technology provides the anaesthesiologists an additional tool by having direct visualization for lung isolation and providing direct visualization at all times to ensure the accuracy of the OLV[1, 5, 16].

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