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Double-lumen tubes and bronchial blockers

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Learning objectives

By reading this article you should be able to:

- Debate the pros and cons of double-lumen tubes and bronchial blockers for lung isolation.
- Discuss the factors that affect the success of lung isolation techniques.
- Develop a systematic strategy for troubleshooting failure of lung isolation in practice.
- Create a safe airway plan in cases of anticipated difficult airway.

Key points

- The two main methods for achieving lung isolation are double-lumen tubes and bronchial blockers.
- When planning one-lung ventilation, the anatomy of the upper and lower airways, the location and extent of the disease process and the planned surgery should all be considered.
- The size and type of the airway device can determine whether lung isolation is successful.
- A systematic approach to confirming successful lung isolation helps prevent intraoperative difficulties in ventilation and gas exchange.
- A systematic approach is essential to managing failed lung isolation.

Lung isolation and one-lung ventilation (OLV) are used to facilitate surgery on the lungs, thoracic aorta, thoracic spine, oesophagus and during minimally invasive cardiac surgery. Lung isolation and OLV are also used for managing air leak into the pleural space (e.g. bronchopleural fistula) and to prevent contamination of healthy lung by blood or infected material. Lung isolation can be achieved with a double-lumen tracheal tube (DLT), bronchial blocker (BB), or—in an emergency—by advancing a single-lumen tracheal tube into a main bronchus.

In this article, we focus on strategies for lung isolation during thoracic surgery. We provide step-by-step guides for inserting DLTs and BBs and describe how to manage common problems. Hypoxaemia during OLV is covered in a separate article in *BJA Education*.[1]

Anatomical considerations

The adult trachea is 10–12 cm long and bifurcates at the carina into the left (LMB) and right (RMB) main bronchi. Anteriorly, the trachea is supported by cartilaginous semicircular rings and posteriorly by the trachealis muscle. At the carina, the RMB more closely follows the trajectory of the trachea than the LMB, which arises at a steeper angle to the midline.

The LMB is narrower and longer than the RMB. The average length of the LMB is 5.3 cm compared with 2.7 cm for the RMB.[2] Given the short length of the RMB, care must be taken to prevent the right upper lobe from being inadvertently occluded by the cuff of the bronchial lumen of a right-sided DLT or BB. For this reason, a left-sided DLT is generally preferred over a right-sided DLT. At bronchoscopy, the carina can be distinguished from more distal lobar branches by

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visualising the right upper lobe bronchus, which trifurcates, resembling a clover leaf (Fig. 1).

Double-lumen tubes compared with bronchial blockers

Double-lumen tubes are the default choice for lung isolation for most patients, as they are quicker to insert, are less prone to displacement and can accommodate the deflation and suctioning of secretions from either lung. A BB may be used when difficulty inserting a DLT is anticipated. Other indications for a BB include a small glottis (e.g. children, radiotherapy to the airway) and tracheal abnormalities (e.g. tracheal bronchus, distortion by a tumour). BBs typically take longer to insert and are more prone to displacement than DLTs. Both techniques allow CPAP to be applied to the operative lung, which may be necessary in patients with severe hypoxaemia.

Table 1 lists the pros and cons of DLTs and BBs.

Double-lumen tubes

Modern DLTs are single use, made of polyvinylchloride and are based on the Robertshaw design. DLTs have a white or clear tracheal lumen and a blue bronchial lumen (Fig. 2). When correctly positioned, the tracheal lumen terminates in the distal trachea and the bronchial lumen terminates in the distal main bronchus. When initiating OLV, the connector to the operative lung is clamped and the lumen opened to air, allowing ventilation of the non-operative lung and deflation of the operative lung. DLT sizes are sized using the French (Fr) gauge system, where 1 Fr=1/3 mm of the outer diameter. Thus, a 37 Fr DLT has an outer diameter of 1/3×37=12.3 mm.

Various novel DLTs have been developed. The VivaSight 2 DLT (Ambu A/S, Ballerup, Denmark) is a single-use DLT with a camera embedded at the end of the tracheal lumen. The camera provides confirmation of the tube position throughout surgery, potentially obviating the need for flexible bronchoscopy. However, the VivaSight 2 is only available in left-sided configurations (sizes 35–41 Fr) and has a larger outer diameter relative to

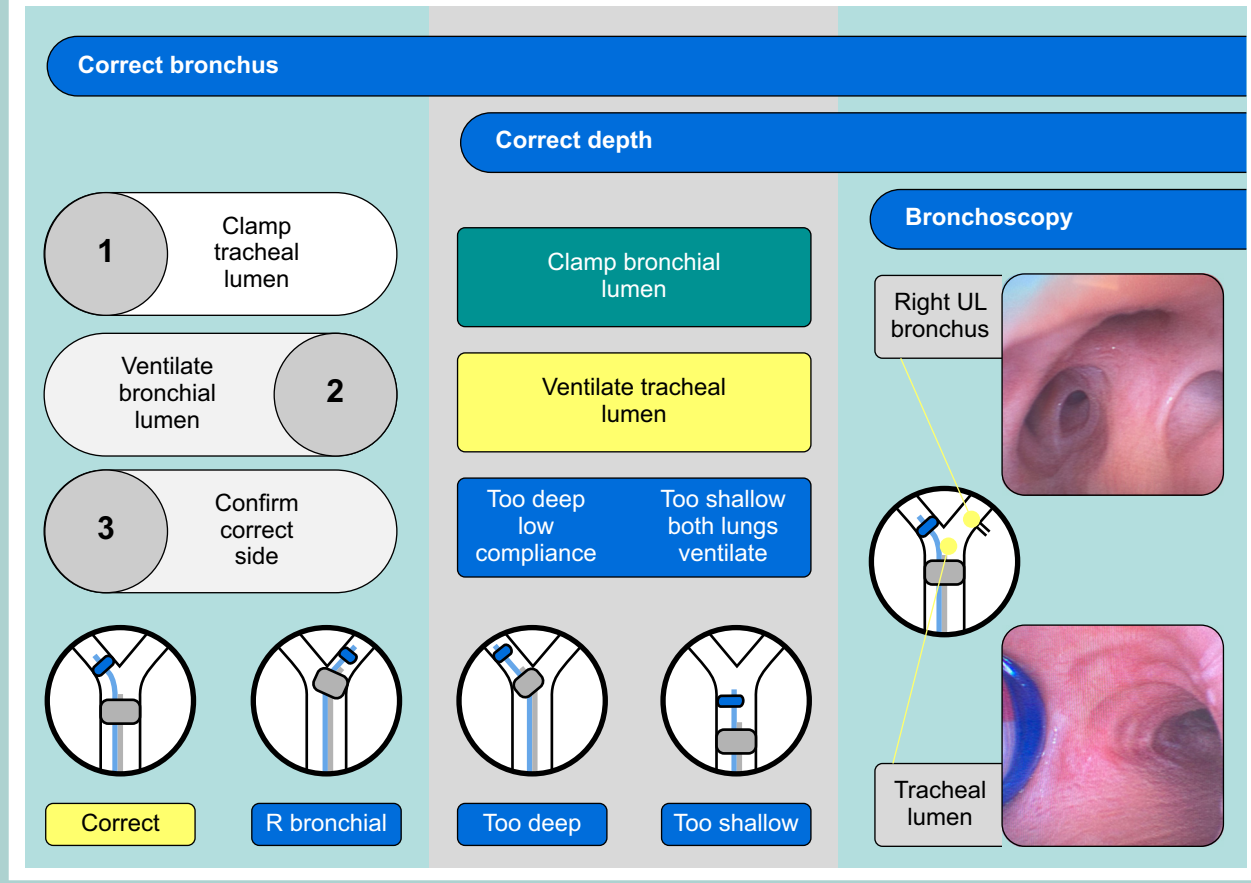


Fig 1 Sequence of clinical check of correct placement of a left-sided double-lumen tube (DLT). Correct bronchus: clamp the tracheal lumen and ventilate through the bronchial lumen. The left lung should ventilate. If the right lung ventilates, the DLT has advanced into the right main bronchus. Correct depth: clamp the bronchial lumen and ventilate through the tracheal lumen. The right lung should ventilate independently and easily. If ventilation of the right lung is met with increased airway resistance, the tube may have advanced too far, such that the orifice of the tracheal lumen is obstructed by the wall of the left main bronchus. If both lungs ventilate, the tube has most likely not been advanced far enough into the left main bronchus. A leak suggests that the tube is not correctly positioned or that the cuffs are not sufficiently inflated. Bronchoscopy: advance the bronchoscope to the tip of the tracheal lumen. The carina should be seen in the centre of the screen and the trachealis muscle identified posteriorly, at the bottom of the screen. The left main bronchus should be seen on the left of the screen with a rim of (blue) bronchial cuff visible. The right main bronchus should be seen on the right of the screen. Advance the bronchoscope into the right main bronchus. The origin of the right upper lobe bronchus should come into view on the top right of the screen. Advance the bronchoscope into the right upper lobe bronchus to identify the three sub-segmental bronchi. UL, upper lobe.

Table 1 Advantages and disadvantages of double-lumen tubes and bronchial blockers. FOB, fibreoptic bronchoscope.

	Advantages	Disadvantages
Double-lumen tube	• Quicker to place • Can alternate ventilation to either lung • Fibreoptic bronchoscope not essential	• Limited sizes available • Difficult to place correctly when anatomy is distorted or abnormal • Not ideal if postoperative ventilation needed • Higher risk of causing airway trauma
Bronchial blocker	• Easy size selection • Can be used with a standard tracheal tube, useful in patients already intubated or with tracheostomy • Used with a single-lumen tube which is easier to insert in cases of difficult intubation • Selective lobar isolation possible • Can be easily withdrawn if postoperative ventilation required	• Takes longer to insert • FOB essential • Suction of isolated lung not as effective • Bronchoscopy of isolated lung not easy • Difficult to alternate side of OLV (e.g. for thoracic sympathectomy) (possible with a Rusch EZ-Bifid blocker) • More prone to displacement intraoperatively

the Mallinckrodt (Medtronic, Minneapolis, MN, USA) equivalent on which it is based.[3] The Silbroncho DLT (Fuji Systems, Tokyo, Japan) is a silicone DLT available in sizes 33–39 Fr in both left and right configurations. A unique feature of the Silbroncho DLT is a flexible wire-reinforced bronchial lumen, which can conform with an acutely angulated bronchus.

Bronchial blockers

Bronchial blockers are used in combination with a standard single-lumen tracheal tube. All BBs rely on fibreoptic bronchoscopy to visualise placement of a balloon tipped catheter into the appropriate bronchus. A 9 Fr blocker is suitable for most adults. We recommend using at least a size 8.0 tracheal tube to accommodate both the blocker and bronchoscope.

Numerous different designs of BBs are available and operator familiarity is of greater importance than which device is used. The Arndt blocker (Cook Medical, Bloomington, IN, USA) has a wire loop at its tip allowing it to be coupled to the bronchoscope, which can then be used to direct the blocker into position (Figs. 2, Fig. 3 online video). The Cohen blocker (Cook Medical) has a wheel at the proximal end, allowing the operator to control the degree of catheter tip deflection and thereby direct it into position. The Rusch EZ-Blocker (Teleflex, Morrisville, NC, USA) has a Y-shaped tip that sits on the carina, with both arms having a distal balloon, thereby allowing the operator to selectively ventilate either lung without having to reposition the blocker. Bronchial blockers can be used with a Vivasight-SL single-lumen tube, which has a camera at the tip.

Step-by-step guides for inserting double-lumen tubes and bronchial blockers

Double-lumen tubes (Figs 1 and 2 online videos)

(i) Select the largest DLT that fits the bronchus: 41 Fr for most males, 39 Fr for small stature males; 37 Fr for most females, 35 Fr for small stature females. Fully deflate both cuffs before insertion. Lubricate the outside of the tube to reduce the risk of damage during insertion. Lubricate the bronchoscope with aqueous gel to aid its smooth passage through the tube.

(ii) With the stylet in place, bend the distal 10 cm of the DLT 60° anteriorly. This manoeuvre aids tracheal intubation and minimises the risk of rupturing the tracheal cuff as it passes over the patient's teeth.

(iii) With the tip directed anteriorly, advance the tip of the tube just through the vocal cords. Remove the stylet.

(iv) Turn the DLT sufficiently to rotate the tip to 90° from the midline to help advance the tube past the thyroid cartilage. For a left-sided DLT, rotate anticlockwise; for a right-sided DLT rotate clockwise. In some circumstances, rotation through 180° may be required to pass the thyroid cartilage.

(v) If a 180° rotation was needed at Step (iv), rotate the DLT 90° in the opposite direction so that the bronchial lumen aligns with the appropriate bronchus. Advance the tube until snug. The average depth of insertion in a 170 cm adult is 29 cm, plus or minus 1 cm for each 10 cm increase or decrease in height.[4] When advancing the tube, turning the patient's head in the opposite direction to the bronchus being intubated helps the tube advance into the correct bronchus.

(vi) Perform clinical and bronchoscopic checks (Fig. 1) to confirm the DLT is correctly positioned and lung isolation has been successful. Inflate both cuffs. Consider measuring the cuff pressure (normal pressure 20–40 cm H_2O, avoid pressure >40 cm H_2O).

(vii) To deflate the operative lung, clamp the soft silicone connector between the breathing system and the DLT on the operative lumen and release the bung on the connector.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.bjae.2023.07.001

Bronchial blocker insertion (Arndt, Cook Medical; Fig 3 online video)

(i) Assemble and check the multiport airway adapter. Lubricate and place the bronchoscope and blocker into their respective ports (Fig. 2). The blocker hub has a tightening screw—leave this loose at this point.

(ii) Intubate the patient's trachea and confirm ventilation of the lungs. Use the bronchoscope to position the tip of the tube 1 cm from the carina and identify the right and left main bronchi.

(iii) Manually thread the bronchoscope tip through the loop of the blocker (Fig. 2). Connect the multiport airway adapter

to the tracheal tube. Connect the breathing system to the side port. Tighten the blocker hub to prevent air leak.

(iv) Advance the bronchoscope to the carina, identifying the trachealis muscle posteriorly. Verbally confirm the side you intend to block and advance the bronchoscope down the chosen bronchus.

(v) Untighten the hub and advance the blocker down the trachea and into the bronchus. Withdraw the bronchoscope to the carina to visualise both bronchi and confirm the position of the blocker within the chosen bronchus. Note the depth on the blocker and secure the mount and blocker hub.

(vi) To deflate the lung, disconnect the breathing system in expiration and inflate the BB cuff under bronchoscopic view (6–12 ml of air). Confirm the inflated cuff is correctly positioned in the proximal bronchus. If not inserted sufficiently far into the bronchus, inflating the cuff can cause the cuff to herniate into the trachea. Reconnect the breathing system and withdraw the inner wire of the blocker. If the blocker has been repositioned from Step (v), note the new depth.

The correct position of the blocker must be confirmed with bronchoscopy whenever the patient is repositioned.

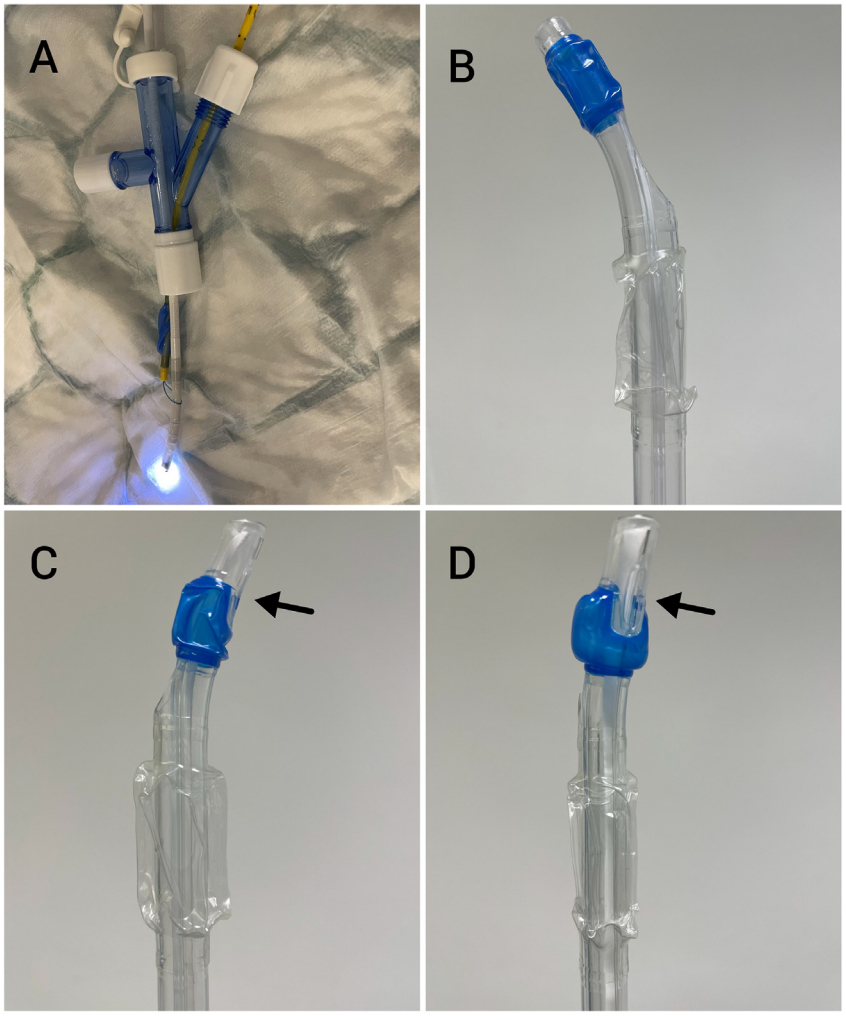


Fig 2 Double-lumen tubes and bronchial blockers. Panel A shows the Arndt bronchial blocker coupled to a flexible bronchoscope with a wire loop through the multiport airway adapter. The two ports seen at the top of the frame are for the bronchoscope and the blocker. The port for the blocker has a screw cap, allowing the blocker to be secured in position. The port at the bottom of the frame connects the adapter to a single-lumen tracheal tube. The port on the left of the frame connects the adapter to a breathing circuit. Notice that the wire loop on the blocker has been placed over the tip of the bronchoscope, allowing the blocker to be advanced into the appropriate bronchus. Panel B shows a left-sided double-lumen tube (Shiley, Medtronic Ltd). The tracheal cuff is clear and the bronchial cuff is blue. Both cuffs are deflated. The orifice of the bronchial lumen is seen beyond the bronchial cuff. The orifice of the tracheal lumen can be seen between the two cuffs. Panel C shows a right-sided double-lumen tube with both cuffs deflated. The orifice of the tracheal lumen can be seen between the two cuffs, on the right. The main orifice of the bronchial lumen can be seen distal to the bronchial (blue) cuff. An arrow indicates the second orifice of the bronchial lumen for ventilating the right upper lobe. Panel D shows a right-sided double-lumen tube with the bronchial cuff inflated. An arrow indicates the second orifice of the bronchial lumen for ventilating the right upper lobe.

Table 2 Clinical signs and management strategies of malposition of a left-sided double-lumen tube (DLT). When repositioning a DLT, both cuffs should be deflated. OLV, one lung ventilation. LMB, left main bronchus.

Type of malposition	Clinical features	Management
Incorrect side The bronchial lumen is positioned in the right-main bronchus instead of the left.	• OLV of the bronchial lumen results in ventilation of the right lung • OLV of the tracheal lumen results in ventilation of the left lung.	• With the bronchoscope down the bronchial lumen, withdraw the DLT until the carina comes into view. Then, advance the tip of the bronchial lumen down the LMB. • With the bronchoscope down the tracheal lumen, check the DLT is correctly positioned by visualising the carina and the orifice of the right upper lobe bronchus.
Correct bronchus but tip too shallow (see Table 3, top two panels) The tip of the bronchial lumen is in the LMB but the bronchial cuff lies partly or entirely within the trachea.	• OLV of the bronchial lumen results in incomplete or failed lung isolation. There may be an air leak from the tracheal lumen. • OLV of the tracheal lumen results in incomplete or failed lung isolation. If the bronchial lumen obstructs the distal trachea, it may be difficult or impossible to ventilate the right lung.	• With the bronchoscope down the tracheal lumen, the tracheal wall is visible through the orifice of the tracheal lumen. The orifice of the tracheal lumen is not typically obstructed. • With the bronchoscope down the bronchial lumen, advance the DLT further into the LMB. • Repeat bronchoscopy down the tracheal lumen confirming the tube is correctly positioned and the bronchial cuff lies completely within the LMB.
Correct bronchus but tip too deep The tip of the bronchial lumen is advanced too far into the LMB. The orifice of the tracheal lumen lies partly or completely within the bronchus and is obstructed.	• Ventilating the bronchial lumen ventilates the left lung but ventilation to the left upper lobe may be poor or non-existent. Airway pressure may be high, and the patient may become hypoxaemic. • Ventilating the tracheal lumen results in obstruction with high airway pressure and the rapid development of hypoxaemia.	• With the bronchoscope down the tracheal lumen the wall of the LMB is visible. The orifice of the tracheal lumen is typically obstructed. • With the bronchoscope down the tracheal lumen, withdraw the DLT until the carina and the right upper lobe bronchus comes into view.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.bjae.2023.07.001

Predicting difficult lung isolation and one-lung ventilation

Before surgery it is important to identify patients who are likely to be difficult to intubate, difficult to achieve lung isolation, or at risk of hypoxemia during OLV. Predictors of hypoxaemia during OLV are discussed in a related article.[1] The only comment we make here is that hypoxaemia can occur in any patient during OLV, including patients with normal pulmonary function. Difficulties with tracheal intubation or lung isolation may be related to the surgery or abnormalities involving the upper or lower airways.

Upper airway

Assessing the difficult airway has been previously reviewed in *BJA Education*.[5] Previous surgery or radiotherapy involving the head and neck is not uncommon in patients requiring lung resection and predicts difficult tracheal intubation. In a large lung cancer screening cohort, 12% of patients with previous head and neck cancer subsequently developed lung cancer, of whom 5% required pulmonary resection.[6]

Lower airways

The preoperative chest CT scan should be reviewed to delineate the tracheobronchial anatomy. Factors to consider include:

(i) Distortion of the trachea or bronchi from external compression.
(ii) Obstruction of the trachea or bronchi from direct tumour invasion.
(iii) The effects of previous thoracic surgery.
(iv) The presence of a tracheal bronchus (see below).
(v) The presence of a tracheostomy.

A small DLT or a single-lumen tube with a BB may be needed if there is compression of a bronchus. A DLT may be difficult to advance past an obstruction, particularly when the obstruction is within the airway.[7] With previous lung resection, the remaining lung parenchyma expands to fill the space, potentially distorting the bronchus on the affected side.

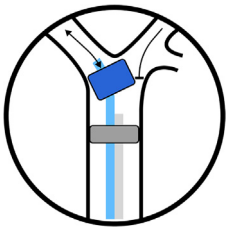
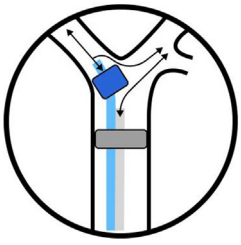
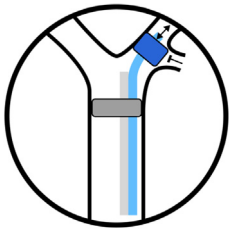
A tracheal bronchus is defined as an abnormal bronchus arising anywhere from the cricoid cartilage to the carina. Tracheal bronchus occurs in up to 2% of the population and is more common on the right than the left side.[2] A DLT can be used in the presence of a tracheal bronchus but care must be taken to ensure the orifice of the tracheal bronchus is not obstructed by the tracheal cuff of the DLT. Alternatively, two BBs can be used, with one inserted into the main bronchus and one into the tracheal bronchus.

Surgical considerations

As noted above, most surgery requiring lung isolation can be performed with a left-sided DLT. Indications for a right sided DLT include:

(i) Surgery involving the LMB (e.g. left pneumonectomy, left lung transplant, repair of left-sided tracheobronchial disruption).
(ii) Proximal obstruction of the LMB.

Table 3 Mechanism and management of double-lumen tube (DLT) malposition. Single headed arrow indicates two-way ventilation and a T-shaped arrow indicates one-way ventilation or gas trapping. OLV, one lung ventilation. LMB, left main bronchus.

Clinical problem after initiating OLV	Likely position	Mechanism	Management
Left-sided DLT with OLV of the left lung (surgery on right lung)			
The right lung does not deflate but not actively ventilating.		• The tip of the DLT is not deep enough in the left main bronchus but the left lung remains isolated from the right lung. • The position of the bronchial cuff prevents deflation of the right lung.	• Deflate both cuffs. • With the bronchoscope down the bronchial lumen, advance the DLT further into the LMB. • Repeat bronchoscopy but this time down the tracheal lumen confirming the tube is correctly positioned and the bronchial cuff lies completely within the LMB.
The right lung remains inflated and is ventilating.		• The DLT is not deep enough in the bronchus and the left lung is not isolated from the right lung. • Gas ventilating the left lung passes to the right lung causing continued ventilation of the right lung. • A leak occurs due to loss of gas via the tracheal lumen.	• Deflate both cuffs. • With the bronchoscope down the bronchial lumen, advance the DLT further into the LMB. • Repeat bronchoscopy but this time down the tracheal lumen confirming the tube is correctly positioned and the bronchial cuff lies completely within the LMB.
Right-sided DLT with OLV of the right lung (surgery on the left lung)			
Right upper lobe is not ventilating.		• The bronchial cuff of the right-sided DLT obstructs the orifice of the right upper lobe bronchus.	• Deflate both cuffs. • With the bronchoscope down the bronchial lumen, advance the bronchoscope until the Murphy eye of the bronchial lumen comes into view. • Look through the Murphy eye. • Adjust the position of the DLT until the Murphy eye is aligned with the orifice of the right upper lobe bronchus. The DLT may need advancing or withdrawing or turning left or right.

(iii) Severe distortion of the LMB (e.g. thoracic aortic aneurysm, enlarged left atrium).

If neither a right-sided DLT nor BB can be successfully placed, one option is to use a left-sided DLT and withdraw the tube before transecting the LMB, ensuring that the tip of the bronchial lumen is entirely within the distal trachea. This option should be discussed with the surgeon before starting the procedure.

Robotic-assisted approaches to lung resection are increasingly common.[8] The position of the robot at the head end impedes access to the airway. If the airway device requires repositioning during the case, the robot may need to be undocked. A DLT is our preferred choice for lung isolation during robotic surgery because DLTs are less susceptible to displacement than BBs.

Troubleshooting and complications

Difficulty advancing the double-lumen tube into the trachea

Difficulty advancing the DLT past the thyroid cartilage is common. Rotating the tube on insertion (see above) helps. Repeated attempts at laryngeal intubation can cause rupture of the tracheal cuff. Cuff integrity must be checked with each attempt at intubation.

Avoiding malposition of a double-lumen tube

Bronchoscopic and clinical checks have distinct and essential roles in confirming DLT position. Bronchoscopic assessment identifies a third of malpositions not identified clinically and malposition predicts hypoxaemia during OLV.[9,10] However, only a clinical check identifies an air leak. Clinical and bronchoscopic checks are described in Fig. 1 and demonstrated in the accompanying online videos.

A common error is confusing the tracheal carina with more distal bifurcations. Various bronchoscopy simulators are available to support learning (e.g. portable trainer ORSIM, Airway Simulation Ltd, Auckland, New Zealand). It is important to use an appropriately sized bronchoscope. In an *ex vivo* study, DLTs sizes 35–41 Fr were able to accommodate a 4 mm (outer) diameter bronchoscope.[11] However, in our experience, *in situ* distortion means a smaller scope (e.g. aScope 4 Broncho 3.8 mm, Ambu A/S, Ballerup,

Denmark) more reliably allows unimpeded passage of the bronchoscope.

Diagnosing malposition of a double-lumen tube

Lung isolation is successful if each lung can be ventilated at appropriate volume (4–5 ml kg^{-1}) and pressure (<25–30 cmH_2O). Malposition results in some combination of (i) high airway pressure, (ii) failure to deflate or persistent ventilation of the operative lung), (iii) circuit leak, (iv) an abnormal capnograph and (v) impaired gas exchange. Common problems caused by malposition are summarised in Tables 2 and 3.

The commonest malposition is when the bronchial lumen has not passed sufficiently far into the bronchus. The clinical findings depend on the position of the tip of the bronchial lumen, the operative side and whether the bronchial cuff has been hyperinflated. Failure of lung isolation is a consistent feature.[7]

Advancing the tip of the DLT too far into the bronchus typically results in high airway pressure, an obstructed capnograph trace and evolving hypoxaemia (Tables 2 and 3). If the orifice of the tracheal lumen lies within a bronchus, the operative lung will not deflate.

When the DLT is too small for the patient there is a risk of advancing the tube too far into the bronchus during insertion. However, when correctly positioned, a small tube may require hyperinflation of the bronchial lumen to achieve lung isolation, which increases the risk the cuff will herniate into the trachea. The need for >3 ml air in the bronchial cuff suggests cuff herniation (Table 3). Solving this problem may require reintubating the patient with a larger DLT.

When the DLT appears to be correctly positioned (Fig. 1) but there is persistent ventilation or non-deflation of the operative lung, the likely causes include:

(i) Insufficient air in the bronchial cuff allowing ventilating gas to leak into the operative side.
(ii) Ventilation of the bronchial lumen at high pressure, such that gas bypasses the bronchial cuff. Reducing the ventilatory pressure or adding more air to the bronchial cuff mitigates this problem.
(iii) Secretions and blood in the airway. Suctioning secretions along with gentle surgical manipulation may facilitate deflation of the operative lung.

Airway trauma

Airway trauma resulting from a DLT is usually minor, involving hoarseness or sore throat. Severe airway trauma, such as arytenoid dislocation, vocal cord tears and airway rupture, are rare. Bronchial blockers may cause less hoarseness than DLTs.[12] Difficulty positioning the DLT, advancing the tube too distally, repetitive forceful movements and tube exchange increase the risk of severe airway injury. Overinflating the tracheal and bronchial cuffs transmits high pressure to the mucosa, causing mucosal erosion and inflammation that, potentially, can lead to scar formation and airway stenosis. Double-lumen tube cuffs should be deflated whenever the tube is repositioned.[13,14]

Airway trauma can be minimised by limiting the number of intubation attempts and by directly visualising the trachea with a bronchoscope as the DLT is advanced after laryngeal intubation.[15] In patients of small stature (<150 cm), a smaller size DLT (e.g. 32 or 28 Fr) or single-lumen tube and BB should be considered.[16]

The anticipated difficult airway

The principles of difficult airway management are the same as for any patient undergoing intubation of their trachea, as outlined in the 2022 American Society of Anesthesiologists guidelines.[17] Videolaryngoscopy under general anaesthesia is a reasonable option for most patients with anticipated difficult tracheal intubation. Awake tracheal intubation is a prudent option when difficulty with facemask ventilation is anticipated.[18]

Videolaryngoscopy

The successful passage of the DLT through the glottis to the trachea and into the correct bronchus is correlated with the glottic view at videolaryngoscopy.[19] However, there is no evidence that first-pass success is higher with a videolaryngoscope compared with direct laryngoscopy when placing a DLT, nor is there evidence for an advantage in terms of correct endobronchial placement.[20,21]

Given that DLTs are bulky, our approach for videolaryngoscopy is to use a low-profile device, such as the GlideScope Spectrum (Verathon, Bothell, WA, USA). When using a hyperangulated blade, the DLT must be bent more than is usual to conform to the shape of the blade.

Awake tracheal intubation

Our approach for awake tracheal intubation is to first place a single-lumen tracheal tube using a recommended technique.[18] Once a single-lumen tube is in place, there are two options for lung isolation. The safest—and our preferred method—is to use a BB. Alternatively, a DLT can be placed using an exchange catheter. The exchange catheter should be long enough to accommodate the DLT and have a diameter that is small enough to fit down the bronchial lumen of the DLT. The 11 Fr 100 cm Cook Airway Exchange Catheter (Cook Medical) is suitable for 35 Fr and larger DLTs. Exchange over an intubating bougie is not recommended, as shearing and disintegration of the bougie has been reported.[22] The bronchoscopy-guided Aintree exchange catheter (Cook Medical) cannot be used for tube exchange, as the catheter diameter is too large to pass through a DLT.

If possible, tube exchange should be done while directly visualising the patient's glottis with a videolaryngoscope. The patient should be thoroughly preoxygenated using an F_{IO_2} of 1.0. There is an appreciable risk of losing control of the patient's airway during the procedure. In one study, a failure rate of 40% (43 of 110 attempts) occurred when a single-lumen tube was exchanged for a DLT.[23] Thus, if facemask ventilation is likely to be difficult or impossible, a BB for lung isolation is the safest option.

Awake tracheal intubation with a DLT is another possibility, but the large size of the tube limits patient acceptability.[24] For patients with limited mouth opening, awake tracheostomy before thoracic surgery may be the only safe option.

Special circumstances

Changing from a double- to a single-lumen tracheal tube

Postoperative ventilation is occasionally required and necessitates changing the DLT to a single-lumen tracheal tube. Factors to consider before changing the tube are the patient's

laryngoscopy grade, anticipated airway oedema and physiological stability. Tube exchange should be preceded by preoxygenation and accompanied by either direct laryngoscopy or videolaryngoscopy. Tube exchange should be done using an airway exchange catheter (e.g. the aforementioned 11 Fr Cook Airway Exchange catheter). Exchanging a DLT for a single-lumen tube has a lower risk of losing control of the patient's airway than when exchanging a single-lumen tube for a DLT.[23]

Tracheostomy

Campos and colleagues have written a comprehensive discussion of lung isolation techniques in patients with a tracheostomy.[25] A patient without an upper airway after laryngectomy requires all airway and lung isolation devices to be placed via the tracheostomy stoma. Our practice for bag-mask ventilation is to use a supraglottic airway over the stoma. In most patients the distance from the stoma to the carina is too short to accommodate a standard DLT, in which case a single-lumen tube and a BB is the best option for lung isolation.

Patients with a temporary tracheostomy—inserted as a component of their ICU management—may not have a well-formed stoma. Removing the tracheostomy may lead to loss of control of the patient's airway. Options in this circumstance are to (i) place a BB through the tracheostomy or (ii) place a DLT via the orotracheal route.[26]

Conclusions

Careful preoperative assessment helps identify patient and surgical factors that complicate lung isolation. Familiarity with at least one type of DLT and one type of BB is required for managing the range of clinical scenarios encountered in thoracic anaesthesia. When lung isolation is difficult, a systematic approach to problem solving is essential. Experience with bronchoscopy of the proximal bronchial anatomy is necessary for managing problems.

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Declaration of interests

The authors declare that they have no conflicts of interest.

Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bjae.2023.07.001.

MCQs

The associated MCQs (to support CME/CPD activity) will be accessible at www.bjaed.org/cme/home by subscribers to *BJA Education*.

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