Lung Isolation in Anesthesia

Peter Slinger, MD, FRCPC

George Kanellakos, MD, FRCPC

Lung isolation has evolved from being a surgical expedient for open thoracotomy to being a surgical necessity for minimally invasive thoracoscopic lung, cardiac, and esophageal procedures. Thus, the ability of the anesthesiologist to provide reliable lung isolation in patients with normal and abnormal upper and lower airways has become a major concern in cardiothoracic anesthesia. This review will outline the current problems which anesthesiologists face providing this service and discuss a variety of potential solutions.

METHODS OF LUNG ISOLATION

There are three basic techniques for lung isolation which have persisted for the past 50 yr: single-lumen endobronchial tubes, bronchial blockers, and double-lumen tubes. Single-lumen endobronchial tubes have infrequent indications in adult surgery, usually for carinal resections or following a previous pneumonectomy. They are still useful in the younger pediatric population. The majority of lung isolation in adults and older children is performed with double-lumen tubes (DLTs) or bronchial blockers (BBs).

The original DLT of Bjork and Carlens (1) has evolved to a tube specifically designed for intraoperative use [as shown by Robertshaw, (2)] with larger, D-shaped, lumens and without a carinal hook. Current disposable polyvinyl-chloride DLTs have incorporated high-volume low-pressure tracheal and bronchial cuffs. Recent DLT refinements have two major drawbacks: 1) These tubes now require fiberoptic bronchoscopy (FOB) for positioning (3) (also see "Bronchoscopic Positioning of Double-lumen Tubes and Blockers" at www.thoracicanesthesia.com) and 2) A satisfactory right-sided DLT has not yet been designed, to deal with the short (average 2 cm) and variable length of the right mainstem bronchus (4). Recently, there has been a revival of interest in BBs because of design advances such as the Univent tube (5), WEB (Arndt) blocker (6), and Cohen blocker (7), also, because of the expanding indications for one-lung anesthesia (8). As one-lung anesthesia is more widely used, the need for lung isolation in patients with difficult airways arises more frequently. Advantages and disadvantages of the various methods for lung isolation are listed in Table 1.

Initial malpositioning of DLTs with blind placement can occur in over 30% (9) of cases. Verification and adjustment with FOB immediately before initiating one-lung ventilation (OLV) is mandatory because these tubes will migrate during patient repositioning (10). Patients are usually intubated with their head and cervical spine in the "sniffing" position. Then after turning the patient to the side, the head is stabilized in the neutral position. This movement is responsible for much of the change in position of the DLT. It is important to confirm the DLT position with the head in a neutral position. DLTs that migrate significantly during patient repositioning are more likely to become malpositioned later in the case (11). Malpositioning after the start of OLV because of dislodgment is more of a problem with bronchial blockers than DLTs.

The anesthesiologist must be comfortable with all three methods of lung-isolation to provide adequate lung separation in the wide variety of patients and clinical situations for which lung separation is now indicated. The **ABC**'s of lung isolation are: know the tracheobronchial **A**natomy, use the fiberoptic **B**ronchoscope, look at the **C**hest imaging (radiograph, CT scan, and MRI).

INDICATIONS FOR LUNG SEPARATION

Because it is impossible to describe one technique as best in all indications for one-lung ventilation (OLV), the various indications will be considered separately.

Elective Pulmonary Resection, Right-Sided

This is the commonest adult indication for OLV. The first choice is a left-DLT. There is a wide margin of safety in positioning left-DLTs. With blind positioning, the incidence of malposition can exceed 20% but is correctable in virtually all cases by fiberoptic adjustment (12). A partial resection can proceed to a pneumonectomy, if required, without loss of lung isolation. There is continuous access to the nonventilated lung for suctioning, fiberoptic monitoring of position, and continuous positive airway pressure (CPAP). Possible alternatives are: (a) Univent tube or BB. The BB can be placed external to or intraluminally with an endotracheal tube (ETT) (13). Lung collapse is frequently unsatisfactory with a BB for a right thoracotomy. A

Table 1. Options for Lung Isolation

Options	Advantages	Disadvantages
Double lumen tube: Direct laryngoscopy; Via tube exchanger; Fiberoptically	Quickest to place successfully; repositioning rarely required; bronchoscopy to isolated lung; suction to isolated lung; CPAP easily added; can alternate OLV to either lung easily; placement still possible if bronchoscopy not available	Size selection more difficult; difficult to place in patients with difficult airways or abnormal tracheas; not optimal for post-operative ventilation; potential laryngeal trauma; potential bronchial trauma
Bronchial blockers (BB): Arndt; Cohen; Fuji; Fogarty catheter	Size selection rarely an issue; easily added to regular ETT; allows ventilation during placement; easier placement in patients with difficult airways and in children; postoperative two lung ventilation by withdrawing blocker; selective lobar lung isolation possible; CPAP to isolated lung possible	More time needed for positioning; repositioning needed more often; bronchoscope essential for positioning; nonoptimal right lung isolation due to RUL anatomy; bronchoscopy to isolated lung impossible; minimal suction to isolated lung; difficult to alternate OLV to either lung
Univent	Same as bronchial blockers; less repositioning compared to BBs	Same as bronchial blockers; ETT portion has higher air flow resistance than regular ETT; ETT portion has larger diameter than regular ETT
Endobronchial tube	Like regular ETTs, easier placement in patients with difficult airways; longer than regular ETT; short cuff designed for lung isolation	Bronchoscopy necessary for placement; does not allow for bronchoscopy, suctioning, or CPAP to isolated lung; difficult right lung OLV
Endotracheal tube advanced into bronchus	Easier placement in patients with difficult airways	Does not allow for bronchoscopy, suctioning, or CPAP to isolated lung; cuff not designed for lung isolation; extremely difficult right OLV

method of using two right-sided BBs (one in the right upper lobe and one in the bronchus intermedius) has been described to deal with this problem (14). (b) Single-lumen EBT. A standard 7.5 mm, 32 cm length ETT can be advanced over a fiberoptic bronchoscope (FOB) into the left mainstem bronchus.

Elective Pulmonary Resection, Left-Sided

Not Pneumonectomy

There is no obvious best choice, between a BB and a left-DLT. The use of a left-DLT for a left thoracotomy is occasionally associated with obstruction of the tracheal lumen by the lateral tracheal wall and subsequent problems with gas exchange in the ventilated lung (V-lung). A right-DLT is an alternate choice, problems with lung isolation and/or positioning with routine FOB placement occur much less frequently than previously thought (15).

Left Pneumonectomy

There is no completely satisfactory choice. Any left pulmonary resection may unforeseeably become a pneumonectomy. When a pneumonectomy is foreseen, a right-DLT is the best choice. A right-DLT will permit the surgeon to palpate the left hilum during OLV without interference from a tube or blocker in the left mainstem bronchus. The disposable right-DLTs currently available in North America vary greatly in design depending on the manufacturer (Mallinckrodt, Rusch, Kendall). All three designs include a ventilating side-slot in the distal bronchial lumen for right upper lobe ventilation. Positioning this slot can be time consuming. These tubes require relatively high bronchial intra-cuff pressures (40–50 cm H_2O vs 20–30 cm H_2O for left-DLTs). However, this is lower than the range of pressures required by a Univent or nondisposable DLTs. Rarely, left lung isolation is impossible in spite of extremely high pressures in the right-DLT bronchial cuff. In these cases, a BB can be passed through the tracheal lumen into the left main bronchus after estimation of depth with a FOB. As an alternative technique, there is no clear preference among a Univent, left-DLT, or other bronchial blocker. These will all require repositioning intraoperatively, but this usually is not a major problem.

Thoracoscopy

Minimally invasive intrathoracic procedures are rapidly becoming the primary indication for lung isolation. Lung biopsies, wedge resection, bleb/bullae resections, and lobectomies can be done using this technique. Video-assisted thoracoscopic surgery (VATS) under general anesthesia requires OLV. During open thoracotomy, the lung can be compressed by the surgeon to facilitate collapse before inflation of a bronchial blocker. This is not possible during thoracoscopy. The operative lung deflates more easily when the nonventilated lung lumen of a DLT is opened to atmosphere than via the 1–2 mm

Table 2. Tracheal and Bronchial Diameters and Recommended Double-lumen Tube Sizes

Tracheal width (mm)	Bronchial diameter (mm)	Size DLT (F)
>18	>12	41
>16	12	39
>15	11	37
>14	10	35
>12	<10	32

Table 3. Comparative Diameters of Single and Double-lumen Tubes

Single lumen tubes		Double lumen tubes		
Internal diameter (mm)	External diameter (mm)	French size (F)	External diameter (mm)	Bronch lumen inner diameter (mm)
6.5	8.9	26	8.7	3.2
7.0	9.5	28	9.3	3.4
8.0	10.8	32	10.7	3.5
8.5	11.4	35	11.7	4.3
9.0	12.1	37	12.3	4.5
9.5	12.8	39	13.0	4.9
10.0	13.5	41	13.7	5.4

suction channel of a Univent tube or BB. A left-DLT is preferred for thoracoscopy of either hemi-thorax.

Pulmonary Hemorrhage

Instances of life-threatening pulmonary hemorrhage can occur due to a wide variety of causes (aspergillosis, tuberculosis, PA catheter trauma, etc.). The anesthesiologist is often called to deal with these cases outside the operating suite. The primary risk for these patients is asphyxiation, and first line treatment is lung isolation. There are several problems associated with using any sort of bronchial blocker in the acute situation: (a) It is often not known which side to occlude. (b) Visualization below the vocal cords to aid placement is difficult. (c) After the blocker is placed there is no access to the involved lung to monitor bleeding. A left-DLT avoids these problems. Tracheobronchial hemorrhage from blunt chest trauma will usually resolve with suctioning, only rarely is lung isolation necessary (16). PA catheter-induced hemorrhage during weaning from bypass should be dealt with by resumption of full bypass, bronchoscopy, and lung isolation. Weaning may then proceed without pulmonary resection in some cases (17). Definitive therapy for massive pulmonary hemorrhage now usually involves radiology and embolization or balloon occlusion (18).

Bronchopleural Fistula

The anesthesiologist is faced with the triple problem of avoiding tension pneumothorax, ensuring adequate ventilation, and protecting the healthy lung from the fluid collection in the involved hemithorax. Management depends on the site of the fistula and the urgency of the clinical situation. For a peripheral bronchopleural fistula in a stable patient, some form of BB or a Univent tube may be acceptable. For a large central fistula, and in urgent situations, the rapidest and most reliable method of securing lung isolation and ventilation is a DLT. In life-threatening situations, a DLT can be placed in the awake patient with direct FOB guidance.

Purulent Secretions

Purulent secretions include lung abscess, hydatid cysts, etc. Lobar or segmental blockade is the ideal. Loss of lung isolation in these cases is not merely a surgical inconvenience, but may be life threatening. Univent tubes or BBs can be used for lobar blockade. A secure technique in these cases is the combined use of a bronchial blocker and a DLT (19).

Nonpulmonary Thoracic Surgery

Thoracic aortic and esophageal surgery requires OLV. Because there is no risk of ventilated-lung contamination, a left-DLT or a BB are equivalent choices. BBs are particularly useful in patients having OLV for major vascular or cardiac surgery in the chest as there is no need to change the ETT for postoperative ventilation.

Bronchial Surgery

An intrabronchial tumor, bronchial trauma, or a bronchial sleeve-resection during a lobectomy require that the surgeon have intraluminal access to the ipsilateral mainstem bronchus. A DLT in the contralateral ventilated-lung is preferred. A single-lumen endobronchial tube advanced into the contra-lateral mainstem bronchus is an option.

Unilateral Lung Lavage, Independent Lung Ventilation, and Lung Transplantation

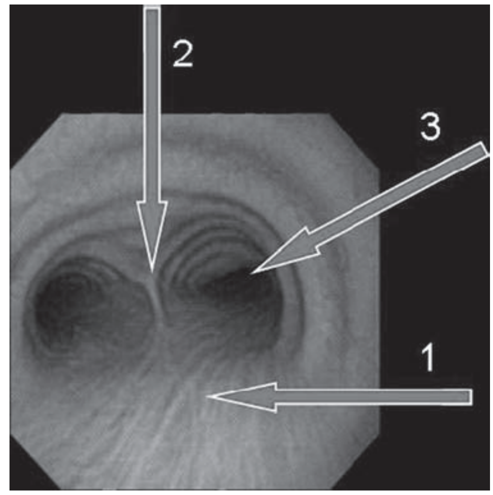
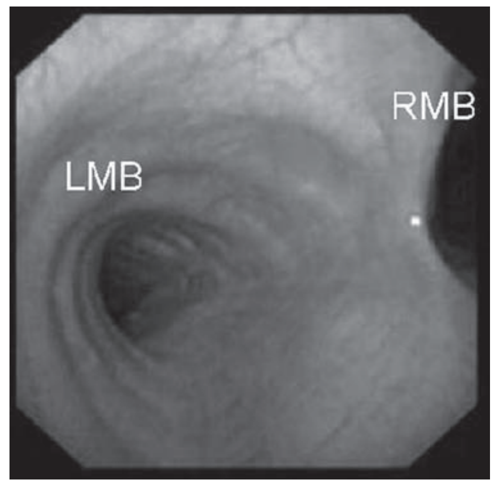
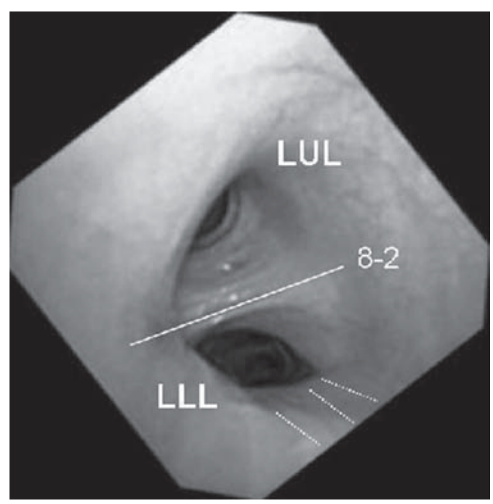
Unilateral lung lavage (20), independent lung ventilation, and lung transplantation are all best accomplished with a left-DLT.

Pediatrics

The increased use of thoracoscopy in children has caused an increase in the need to provide lung isolation in pediatric anesthesia. Pediatric-size Arndt BBs (5F) are useful in the patients of age range 4–12 yr. Younger patients can be managed by advancing an uncuffed single-lumen ETT with FOB guidance into a mainstem bronchus as needed for OLV. Older children can be managed with the smaller size (26–32F) DLTs.

Avoiding Airway Trauma. Iatrogenic injury has been estimated to occur in 0.5–2 per 1000 cases with DLTs (21). Common factors in many of these case reports are: small stature, female patient, esophageal surgery, and previous radiotherapy (22). Patients with any combination of these risk factors are at increased risk for tracheobronchial trauma from DLT.

Table 4. Bronchial Anatomy (Supine Patient)

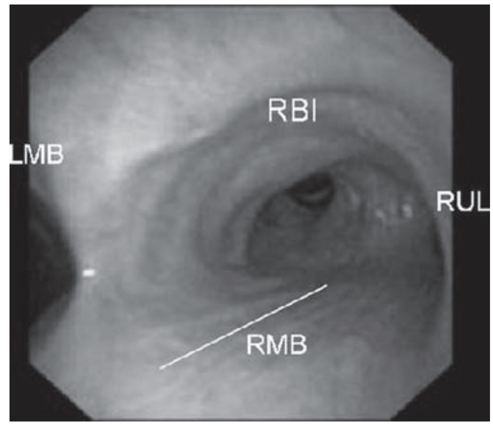
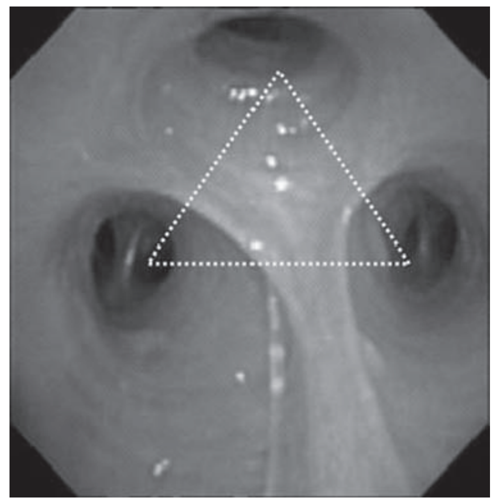
Anatomical structure	Fiberoptic view
Trachea and carina 1. Membranous trachea posteriorly, flat or bulging anteriorly 2. Carinal bifurcation is sharp (12–6 o'clock) 3. First generation bronchi are large and have no bifurcations in sight	
Left mainstem bronchus (LMB) Long, average length 5 cm Bifurcation of left upper and lower lobes not visible	
Left upper lobe (LUL) and left lower lobe (LLL) bronchi Longitudinal elastic bundles run posteriorly into lower lobe (dashed lines) LLL-LUL 2° carina angled 8–2 o'clock	

(1) The majority of difficult endobronchial tube placements can be predicted from viewing the chest radiograph (23) or CT scan (24) for evidence of abnormal anatomy. There is no substitute for the Anesthesiologist assessing the film him/herself before induction.

(2) Avoid nitrous oxide: Nitrous oxide 70% can increase the bronchial cuff volume from 5 to 16 mL intraoperatively (25).

(3) Inflate the bronchial cuff/blocker only to the minimal volume required for lung isolation and for the minimal time required. This volume is

Table 4. (continued)

Anatomical structure	Fiberoptic view
Right mainstem bronchus (RMB) Short, average length 2.5 cm (dashed line) Leads directly to right bronchus intermedius (RBI) Right upper lobe (RUL) bronchus visible at 3–4 o'clock	
Right upper lobe bronchus (RUL) Characteristic bronchial trifurcation. Anterior, posterior, and apical segments	

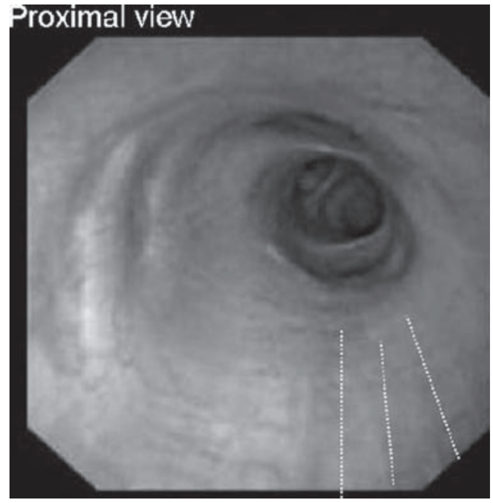
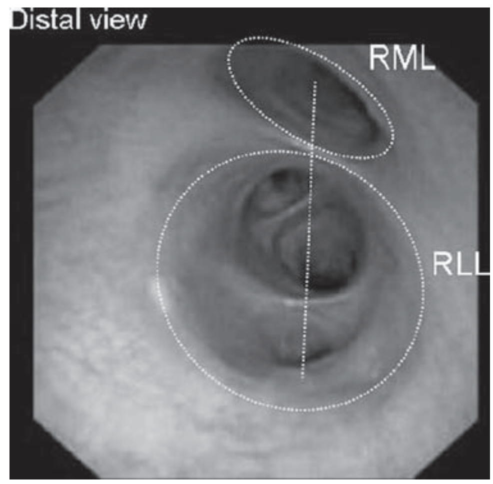
usually <3 mL for endobronchial cuffs. Inflating the bronchial cuff does not stabilize the DLT position when the patient is turned to the lateral position (26). Although BBs have low-volume high-pressure balloons, because of their internal elastic recoil the pressure actually transmitted to the bronchial wall is not higher than that from DLTs (27).

(4) Endobronchial intubation must be done gently and with fiberoptic guidance if resistance is met.

(5) Use of an appropriate size tube. Too small a tube will make lung isolation difficult. Too large a tube is more likely to cause trauma. Tracheobronchial dimensions correlate with height (28). Useful guidelines for DLT sizes in adults are: females height <1.6 m (63 in): 35F; females ≥1.6 m: 37F; small females <1.5 m (59 in) consider 32F. Males <1.7 m (67 in): 39F; males ≥1.7 m: 41F, small males <1.6 m consider 37F. Some authors advocate the measurement of the tracheal or bronchial diameters from the preoperative imaging and using these diameters to guide choice of DLT size (see Table 2) (29). It is useful to appreciate the comparative diameters of single and DLTs and to avoid using a DLT which exceeds the maximum size of a single-lumen tube which could be safely used in a given patient (see Table 3) (30). One clinical problem with DLT ≤32F is that the commonly available sizes of pediatric FOB (4 mm) will not pass through the lumens of these tubes. Clinical judgment and/or infant FOBs are required to position these smaller DLTs.

(6) Avoid passing a DLT as far as possible (until resistance is met). This was the previous teaching with tubes, such as the Carlen's, which had a carinal hook. Modern DLTs will not meet resistance until the bronchial lumen is impacted in the lower lobe bronchus. The average depth at insertion, from the teeth, for a left-DLT is 29 cm in an adult and varies ±1 cm for each 10 cm of patient height above/below 170 cm (31). Tubes should be passed to an appropriate depth and then verified with FOB.

Table 4. (continued)

Anatomical structure	Fiberoptic view
Right bronchus intermedius (RBI) Longitudinal bundles run into right lower lobe (dashed lines at 6 o'clock in proximal view) Right lower lobe (RLL) with segmental bronchi immediately visible Smaller right middle lobe (RML) bronchus with segmental bronchi not visible RML-RLL 2° carina normally oriented 3–9 o'clock. Superior segmental bronchus seen within RLL at 5–6 o'clock	 

DIFFICULT AIRWAYS

The new devices available for airway management and lung isolation have increased the options for achieving one-lung anesthesia in patients with difficult airways. A useful clinical plan is to initially place a single-lumen tube either with a fiberoptic bronchoscope or a video-laryngoscope (32), before or after induction of anesthesia depending on the case. Then, according to the clinical scenario, we choose either to use a bronchial blocker through the single-lumen tube or to replace the single-lumen tube with a DLT using an airway exchange catheter. It should be appreciated that even a 35F DLT (which is considered a small DLT) has a larger external diameter than a 8.5-mm ETT (see Table 3). There are commercially available exchange catheters designed specifically for this purpose, which have adequate length (100 cm) and a range of appropriate sizes (11F–14F). To avoid trauma, both to the patient and the tracheal cuff of the DLT, it is advisable to use a laryngoscope during this tube exchange to help align the normal oropharyngeal and tracheal axes. The new video-laryngoscopes (e.g., glidescope) are particularly useful for this purpose, allowing for direct visualization and manipulation to facilitate passing the DLT through the glottis. The anesthesiologist needs to be vigilant not to advance the tube-exchanger distally into the bronchi as this can cause bronchial trauma. Exchange catheters with soft tips are now available to try and decrease the risk of bronchial injury. Many varied techniques using single-lumen endobronchial tubes and/or the new bronchial blockers have been described to deal with specific abnormal upper or lower airway anatomy. The use of a bronchial blocker has even been described via a laryngeal mask airway (33).

With modern bronchial blockers, lobar bronchial blockade has become a clinically useful technique in thoracic anesthesia. This technique can be used for isolation of a single lobe or lobes on the side of surgery in patients who have had previous contra-lateral pulmonary resections (34).

The airflow resistance from a 37F DLT exceeds that of a #9 Univent by $<$10%. These flow resistances are both less than a 8.0 mm ID ETT, but exceed a 9.0 mm ETT. For short periods of postoperative ventilation and weaning, airflow resistance is not a problem with a modern DLT (35).

SUMMARY

Whether it is a "Standard of Practice" to always use a FOB to position a DLT or bronchial blocker has been a source of debate. Several authors (36) have written that clinical positioning of DLTs with auscultation is adequate and fiberoptic bronchoscopy does not need to be used routinely (37). Anesthesiologists should consider what the majority of practitioners in their region do as a form of "Standard." Complications during thoracic anesthesia may not be defensible if a FOB is not used (38). Also, it is advisable to use a fiberoptic bronchoscope in every case because anesthesiologists need to avail themselves of every opportunity to review tracheobronchial anatomy *in vivo* (as shown in Table 4). It is becoming evident that practicing anesthesiologists' baseline knowledge of tracheobronchial anatomy is often not adequate to position DLTs and blockers in the wide variety of clinical scenarios that can present for one-lung ventilation (39). This is currently one of the major problems in cardiothoracic anesthesia and it will require a concerted effort in both postgraduate and continuing medial education to raise the skills of anesthesiologists to the required level.

REFERENCES

1. Bjork VO, Carlens E. The prevention of spread during pulmonary resection surgery by the use of a double-lumen catheter. J Thorac Surg 1950;20:151–7.
2. Robertshaw FL. Low resistance double-lumen endobronchial tubes. Br J Anaesth 1962;34:576–81.
3. Slinger P. Fiberoptic positioning of double-lumen tubes. J Cardiothorac Anesth 1989;3: 486–96.
4. Benumof JL, Partridge BL, Salvatierra C, Keating J. Margin of safety in positioning modern double-lumen endotracheal tubes. Anesthesiology 1987;67:729–38.
5. Inoue H. New device for one lung anesthesia, endotracheal tube with movable blocker. J Thorac Cardiovasc Surg 1982;83:940.
6. Arndt GA, Buchika S, Kranner PW, DeLessio ST. Wire-guided endobronchial blockade in a patient with a limited mouth opening. Can J Anaesth 1999;46:87–9.
7. Cohen E. The Cohen flexitip endobronchial blocker: an alternative to a double-lumen tube. Anesth Analg 2005;101:1877–9.
8. Grocott HP, Darrow TR, Whiteheart DL, et al. Lung isolation during port-access cardiac surgery: double-lumen endotracheal tube versus single-lumen endotracheal tube with a bronchial blocker. J Cardiothorac Vasc Anesth 2003;17:725–7.
9. Klein U, Karzai W, Bloos F, et al. Role of fiberoptic bronchoscopy in conjunction with the use of double-lumen tubes for thoracic anesthesia. Anesthesiology 1998;88:346–50.
10. Riley RH, Marples IL. Relocation of a double-lumen tube during patient positioning. Anesth Analg 1992;75:1070.
11. Inoue S, Nishimine N, Kitaguchi K, et al. Double-lumen tube location predicts tube malposition and hypoxaemia during one-lung ventilation. Br J Anaesth 2004;92:195–201.
12. Bauer C, Bauer C, Winter, C, Hentz JG. Bronchial blocker compared to double-lumen tube for one-lung ventilation during thoracoscopy. Acta Anaesthesiol Scand 2001;45:250–4.
13. Smith GB, Hirsch NP, Ehrenworth J. Placement of double-lumen endobronchial tubes. Correlation between clinical impressions and bronchoscopic findings. Br J Anaesth 1986;58:1317–20.
14. Amar D, Desiderio D, Bains MS, Wilson RS. A novel method of one-lung isolation using a double endobronchial blocker technique. Anesthesiology 2001;95:1528–32.
15. Campos J, Massa C. Is there a better right-sided tube for one-lung ventilation? A comparison of the right-sided double-lumen tube with the single-lumen tube with right-sided enclosed bronchial blocker. Anesth Analg 1998;86:696–700.
16. Devitt JH, McLean RF, Koch JP. Anaesthetic management of acute blunt thoracic trauma. Can J Anaesth 1991;38:506–10.
17. Purut CM, Scott SM, Parham JV, Smith PK. Intraoperative management of severe endobronchial hemorrhage. Ann Thorac Surg 1991;51:304–7.
18. Fortin M, Turcotte R, Gleeton O, Bussieres JS. Catheter-induced pulmonary artery rupture: using occlusion balloon to avoid lung isolation. J Cardiothorac Vasc Anesth 2006;20:376–8.
19. Otruba Z, Oxorn D. Lobar bronchial blockade in bronchopleural fistula. Can J Anaesth 1992;39:176–8.
20. Nadeau MJ, Cote D, Bussieres JS. The combination of inhaled nitric oxide and pulmonary artery balloon inflation improves oxygenation during whole-lung lavage. Anesth Analg 2004;99: 676–9.
21. Massard G, Rouge C, Dabbagh A. Tracheobronchial lacerations after intubation and tracheostomy. Ann Thorac Surg 1996;61: 1483–7.
22. Jha RR, Mishra S, Bhatnagar S. Rupture of the left main bronchus associated with radiotherapy induced bronchial injury and use of a double-lumen tube in oesophageal cancer surgery. Anaesth Intensive Care 2004;32:104–7.
23. Saito S, Dohi S, Tajima K. Failure of double-lumen endobronchial tube placement: congenital tracheal stenosis in an adult. Anesthesiology 1987;66:83–6.
24. Bayes J, Salter EM, Hadberg PS, Lawson D. Obstruction of a double-lumen tube by a saber-sheath trachea. Anesth Analg 1994;79:186–8.
25. Peden CJ, Galizia EJ, Smith RB. Bronchial trauma secondary to intubation with a PVC double-lumen tube. J R Soc Med 1992;85:705.
26. Desiderio DP, Burt M, Kolker AC, et al. The effects of endobronchial cuff inflation on double-lumen tube movement after lateral decubitus positioning. J Cardiothorac Vasc Anesth 1997;11: 595–8.
27. Roscoe A, Kanellakos G, McRae K, Slinger P. Pressures exerted by endobronchial devices. Anesth Analg. In press.
28. Eagle CCP. The relationship between a person's height and appropriate endotracheal tube length. Anaesth Intensive Care 1992;20:156.
29. Brodsky JB, Malott K, Angst M, Fitzmaurice BG. The relationship between tracheal width and left bronchial width: implications for left-sided double-lumen tubes. J Cardiothorac Vasc Anesth 2001;15:216–17.
30. Campos JH. Lung separation techniques. In: Caplan JA, Slinger PD, eds. Thoracic anesthesia. 3rd ed. Philadelphia: Churchill Livingston, 2003:159–73.
31. Brodsky JB, Benumof JL, Ehrenworth J. Depth of placement of left double-lumen tubes. Anesth Analg 1991;73:570–6.
32. Doyle DJ. Awake intubation using the glidescope video laryngoscope: initial experience in four cases. Can J Anaesth 2004;51:520–1.
33. Ozaki M, Murashima K, Fukutome T. One-lung ventilation using the Proseal laryngeal mask airway. Anaesthesia 2004;59:726–7.
34. McGlade D, Slinger P. The elective combined use of a double lumen tube and endobronchial blocker to provide selective lobar isolation for lung resection following contralateral lobectomy. Anesthesiology 2003;99:1021–2.
35. Slinger P, Lesiuk L. Flow resistances of disposable double-lumen, single-lumen, and Univent tubes. J Cardiothorac Vasc Anesth 1998;12:133–6.
36. Brodsky J, Lemmens HJ. Left double-lumen tubes: clinical experience with 1170 patients. J Cardiothorac Vasc Anesth 2003;17:289–98.
37. Seymour AH, Prasad B, McKenzie RJ. Audit of double-lumen endobronchial intubation. Br J Anaesth 2004;93:525–7.
38. Pennefather SH, Russel GN. Placement of double-lumen tubes-time to shed light on an old problem. Br J Anaesth 2000;84:308–10.
39. Campos JH, Hallen E, Van Natta T, Kernstein HK. Devices for lung isolation used by anesthesiologists with limited thoracic experience: comparison of double-lumen endotracheal tube, Univent torque control blocker, and Arndt wire-guided endobronchial blocker. Anesthesiology 2006;104:261–6.