Journal of Cardiothoracic and Vascular Anesthesia 000 (2025) 1–12

Contents lists available at ScienceDirect

Journal of Cardiothoracic and Vascular Anesthesia

journal homepage: www.jcvaonline.com

Review Article

Airway Management in Thoracic Anesthesia

Manuel Granell, MD, PhD, Master Degree[*,2,1], Caroline Vanpeteghem, MD, PhD[†,2], Jo Mourisse, MD, PhD[‡,2], Mert Sentürk, MD[§,2], Laszlo Szegedi, MD, PhD[||], Mohamed El Tahan, MD[¶], Chirojit Mukherjee, MD[#,3], Izumi Kawagoe, MD, PhD[**], Waheed Karzai, MD, PhD[††], Ross Hofmeyr, MD, Master Degree[‡‡], Katarina Lenartova, MD, PhD[§§], Maria Martinez Alberici, MD[||||], Nandor Marczin, MD, PhD[¶¶], on behalf of the TOSSCA Consensus Group

[*]*University of Valencia, Spain, Consorcio Hospital General University of Valencia, Spain*
[†]*Ghent University Hospital, Gent, Belgium*
[‡]*Anaesthesiology, Pain and Palliative Medicine, Radboud University Medical Centre, Nijmegen, The Netherlands*
[§]*Acibadem University, School of Medicine, Department of Anesthesiology and Reanimation, Chair, Istanbul Turkey*
[||]*Department of Anesthesiology, Université Libre de Bruxelles, HUB Hôpital Erasme, Brussels*
[¶]*Mansoura University, Mansoura, Egypt, Cardiothoracic Anaesthesia, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia*
[#]*HELIOS Clinic for Cardiac Surgery Karlsruhe, Karlsruhe, Germany*
[**]*Department of Anaesthesia and Perioperative Medicine, Department of Anesthesiology and Pain Medicine, Juntendo University School of Medicine, Tokyo, Japan*
[††]*Jena University, Jena, Germany*
[‡‡]*Department of Anaesthesia and Perioperative Medicine, University of Cape Town, Cape Town, South Africa*
[§§]*Department of Anaesthesia and Critical Care, Harefield Hospital, Royal Brompton and Harefield hospitals, Guy's and St Thomas' National Health Service (NHS) Foundation Trust, UK*
[||||]*Department of Anaesthesia and Critical Care, Harefield Hospital, Royal Brompton and Harefield hospitals, Guy's and St Thomas' NHS Foundation Trust, UK*
[¶¶]*Division of Anaesthesia, Pain Medicine and Intensive Care, Imperial College London, Royal Brompton & Harefield Hospitals, Guy's & St. Thomas' NHS, London, United Kingdom, Department of Anesthesia and Intensive Care, Semmelweis University, Budapest, Hungary*

This article is the third in a series of articles prepared as part of a comprehensive, international and professional society–approved consensus project to advise on thoracic anesthesia. It represents the views and structured opinions of experts delegated to the Airway Management Task

This document was reviewed and approved by the Guideline Committee and Board of Directors of the European Association of Cardiothoracic Anaesthesiology and Intensive Care. The chair and members of the committee are as follows: Gabor Erdoes, Switzerland (Chair); Theofani Antoniou, Greece; Alessandro Belletti, Italy; Pietro Bertini, Italy; Gudrun Kunst, United Kingdom; and Reiner M. Waeschle, Germany.

M. Granell, C. Vanpeteghem, J. Mourisse, and M. Sentürk are joint first authors.

C. Mukherjee is European Association of Cardiothoracic Anaesthesiology and Intensive Care (EACTAIC) Board Member and President.

[1]*Address correspondence to:* Manuel Granell, Consorcio Hospital General University of Valencia, Avenida de Francia, n°2, 37; 46023, Valencia, Spain.

E-mail addresses: manuel.granell@uv.es (M. Granell), senturkm@istanbul.edu.tr (M. Sentürk), laszlo.szegedi@skynet.be (L. Szegedi), mohamedrefaateltahan@yahoo.com (M. El Tahan), chirojit.mukherjee@helios-gesundheit.de (C. Mukherjee), waheedk@live.de (W. Karzai), ross.hofmeyr@uct.ac.za (R. Hofmeyr), Mariamartinezalberici44@gmail.com (M.M. Alberici), n.marczin@imperial.ac.uk (N. Marczin).

[2]Joint 1st authors.

[3]EACTAIC Board member, President.

https://doi.org/10.1053/j.jvca.2025.11.004

Force of the Thoracic Subcommittee of the European Association of Cardiothoracic Anaesthesiology and Intensive Care (EACTAIC). This review highlights the main concepts and expert opinion of international leaders on the task of lung isolation and separation, as well as the current recommendations on the benefits and disadvantages of different devices in both routine and difficult airway scenarios. The consensus statement addresses the following main clinical topics and questions: (1) What are the overall goals and means of lung isolation and separation? (2) What are the best practices for using double-lumen tubes? (3) What is the role of alternative devices, specifically bronchial blockers? (4) What are the best practices for managing a difficult airway? (5) What are the recommendations for special cases? (6) What are the research priorities for thoracic anesthesia regarding airway management? The authors conclude with a brief reference to how these recommendations relate to the concepts of good clinical practice and enhanced recovery. The document was developed and formally evaluated by senior clinicians representing the core membership of the EACTAIC Thoracic Subcommittee from Europe, the United States, Africa, and the Middle East. Although the high-level evidence base is generally limited and significant controversies remain, all recommendations of the Task Force achieved an agreed (>60%), strong (>80%), or sometimes full (>95%) consensus. This consensus should serve as a consolidation of diverse practices of thoracic anesthesia and a starting point toward obtaining stronger evidence to further enhance our clinical practice in the future.

Key Words: one-lung ventilation; double-lumen tube; bronchial blocker; flexible fiberoptic/video bronchoscopy; difficult airway; minimally invasive thoracic surgery

THE MAJORITY OF thoracic surgical procedures involve specific management of the airways, with lung isolation and separation being the fundamental component of thoracic anesthesia, especially in the current era of video-assisted thoracoscopic or robotic surgery. Lung isolation allows single-lung ventilation and collapse of the contralateral lung, which allows improved surgical access and visualization of intrathoracic structures. Our repertoire of airway devices has evolved over time, and current practices rely on using various double-lumen tubes (DLTs) and a plethora of bronchial blockers (BBs) of a variety of designs to be applied through a common single-lumen endotracheal tube (SLT). Placing and maintaining these devices requires special expertise. Although significant research has been devoted to establish the pros and cons of these devices, national and international surveys suggest a dominance of DLTs in the landscape of thoracic anesthesia. In the absence of large, international and randomized controlled trials (RCTs), there is a need for expert consensus and practical recommendations. This article represents the effort toward international consensus regarding airway management in thoracic anesthesia by members of the thoracic subspecialty committee of the European Association of Cardiothoracic Anaesthesiology and Intensive Care (EACTAIC) professional society. It is an expert opinion based on an extensive review of the current literature and clinical experience of a large membership of the consensus project in an effort to plan and provide optimal care to thoracic surgical patients.

Methods

The framework, including the scope, strategy, and methodology of the consensus project, including formulation of the recommendations and their online quantitative evaluation by members, has been detailed in the first article in this series ("General Aspects of Thoracic Anesthesia: Monitoring"). Methodologically, the core of this article consists of the results of online voting on the recommendations of the Airway Management Task Force. Members of the Task Force have identified 6 specific topics: (1) goals and means of lung isolation and separation, (2) DLTs, (3) role of BBs, (4) managing the difficult airway, (5) recommendations for specific cases, and (6) future research priorities. The main article focuses primarily on concepts and comparing advantages and disadvantages of different airway devices, with more practical recommendations being provided in Appendix A. The authors decided to focus on tubeless thoracic surgery through a separate task force.

Consensus Statements

Lung Separation and Isolation for One-Lung Ventilation

At the core of this topic is the task of achieving a degree of separating one lung from the other, either because of patient conditions or facilitation of one-lung ventilation (OLV) for surgical reasons for a period during surgery. It is helpful to differentiate lung separation and isolation regarding the completeness of securing the airway, achieving either a full anatomic seal or only a temporary functional seal; the required duration of seal; and the preferential airway devices to achieve those tasks. Anatomic sealing of one lung from the other generally is required to protect it from harm from the contralateral lung for the duration of surgery. Historically, these have represented "absolute" indications for lung separation. "Relative" indications usually refer to only a functional way of lung sealing at desired periods of surgery, commonly to facilitate a surgical approach. Anatomic lung separation is achieved best by DLTs, whereas BBs primarily should be used for "functional" lung isolation.[1,2]

There is a spectrum of both pulmonary and extrapulmonary surgical procedures in which OLV by "functional sealing" is sufficient. These indications can be further classified as high priority or low priority, but again, it should be underlined that even the "low-priority" indications are associated with an improvement in perioperative success.[3] It should be noted that surgical approach is also important within this prioritization given that the requirement for OLV in video-assisted thoracic surgery (VATS) and robot-assisted thoracic surgery (RATS)

procedures is higher than that in the respective open surgical procedures.[4]

Successful achievement of lung isolation and its maintenance need to be confirmed at various stages of surgery. Traditionally, clinical methods such as differential ventilation parameters, air leak, observation of unilateral ascent of the ventilated hemithorax, and auscultation are indicative of successful lung isolation. However, such assessment remains unsatisfactory even in the hands of expert thoracic anesthesiologists. Moreover, there is some evidence that ultrasound could be a better skill than traditional clinical methods to assess the optimal lung collapse during lung isolation.[5] Nevertheless, the authors consider that the correct position of standard DLTs and BBs must be confirmed by flexible fiberoptic-video bronchoscopy (FOB).[6]

FOB should be performed in the following situations: (1) after intubation to ensure correct placement and positioning of a DLT or BB; (2) after position change from supine to lateral decubitus; and (3) in case of significant intraoperative changes in oxygenation, gas exchange (monitoring of peripheral oxygen saturation (SpO_2) and end-tidal CO_2 ($ETCO_2$)) and airway pressures (peak and plateau pressures), tidal volume, and flow or spirometric changes.[7] Additionally, FOB performed by the anesthesiologist can be indicated for guiding the surgical approach and evaluating the anastomosis to prevent leakage, for identification of fistulas or the source of hemorrhage, and repeatedly for bronchial toilet to clear the airways from secretions and blood.[8] The advantages and disadvantages of single-use versus reusable FOB devices[9] and their appropriate size in thoracic surgery are discussed in Appendix A.

Recommendations

Recommendation 1. To avoid confusion with the historical classification of absolute and relative indications, the authors suggest differentiating between the cases in which "anatomic" sealing of one lung is mandatory and the cases in which functional sealing of one lung is sufficient to improve surgical and anesthesia needs. DLTs should be chosen to achieve anatomic separation, whereas BBs are not appropriate for this purpose. For recommendation 1, the strength of agreement is 90% (consensus recommendation [CoR]: strong consensus).

Recommendation 2. The indications for anatomic sealing of one lung include (1) securing the airways and protection of the healthy lung from contamination from the contralateral lung in potentially life-threatening conditions (eg, massive pulmonary hemorrhage or pneumonia with pus and lung abscess); (2) providing differential ventilation and gas exchange for unilateral thoracic disorders (eg, in the case of giant emphysematous bullae, bronchopleural fistulas, or bronchial interruptions); and (3) facilitating exposure of intrathoracic anatomic structures for diagnostic and therapeutic procedures (unilateral bronchoalveolar lavage or sleeve pneumonectomy). For recommendation 2, the strength of agreement is 93% (CoR: strong consensus).

Recommendation 3. High priorities for selective lung ventilation with an anatomic seal include achieving optimal surgical exposure for pneumonectomy, sleeve resection on the bronchial mainstem, lung transplantation, and thoracic aneurysm surgery. For these conditions, DLTs are preferentially recommended. For recommendation 3, the strength of agreement is 84% (CoR: strong consensus).

Recommendation 4. Selective lung ventilation with a functional seal is desired to facilitate surgical exposure for lobectomy and lesser lung resection, interventions on the pleura and mediastinal structures, and minimally invasive cardiac surgery and esophageal surgery. Both BBs and DLTs are generally adequate for functional lung sealing during these procedures. For recommendation 4, the strength of agreement is 94% (CoR: strong consensus).

Recommendation 5. FOB is a mandatory procedure during thoracic anesthesia. FOB facilitates correct placement of DLTs and BBs, as well as recognition of their potential malpositioning or displacement. It provides guidance for surgical approaches, particularly during resection and anastomosis. FOB also helps to identify the pathologic anatomy and localization of foreign bodies, the stoma of tracheoesophageal or bronchopleural fistulas, or the source of hemoptysis or air leak. For recommendation 5, the strength of agreement is 93% (CoR: strong consensus).

Double-lumen Tubes

DLTs have been mainstream devices for lung isolation in thoracic anesthesia. A DLT is a combined tube with one tube with a distal-end bronchial lumen and cuff, which must be placed in a bronchus, and a more proximal-end tracheal lumen and cuff. Some practical guidance is provided in Appendix A. Although not recommended under normal circumstances, blind insertion and successful placement of a DLT using auscultation to confirm correct position are possible.[10]

DLTs have many advantages with respect to BBs, such as faster insertion and less incidence of displacement. However, they may be associated with some disadvantages, such as more frequent and severe airway injury. Appropriate sizing could be challenging especially in smaller and pediatric patients. In "difficult airway" cases (both upper and lower airways), intubation with DLTs can be very difficult and sometimes impossible.[11] Nasal intubation is impossible with DLTs. Finally, they are not recommended for routine use in the intensive care unit (ICU) setting.

One important component of successful airway management is the determination of the appropriate size of DLT.[11] Experts consider that the height and sex of the patient should be taken into account when choosing the size of the DLT[12]; in addition, chest radiographs and computed tomography (CT) scans provide crucial information on the pathologic appearance of the trachea and main bronchi to aid in selecting the optimal device and size.[13,14]

The authors provide practical guidance for the placement of DLTs and how to perform replacement of a defective DLT.

After DLT placement and provision of an anatomic seal, lung collapse can be achieved by a variety of means (Appendix A).

In the majority of surgical procedures, a left DLT (L-DLT) is suitable for both left- and right-sided thoracic surgical procedures and is preferred to a right DLT (R-DLT) given the special anatomy of the right upper lobe bronchus.[15] This positioning can be challenging and sometimes even impossible for patients if the orifice is outside the reference distance of the R-DLT.[16] However, there are some special indications for using an R-DLT.[17] Thus, thoracic anesthesiologists should be prepared and trained for placement of an R-DLT so that it also can be used for training purposes and for educational and skill maintenance indications.[18]

Recently, technological developments have enabled the use of special DLTs with embedded cameras (Fig 1). These have significant advantages but also present some pitfalls. DLTs with embedded cameras have a diameter 30% larger and are less flexible than standard DLTs with the same labeled size. The increased size compared with the conventional DLT could be considered a disadvantage during tracheal intubation and positioning of the DLT.[19] Currently, these types of DLTs are more expensive.

Although most thoracic procedures are completed with full extubation and waking of the patient, in some situations, invasive postoperative mechanical ventilation is required, necessitating exchange of the DLT for an SLT.[20] Practical guidance about airway exchange catheter (AEC) use for DLT replacement[20] is provided in Appendix A.

Recommendations

Recommendation 6. DLTs allow anatomic lung separation and, therefore, protection from contralateral cross contamination during surgery. Furthermore, they allow sufficient gas exchange in the setting of bronchial disruption. Procedural advantages of DLTs include faster insertion, faster lung collapse, and lower incidence of intraoperative displacement as compared with BBs. DLTs also facilitate efficient clearance of blood, pus, or secretion from the airway and allow application of continuous positive airway pressure to the non-dependent lung. Currently, DLTs are less expensive than the alternative airway devices available. For recommendation 6, the strength of agreement is 91% (CoR: strong consensus).

Recommendation 7. Blind insertion of DLTs is widely used by many clinicians, but FOB identifies a high frequency of malposition; hence, fiberoptic evaluation after blind insertion is mandatory. Visualization of the tracheal carina, appropriate placement of the DLT into the correct main bronchus, and patency of the lobar bronchi must be verified. Herniation of the bronchial cuff over the carina and partial occlusion of the contralateral main bronchus should be excluded. When using a right-sided DLT, alignment of the right upper lobe bronchial orifice must be confirmed with the right upper lobe ventilating slot of the DLT. For recommendation 7, the strength of agreement is 91% (CoR: strong consensus).

Recommendation 8. The size of the DLT used depends on the characteristics of the patient (height, weight, sex), the ease or difficulty of the airway, the dimensions of the trachea and the main bronchi, the pathology present in the airways, the brand and dimensions of the DLT, and the experience of the anesthesiologist. At a minimum, DLT size should be adapted to height and sex. Chest radiographs and CT scans always must be reviewed to adjust DLT size to the dimensions and pathology of the trachea and main bronchi. For recommendation 8, the strength of agreement is 89% (CoR: strong consensus).

Recommendation 9. Collapse of the non-dependent lung is facilitated by clamping the proximal connector of the DLT, followed by opening the venting slot to the atmosphere. Carefully intermittent aspiration (<30 cmH_2O) must be considered if this maneuver is necessary to improve the quality and speed of lung collapse of the non-dependent lung. For recommendation 9, the strength of agreement is 87% (CoR: strong consensus).

Recommendation 10. Absolute indications for placing an R-DLT include (1) left mainstem obstruction (eg, endobronchial tumor), (2) left mainstem sleeve resection, (3) left tracheobronchial disruption, and (4) left mainstem compression (eg, aortic aneurysm or mediastinal mass). Relative indications include (1) left-sided pneumonectomy and (2) anatomic distortion of the left mainstem, making the insertion of the L-DLT difficult, as well as specific cases of tracheal compression. For recommendation 10, the strength of agreement is 91% (CoR: strong consensus).

Recommendation 11. DLTs with embedded cameras offer the possibility of direct and real-time confirmation of tracheal intubation, continuous monitoring of tube position, early detection of tube displacement, and potentially, reduction of repeated airway manipulation. This is particularly relevant in cases in which access to the patient is challenging, for instance, during

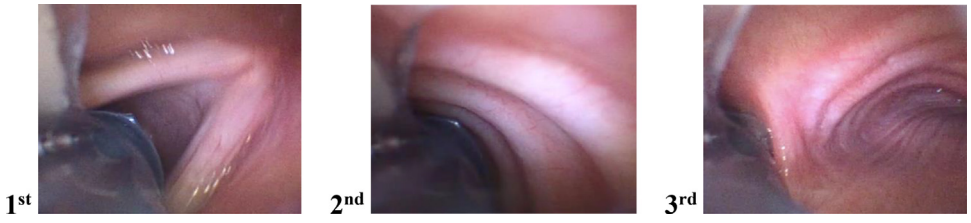

Fig 1. Insertion of a double-lumen tube with an embedded camera in 3 stages: through the vocal cords (1) and tracheal lumen (2), with the final position in the left main bronchus (3).

RATS. The requirement for FOB is not eliminated but is decreased with a DLT with an embedded camera. For recommendation 11, the strength of agreement is 86% (CoR: strong consensus).

Recommendation 12. It is appropriate to proceed with routine extubation and reintubation in low-risk patients who require postoperative mechanical ventilation and who underwent easy intubation and straightforward procedures. However, postoperative ventilation is usually required in high-risk patients after prolonged, complex procedures with complications. For this scenario, the authors recommend exchanging the DLT with a flexible-tip AEC to ensure securing of the airway and preservation of gas exchange during exchange. For recommendation 12, the strength of agreement is 87% (CoR: strong consensus).

Bronchial Blockers

BBs are increasingly popular devices for OLV, and every anesthesiologist performing OLV should be familiar with both DLTs and BBs. BBs are thin, long, rather stiff catheters that are mostly guided through an SLT toward the bronchus to be blocked. Currently available BBs can be classified as (1) torque control, (2) wire guided, (3) bifurcated, and (4) flexible tip (Fig 2).

Practical guidance on BBs is provided in Appendix A. Disadvantages include more frequent intraoperative displacement or loss of seal, as well as difficulties in repositioning,[21,22] but there are differences depending on the type of BB. There are many indications to use BBs.[23] Moreover, tracheal tubes with embedded cameras allow BB-guided insertion, in addition to continuous monitoring and correction of displacement.[24]

Recommendations

Recommendation 13. BBs allow a functional seal for lung separation. Procedural advantages of BBs include easier insertion in case of a difficult airway and less frequent airway injury and postoperative sore throat or hoarseness. BBs should not be used to obtain an anatomic seal unless it is impossible to insert a DLT. For recommendation 13, the strength of agreement is 89% (CoR: strong consensus).

Recommendation 14. FOB guidance is mandatory for positioning the BB in the correct bronchus and determining the inflating volume of the balloon. Alternatively, an endotracheal tube (ETT) with an embedded camera can be used. Three sizes of BB are available, with 1 size (5F) for pediatric patients and 2 sizes (7F and 9F) for adults. For recommendation 14, the strength of agreement is 88% (CoR: strong consensus).

Recommendation 15. Specific indications to use BBs for OLV are as follows: (1) difficult airways, (2) nasotracheal intubation, (3) selective lobar blockade (SLB), (4) cases in which OLV becomes indicated during surgery, (5) pediatric OLV, (6) already intubated patients requiring OLV, (7) patients in whom mechanical ventilation has to be continued after surgery, and (8) patients with a tracheostoma requiring OLV. For recommendation 15, the strength of agreement is 90% (CoR: strong consensus).

Recommendation 16. There should always be good communication with the surgical team about the type of lung isolation device used (DLT or BB) before the incision and during surgery, especially when a BB or DLT is in the bronchus on the operated side. For recommendation 16, the strength of agreement is 88% (CoR: strong consensus).

Recommendation 17. Advantages of tracheal tubes with embedded cameras compared with standard tubes when using BB include the possibility of guided BB insertion, with continuous monitoring of the position of the BB and, therefore, easy recognition and correction of a displaced BB. For recommendation 17, the strength of agreement is 85% (CoR: strong consensus).

Recommendations for Difficult Airway Scenario in Thoracic Surgery

An airway is considered difficult when a conventionally trained anesthesiologist encounters problems with either face-mask ventilation, intubation, or a combination of both situations. Identification of patients with a potentially difficult intubation is made based on the difficult upper airway assessment as recommended in published guidelines.[2] Thorough review of the relevant medical history including surgery and radiotherapy, comorbidities affecting the upper

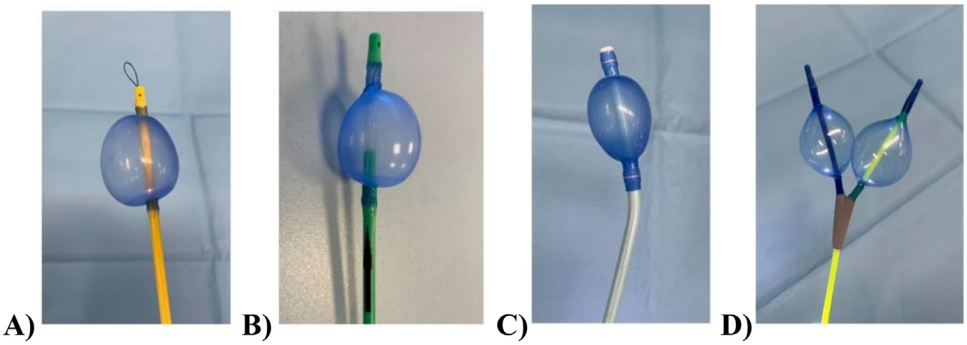

Fig 2. Different types of bronchial blocker (BB) cuffs. (A) Arndt BB. (B) Cohen BB. (C) Uniblocker (Fuji). (D) EZ-Blocker.

and lower airways, and details of prior airway management, in addition to detailed radiologic assessment of airways, should be undertaken.[25] This general evaluation should then be reconciled with an informed decision regarding the need for an anatomic or functional seal for lung isolation and its priority. It is important to note that DLTs are thicker and stiffer than conventional ETTs and, therefore, are more difficult to manipulate.

Thus, most experts advise using intubation with an SLT placed under fiberoptic or video-assisted guidance in patients with a difficult upper airway who require lung isolation while maintaining spontaneous ventilation.[26-28] On the other hand, only in patients who are easy to ventilate with a mask can anesthetic induction be performed and the airway managed via FOB, by a video laryngoscope directly, or through a laryngeal mask.[26] After orotracheal intubation, lung isolation generally should be achieved with a BB or with DLT exchange in indicated cases of anatomic sealing[29] (Fig 3). Exchange of an SLT for a DLT in the context of a difficult airway must be fully justified, and losing airway patency during the exchange maneuver must always be avoided.[11,30]

As with general airway management, video laryngoscopy reduces the Cormack-Lehane grade (C&L grade), increases the percentage of glottic opening (POGO) score, and improves the intubation success rate.[31] Video laryngoscopy–guided SLT intubation under topical anesthesia is also an alternative option for awake FOB in spontaneously breathing patients.[32] In addition, the use of a video laryngoscope during anesthesia induction could facilitate the introduction of a DLT directly or with an intubation bougie.[33]

Beside difficult intubation scenarios, a difficult airway in thoracic anesthesia includes difficulties in achieving adequate lung sealing. The latter is due to anatomic abnormalities of the lower airways (eg, in the presence of an endoluminal tumor[28] or a tracheal bronchus),[34,35] rendering positioning difficulties for the DLT or BB that require a CT scan[36] and, eventually, virtual bronchoscopy (Fig 4).[37] The presence of a tracheal bronchus (the bronchus directed to the right upper lobe arises from the trachea) is a rare, congenital anomaly but represents a major difficulty for the anesthesiologist (Fig 5).[34,38,39]

Lung isolation with existing tracheostomy requires special airway management due to the complexities of the shortened airway, potential size mismatch of the airway device and stoma, and generally impaired respiratory reserve of these patients. It is essential to understand the indications for tracheostomy and to consider the duration and physical properties of the stoma.

The preferred strategy to facilitate OLV in patients with tracheostomy is the introduction of a BB, but the short distance between the tracheostomy and the carina may present additional challenges for manipulating the BB. All types of BBs, including the EZ-Blocker (Teleflex), can be chosen for the procedure.

The special tracheostomy DLTs are shorter and softer than conventional DLTs and are curved between the intra- and extra-tracheal parts. However, their availability is limited. Alternatively, a standard DLT may be introduced orally into the trachea under FOB guidance.[20]

Recommendations

Recommendation 18. When dealing with a predicted difficult upper airway in the context of the need for lung isolation, the primary goal is to establish a patent airway with an SLT placed orally with the aid of an FOB device. Awake fiberoptic or video-assisted intubation is recommended with maintenance of spontaneous ventilation. In selected patients who are deemed easy to ventilate with a mask or who refuse or are unsuitable for awake tracheal intubation, it is appropriate to proceed with anesthesia induction and to secure the airway with the use of an FOB device or with a video laryngoscope directly or through a laryngeal mask airway.

Once the SLT is secured, the safest way to achieve lung isolation is by using a BB. Should a high-priority indication for anatomic sealing of one lung be established, the SLT could be exchanged for a DLT using an AEC. This decision needs to be balanced by the conditions and difficulties encountered during the placement of the SLT. For recommendation 18, the strength of agreement is 89% (CoR: strong consensus).

Recommendation 19. Exchange of an SLT to an DLT in the context of a difficult airway remains a risky procedure, and the requirement for a DLT versus a BB needs to be fully justified. The principles described for airway exchange in DLTs should be strictly followed, and extreme care should be exercised not to lose airway patency during exchange.

With a difficult upper airway, the risk of arytenoid or vocal cord impingement and the difficulty of advancing the DLT to the proximal trachea are substantial. Therefore, adequate preoxygenation is paramount, in addition to immediate availability of escape ventilation. For recommendation 19, the strength of agreement is 91% (CoR: strong consensus).

Recommendation 20. To manage lung isolation in a patient with an unpredicted difficult airway, the strategies listed for predicted difficult airways can be followed if there are no difficulties in ventilating the patient by either manual ventilation or by introducing a laryngeal mask airway (LMA). If intubation is not possible, there should be a low threshold to wake the patient and plan for awake fiberoptic intubation. For recommendation 20, the strength of agreement is 88% (CoR: strong consensus).

Recommendation 21. Video laryngoscopy is advised in patients with difficult upper airways to improve intubating conditions and to facilitate securing the airway with an SLT. In the case of high priority for anatomic lung sealing, video laryngoscopy also may facilitate the introduction of a DLT directly or with an intubating bougie. For recommendation

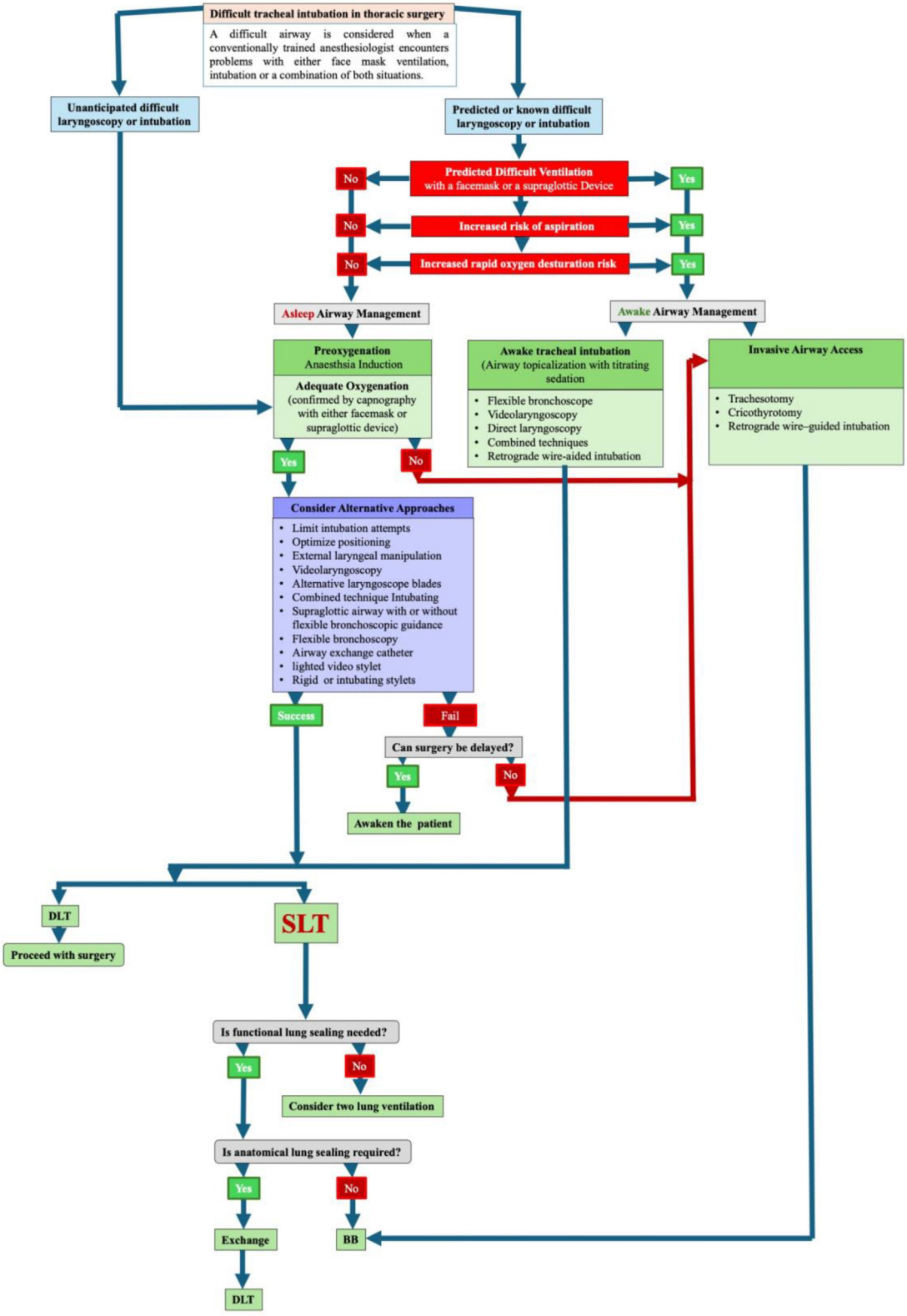

Fig 3. Difficult airway algorithm in thoracic surgery, modified from Granell et al.[28] BB, bronchial blocker; DLT, double-lumen tube; SLT, single-lumen endotracheal tube.

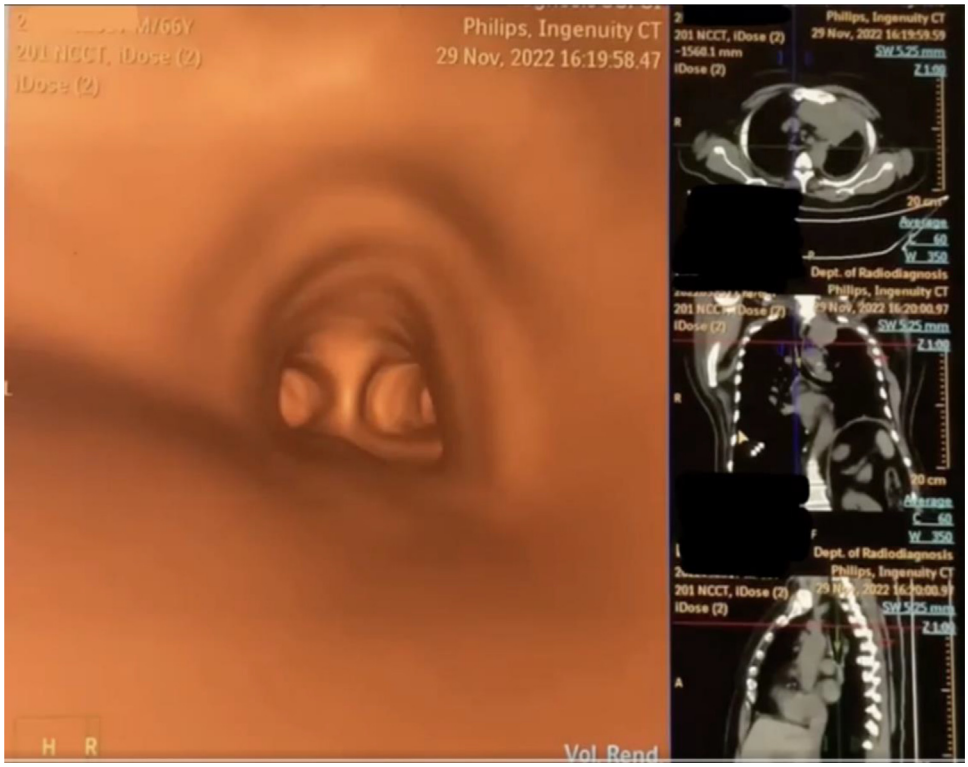

Fig 4. Virtual bronchoscopy to rule out tracheal compression.[36]

21, the strength of agreement is 91% (CoR: strong consensus).

Recommendation 22. Detailed knowledge of the anatomy from imaging techniques, especially CT scans, and eventually, virtual bronchoscopy, is required in patients with lower airway abnormalities. Complete FOB examination of the lower airway prior to placement of the lung isolation device is recommended. For recommendation 22, the strength of agreement is 88% (CoR: strong consensus).

Recommendation 23. In most situations of difficult lower airways, the safest method for facilitating lung isolation is fiberoptic intubation with an SLT, followed by insertion of a BB. Some particular lesions may require lobar isolation. For recommendation 23, the strength of agreement is 87% (CoR: strong consensus).

Recommendation 24. In the case of a tracheal bronchus, an R-DLT is not suitable for right lung collapse because it isolates only the right middle and lower lobes. When a carinal tracheal bronchus is present, an L-DLT can be used, preferably guided by FOB. In the case of a supracarinal tracheal bronchus with the orifice of the right upper lobe located at the level of or above the tracheal cuff, an L-DLT cannot be used because it will obstruct the right upper lobe orifice. In this situation, an SLT with a left BB is the best option for left-sided surgery. For right-sided surgery, an option is to introduce an SLT and use 2

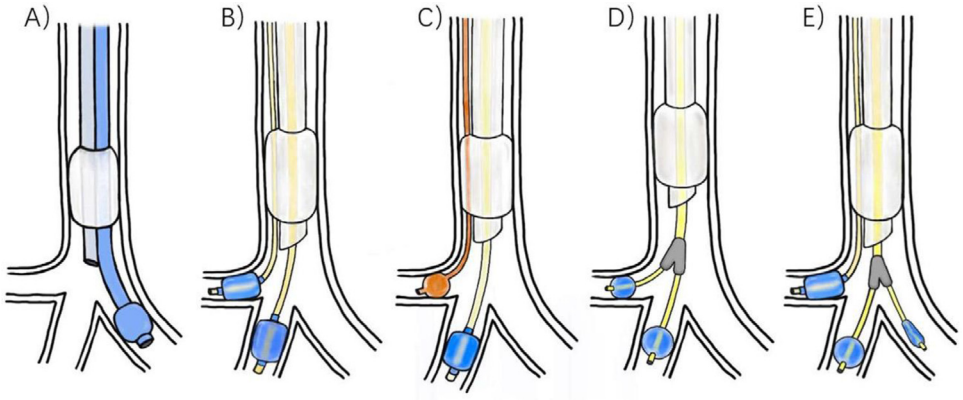

Fig 5. Management of one-lung ventilation in patients with carinal tracheal bronchus (who require surgery on the right lung). (A) Left double-lumen tube. (B) Two bronchial blockers. (C) One bronchial blocker and one Fogarty catheter. (D) EZ-Blocker. (E) One bronchial blocker and one EZ-Blocker.[40]

BBs (1 to exclude the tracheal bronchus and 1 positioned in the intermediate bronchus). An alternative option is to introduce an SLT into the left main bronchus guided by FOB. For recommendation 24, the strength of agreement is 89% (CoR: strong consensus).

Recommendation 25. The preferred strategy for facilitating OLV in patients with a tracheostomy is to introduce a BB either through the tracheostomy (within or next to the cannula or SLT inserted through the tracheostoma) or through an SLT after oral intubation. In cases of a well-formed stoma, it is appropriate to remove the tracheostomy tube and introduce a specially designed DLT if there are high-priority indications for anatomic lung sealing. For recommendation 25, the strength of agreement is 91% (CoR: strong consensus).

Recommendations for Specific Cases

Lung isolation in patients with a previous lung resection can be achieved by either DLTs or BBs applying lung collapse or SLB depending on the lung reserve and type of surgery. For patients with severe pulmonary dysfunction, minimal alveolar concentration (MAC) sedation with local or regional anesthesia could be considered as an alternative approach.[41-44]

In patients with a previous left upper lobectomy scheduled for right lung resection, a special L-DLT with a reinforced flexible tip may be more easily placed compared with the standard L-DLT. An R-DLT also may be indicated.[45]

DLTs and BBs are equally appropriate airway devices for lung isolation in VATS lung resection depending on the experience and preference of the anesthesiologist and the specific conditions of the patient, although BBs may be associated with a higher incidence of displacement and lower degree of collapse.[46,47] However, RATS procedures limit working space and make access to the head and/or airway difficult for anesthesiologists, so more stable airway devices (eg, DLTs) are preferred.[48]

Lung isolation in children remains challenging but may be required both in the elective setting in specialized centers and for acute presentations in non-specialized general hospitals. Where there is an acute need for lung isolation, it may be possible to selectively place the ETT (half a size smaller tube) in a main bronchus (right or left), guided by FOB or blindly. Placing a DLT or BB (inside or outside the ETT) can be performed by skilled specialists depending on the patient and type of surgery.[49] However, FOB even with a small bronchoscope remains challenging for the combination of a BB and FOB with pediatric ETT.

Recommendations

Recommendation 26. Lung isolation can be achieved with either DLTs or BBs in patients undergoing limited contralateral anatomic pulmonary resections (eg, wedge resection, segmentectomy, or lobectomy) without associated severe pulmonary dysfunction. SLB with a BB is helpful in patients presenting with contralateral pneumonectomy, bi-lobectomy, or lobectomy with severe pulmonary dysfunction. For recommendation 26, the strength of agreement is 88% (CoR: strong consensus).

Recommendation 27. SLB would be helpful in patients with previous contralateral pneumonectomy or at high risk of experiencing hypoxemia during OLV. Compared with the other lobes, blockade of the right upper lobe is very difficult—and sometimes impossible. SLB can be achieved only with BBs. Generally, longer BBs can be preferred for SLB; the Arndt blocker can be used for SLB and may be considered the most suitable blocker for selective blockade of the right upper lobe. For recommendation 27, the strength of agreement is 83% (CoR: strong consensus).

Recommendation 28. DLTs and BBs are equally appropriate airway devices for lung isolation in VATS lung resection based on the expertise and preference of the anesthesiologist and the specific conditions of the patient (ie, need for an anatomic or functional seal). For recommendation 28, the strength of agreement is 90% (CoR: strong consensus).

Recommendation 29. RATS procedures present limited working space for the anesthesiologist and lesser accessibility to the patient's face and airway. Therefore, DLTs are preferable to BBs during RATS procedures, especially DLTs with embedded cameras. For recommendation 29, the strength of agreement is 89% (CoR: strong consensus).

Recommendation 30. For the management of lung isolation in neonatal thoracic surgery, an SLT is recommended. For children older than 3 years who can be intubated with an ETT of 4.5 mm or higher, intraluminal placement of a 5F BB is indicated. For smaller children or those with an ETT below 4.5 mm, extraluminal placement of the BB is necessary. Finally, a 26F DLT is usually suitable for children aged around 9 to 11 years, and a 28F DLT, for those aged 11 to 12 years. For recommendation 30, the strength of agreement is 88% (CoR: strong consensus).

Research Priorities

In the preparation phase of the Delphi process, members of the consensus project have provided 26 research priority topics in the area of airway management for thoracic anesthesia. There is top priority for an RCT on the use of video laryngoscopy for facilitating DLT placement. There is also enthusiasm for different opinion or practice surveys. The Research Priority Task Force suggested bringing these survey topics under one umbrella and designing a large international prospective observational study on relevant aspects of airway management. The proposal is the SAN FRANCISCO (Airway) study: Observational Study to Delineate Current Practices and the Influence of Thoracic Anaesthesia on Postoperative Pulmonary Complications and Surgical Outcomes.

There is also strong support for a large definitive trial between DLTs and blockers. In line with the conclusion of the

systematic review by Clayton-Smith et al.,[22] members of the consensus project believe that further conclusive evidence is required on important clinical outcomes such as efficacy and patient safety by means of a definitive and robustly designed RCT. The authors recommend a high-quality and large multicenter health technology assessment of DLTs versus BBs. The RCT design should be pragmatic and should include an assessment of DLTs with and without embedded cameras and compare these with the most popular BBs. End points should reflect the message of the systematic review,[22] with efficacy reflected by the quality of lung collapse, occurrence of clinically relevant malpositions, and anesthesiologist and surgeon satisfaction, while safety could be assessed by patient satisfaction and pulmonary complications.

Recommendations

Recommendation 31. Nine members have provided 26 individual research projects with personal priorities and rankings (first, second, and third) for the airway aspects of thoracic anesthesia. There is enthusiasm for different opinion or practice surveys, for instance, a survey of EACTAIC to compare the use of BBs with DLTs in thoracic surgery, the current use of Vivasight (Ambu), and the current use of methods for reducing sore throat. The Research Priority Task Force suggested bringing these survey topics under one umbrella and designing a large international prospective observational study on relevant aspects of airway management. The proposal is the SAN FRANCISCO (Airway) study: Observational Study to Delineate Current Practices and the Influence of Thoracic Anaesthesia on Postoperative Pulmonary Complications and Surgical Outcomes. For recommendation 31, the strength of agreement is 85% (CoR: strong consensus).

Recommendation 32. There is strong support for a large definitive trial between DLTs and blockers. In line with the conclusion of the systematic review by Clayton-Smith et al.,[22] members of the consensus project believe that further conclusive evidence is required on important clinical outcomes such as efficacy and patient safety by means of a definitive and robustly designed RCT. The authors recommend a high-quality and large multicenter health technology assessment of DLTs versus BBs. The RCT design should be pragmatic and should include an assessment of DLTs with and without embedded cameras and compare these with the most popular BBs. End points should reflect the message of the systematic review, with efficacy reflected by the quality of lung collapse, occurrence of clinically relevant malpositions, and anesthesiologist and surgeon satisfaction, while safety could be assessed by patient satisfaction and pulmonary complications. For recommendation 32, the strength of agreement is 85% (CoR: strong consensus).

Recommendation 33. Several members expressed a priority for an RCT on the use of video laryngoscopy to facilitate DLT placement. This is supported by first-priority proposals and a number of second- and third-ranked and related project titles. The authors recommend bringing these groups together to fully develop this proposal for an international RCT. The design of this trial should be pragmatic and include various devices on the market, and it should focus on patients with a degree of expected or unexpected airway difficulty, such as limited neck movement or small mouth opening and a grade 2/3 Mallampati score. For recommendation 33, the strength of agreement is 82% (CoR: strong consensus).

Implications for Good Clinical Practice and Enhanced Recovery

The good clinical practice component of our consensus intends to set basic clinical goals to spread the fundamental clinical approaches and the essential requirements to ensure quality patient care before and during thoracic surgery. For airway management, the stated goal is that appropriate equipment to manage OLV must be available in the surgical block. Specifically, beyond the standard equipment for airway management, the following devices to manage the OLV must be available: L-DLT, R-DLT, BB, adult and pediatric FOB devices, AEC for DLT, and video laryngoscope.

Possible effects of airway management on enhanced recovery after thoracic surgery are not examined at all. However, one of the most important reasons for the decrease in the incidence of hypoxia during OLV is the routine use of FOB to secure the optimal positioning of airway devices (both DLTs and BBs). Consequently, it can be speculated that there is at least an indirect relationship between target-oriented, rational airway management and postoperative outcome. However, this assumption needs to be proven with well-powered studies.

Conclusions

Thoracic surgery and anesthesia have evolved over the past several decades. The central task of thoracic anesthesia—providing OLV using specialized airway management—was dominated by leading individuals and their expert opinion rather than society-approved collective consensus or rigorous data arising from full health technology assessment. The large international leadership of the Thoracic Subcommittee of EACTAIC and its airway experts, supported by the large membership of the consensus project, adds significant weight to the current consensus and collective knowledge represented in this article and their implications for good clinical practice and enhanced recovery (ERAS) protocols. The high level of consensus agreement for most dilemmas allows generally strong recommendations on the principal aspects and also on practical recommendations. Nevertheless, because there is an overall lack of high-quality evidence, individual disagreement remains, as described in Appendix B. Through a robust exercise of research prioritization, the authors hope that this consensus forms the basis of future high-quality scientific investigations toward establishing the much-needed stronger evidence base for airway management in thoracic anesthesia.

Declaration of competing interest

M.G. reports receiving financial compensation from Medtronic, Teleflex, and Tappa Medical for participating as a speaker at conferences and webinars between 2022 and 2024. M.S. reports receiving conference honoraria as speaker at industry symposia from Tappa Medical, Ambu International, Mindray, and Getinge and travel support from Getinge. M.S. is Chair of the European Association of Cardiothoracic Anaesthesiology and Intensive Care Thoracic Subspecialty Committee. B.S. is Trustee of the *British Journal of Anaesthesia*. The other authors report no competing interests.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2025.11.004.

References

1 Cohen E. Pro: The new bronchial blockers are preferable to double-lumen tubes for lung isolation. J Cardiothorac Vasc Anesth 2008;22:920–4.
2 Campos JH. Which device should be considered the best for lung isolation: Double-lumen endotracheal tube versus bronchial blockers. Curr Opin Anaesthesiol 2007;20;27e31.
3 Della Rocca G, Coccia C. Acute lung injury in thoracic surgery. Curr Opin Anaesthesiol 2013;26:40–6.
4 McCall P, Steven M, Shelley B. Anaesthesia for video-assisted and robotic thoracic surgery. BJA Educ 2019;19:405–11.
5 Moharir A, Yamaguchi Y, Aldrink JH, et al. Point-of-care lung ultrasound to evaluate lung isolation during one-lung ventilation in children: A blinded observational feasibility study. Anesth Analg 2024;139:1294–9.
6 Eldawlatly AA, Basheer MK, AlHamdi MA, et al. Expert opinion on the use of fiberoptic bronchospe to check the insertion depth of the left-sided double-lumen tube. Saudi J Anaesth 2024;18:272–5.
7 Patel M, Wilson A, Ong C. Double-lumen tubes and bronchial blockers. BJA Educ 2023;23:416–24.
8 Villalonga A, El Tahan M. Utility of bronchoscope in thoracic surgery. In: Granell Gil M, Şentürk M, editors. Anesthesia in thoracic surgery, Cham: Springer; 2020. p. 77–86.
9 Videau M, Rghioui K, Mottet B, et al. A comparative cost analysis of single-use versus reusable fiberoptic bronchoscopes: Is single-use fiberscope worth it? Ann Pharm Fr 2017;75:473–9.
10 Boucek CD, Landreneau R, Freeman JA, et al. A comparison of techniques for placement of double-lumen endobronchial tubes. J Clin Anesth 1998;10:557–60.
11 Langiano N, Fiorelli S, Deana C, et al. Airway management in anesthesia for thoracic surgery: A "real life" observational study. J Thorac Dis 2019;11:3257–69.
12 Brodsky JB, Lemmens HJ. Tracheal width and left double-lumen tube size: A formula to estimate left-bronchial width. J Clin Anesth 2005;17:267–70.
13 Mihatsch LL, Weiland S, Helmberger T, et al. Common double-lumen tube selection methods overestimate adequate tube sizes in individual patients—A 3D reconstruction study. BMC Anesthesiol 2024;24:215.
14 Shah SB, Hariharan U, Chawla R. Choosing the correct-sized adult double-lumen tube: Quest for the holy grail. Ann Card Anaesth 2023;26:124–32.
15 Benumof JL, Partridge BL, Salvatierra C, et al. Margin of safety in positioning modern double-lumen endotracheal tubes. Anesthesiology 1987;67:729–38.
16 Cohen E. Con: right-sided double-lumen endotracheal tubes should not be routinely used in thoracic surgery. J Cardiothorac Vasc Anesth 2002;16:249–52.
17 Campos JH, Gomez MN. Pro: right-sided double-lumen endotracheal tubes should be routinely used in thoracic surgery. J Cardiothorac Vasc Anesth 2002;16:246–8.
18 Slinger P. The clinical use of right-sided double-lumen tubes. Can J Anaesth 2010;57:293–300.
19 Granell M, Petrini G, Kot P, et al. Intubation with Vivasight double-lumen tube versus conventional double-lumen tube in adult patients undergoing lung resection: A retrospective analysis. Ann Card Anaesth 2022;25:279–85.
20 Campos JH, Granell Gil M. Difficult airway management in thoracic surgery. In: Granell Gil M, Şentürk M, editors. Anesthesia in thoracic surgery, Cham: Springer; 2020. p. 111–24.
21 Kumar N, Mitchell J, Siemens A, et al. Left-sided double-lumen tube vs EZ-Blocker for one-lung ventilation in thoracic surgery: A systematic review and meta-analysis. Semin Cardiothorac Vasc Anesth 2023;27:171–80.
22 Clayton-Smith A, Bennett K, Alston RP, et al. A comparison of the efficacy and adverse effects of double-lumen endobronchial tubes and bronchial blockers in thoracic surgery: A systematic review and meta-analysis of randomized controlled trials. J Cardiothorac Vasc Anesth 2015;29:955–66.
23 Campos J. Lung Isolation. In: Slinger P (Ed), Randal S. Blank · Javier Campos Jens Lohser and Karen McRae (Associate Editors). Principles and Practice of Anesthesia For Thoracic Surgery (Second edition). Springer, Cham. 2019. Pag 283-310.
24 Liu HH, Dong F, Liu JY, et al. The use of ETView endotracheal tube for surveillance after tube positioning in patients undergoing lobectomy, randomized trial. Medicine (Baltimore) 2018;97:e13170.
25 Groenewold MD, Olthof CG, Bosch DJ. Anaesthesia after neoadjuvant chemotherapy, immunotherapy or radiotherapy. BJA Edu 2022;22:12–9.
26 Collins SR, Titus BJ, Campos JH, et al. Lung isolation in the patient with a difficult airway. Anesth Analg 2018;126:1968–78.
27 Alhomary M, Ramadan E, Curran E, et al. Videolaryngoscopy vs. fibreoptic bronchoscopy for awake tracheal intubation: A systematic review and meta-analysis. Anaesthesia 2018;73:1151–61.
28 Granell M, Parra MJ, Jiménez MJ, et al. Review of difficult airway management in thoracic surgery. Rev Esp Anestesiol Reanim (Engl Ed) 2018;65:31–40.
29 Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: An updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2013;118:251–70.
30 Thomas V, Neustein SM. Tracheal laceration after the use of an airway exchange catheter for double-lumen tube placement. J Cardiothorac Vasc Anesth 2007;21:718–9.
31 Hansel J, Rogers AM, Lewis SR, et al. Videolaryngoscopy versus direct laryngoscopy for adults undergoing tracheal intubation. Cochrane Database Syst Rev 2022;4;CD011136.
32 Jiang J, Ma DX, Li B, et al. Videolaryngoscopy versus fiberoptic bronchoscope for awake intubation—A systematic review and meta-analysis of randomized controlled trials. Ther Clin Risk Manag 2018;14:1955–63.
33 Huang P, Qiu Y, Xu T, et al. GlideScope versus C-MAC D-blade videolaryngoscope for double-lumen tube intubation in patients with anticipated difficult airways: A multi-center, prospective, randomized, controlled trial. J Clin Anesth 2023;91:111274.
34 Tang JE, Tybout CE, Csernak LM, et al. Tracheal bronchus and successful right-sided isolation with a bronchial blocker. Semin Cardiothorac Vasc Anesth 2023;27:235–8.
35 Sato M, Hasegawa S, Shoji T, Wada H. Tracheobronchoplasty for resection of lung cancer arising from a tracheal bronchus. Ann Thorac Surg 2002;73:310–2.
36 Cameron RB, Peacock WJ, Chang XG, et al. Double lumen endobronchial tube intubation: Lessons learned from anatomy. BMC Anesthesiol 2024;24:150.
37 Arora D, Tewari P, Shamshery C, et al. 3D virtual bronchoscopy as an aid to airway management in a patient with anterior mediastinal mass. Ann Card Anaesth 2024;27:165–8.

38 Friedlander DA, Panigrahi R, Palaniappan D. Tracheal bronchus with difficult lung isolation: A case report. Semin Cardiothorac Vasc Anesth 2022;26:237–40.
39 Jain P, Nguyen DM, Fermin L, et al. Tracheal bronchus: Anesthetic implications and importance of early recognition in the context of bronchial blocker use for lung isolation. J Cardiothorac Vasc Anesth 2020;34:1019–22.
40 Xu Z, Zhang L, Liu Y, et al. Anesthetic management of one-lung ventilation in patients with tracheal bronchus: A narrative review. J Cardiothorac Vasc Anesth 2024;38:2426–32.
41 Kawamoto N, Furukawa M, Okita R, et al. Contralateral pulmonary resection using selective bronchial blockade in postpneumonectomy patients. Thorac Cancer 2020;11:3528–35.
42 Granell Gil M, Kawagoe I, Sentürk E, et al. Thoracic surgery in patients with previous lung resection. In: Granell Gil M, Şentürk M, editors. Anesthesia in thoracic surgery, Cham: Springer; 2020.. p. 313–25.
43 Gil MG, Rubio-Haro R, Morales-Sarabia J, et al. A new strategy in lung/lobe isolation in patients with a lung abscess or a previous lung resection using double lumen tubes combined with bronchial blockers. Ann Card Anaesth 2022;25:343–5.
44 Ren Y, Lyu Y, Yu Y, et al. Selective right middle and lower lobar blockade for minimally invasive cardiac surgery: A prospective, single-center, randomized controlled study. Ann Transl Med 2021;9:254.
45 Kawagoe I, Hayashida M, Suzuki K, et al. Anesthetic management of patients undergoing right lung surgery after left upper lobectomy: Selection of tubes for one-lung ventilation (OLV) and oxygenation during OLV. J Cardiothorac Vasc Anesth 2016;30:961–6.
46 Bussières JS, Somma J, Del Castillo JL, et al. Bronchial blocker versus left double-lumen endotracheal tube in video-assisted thoracoscopic surgery: A randomized-controlled trial examining time and quality of lung deflation. Can J Anaesth 2016;63:818–27.
47 Cheng Q, He Z, Xue P, et al. The disconnection technique with the use of a bronchial blocker for improving nonventilated lung collapse in video-assisted thoracoscopic surgery. J Thorac Dis 2020;12:876–82.
48 Smets D, Papegay B, Szegedi LL. Robot-assisted thoracic surgery and anesthesia. In: Granell Gil M, Şentürk M, editors. Anesthesia in thoracic surgery, Cham: Springer; 2020. p. 379–90.
49 Templeton TW, Piccioni F, Chatterjee D. An update on one-lung ventilation in children. Anesth Analg 2021;132:1389–99.