The anatomical landmarks for positioning of double lumen endotracheal tube using flexible bronchoscopy: A prospective observational study

Chao Liang*,1, Ling Jiang1, Yiming Liu1, Minmin Yao, Jing Cang, Changhong Miao**

Department of Anesthesiology, Zhongshan Hospital, Fudan University, Shanghai, China

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ABSTRACT

Background: To examine the tracheobronchial anatomy and its common variations after double-lumen tube (DLT) placement, and to determine the anatomical landmarks that can be easily identified by practitioners for DLT positioning.

Method: In total, 200 patients with American Society of Anesthesiologists I–II, who were aged 20–75 years and scheduled for video-assisted thoracic surgery (VATS), were prospectively enrolled. The types of DLT position in each patient was recorded [Type I, the DLT bronchial end was in the left main bronchus (LMB), and the primary carina could be observed; Type II, the DLT bronchial end was in the right bronchus intermedius (RBI); and Type III, an unidentified trachea or bronchus wall was observed from the DLT tracheal lumen] and the main tracheobronchial tree images were collected using Flexible bronchoscopy (FB).

Result: Five patients were excluded due to excessive bronchus secretions impacting image collection. Type I, II, and III positions of DLT were detected in 134 (68.7%) patients, 28 (14.4%) patients, and 33 (16.9%) patients, respectively. Examples of the tracheobronchial tree, common features, and variations in each lung lobe were demonstrated using FB. Furthermore, image analysis showed that each superior segment orifice of the right lower lobe (RLL) and left lower lobe (LLL) was less variable and recognizable, determining it an important anatomical landmark for DLT positioning.

Conclusion: The tracheobronchial tree and its common variations after DLT placement were described. The superior segment orifice of the RLL and LLL can be considered as an important landmark for DLT positioning.

1. Introduction

One-lung ventilation (OLV) is required in several clinical situations, especially in thoracic surgeries, allowing exposure of the surgical field in the operative lung and normal ventilation in the non-operative lung. The double-lumen endotracheal tube (DLT) is the most common method for OLV (Brodsky, 2015; Narayanaswamy et al., 2009; Zhong et al., 2009), allowing for faster placement, better lung isolation, and more accurate positioning than that when using other devices such as bronchial blockers (b-blockers) (Campos et al., 2006; Narayanaswamy et al., 2009).

The DLT consists of a distal bronchial end and a proximal tracheal end, wherein the former can extend into either the left or right side of the lung. Accurate DLT positioning, in particular, is a prerequisite for effective lung isolation and ventilation. The methods for DLT positioning mainly include flexible bronchoscopy (FB), auscultation, chest wall movement observation, measurement of peak inspiratory pressures during independent ventilation of each lung (Campos, 2009; Cohen, 2004; Kim et al., 2014), and Electrical impedance tomography (EIT) (Steinmann et al., 2008), with FB as the gold standard technique for the confirmation of accurate DLT positioning (Cohen, 2004). In fact, auscultation of each DLT lumen ventilation has been reported to be an unreliable method to verify DLT positioning, leading up to a 35% malposition incidence, which were all corrected by FB examination (Klein et al., 1998). As a non-invasive method, EIT enables accurate display of left and right lung ventilation and, thus identifies the misplacement of left-sided DLTs in the contralateral main bronchus. However, as distribution of ventilation do not correlate with endobronchial cuff placement, EIT cannot replace FB in the routine management of DLT position (Steinmann et al., 2008). A previous study suggested that for anesthesiologists who only occasionally use DLT, FB would be extremely helpful and should be used (Brodsky and Lemmens, 2003). However, for practitioners who are unfamiliar with tracheobronchial

* Corresponding author.
** Corresponding author.
E-mail addresses: liang.chao@zs-hospital.sh.cn (C. Liang), changhong1231988@126.com (C. Miao).
1 These authors contributed equally to this work.

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anatomical landmarks or with the use of FB, there was still a high incidence of malposition while placing lung isolation devices (Campos, 2009).

After DLT placement, the common procedures to verify its position using FB are as follows (for left-side DLT) (Campos, 2009; Klein et al., 1998; Park et al., 2020): First, when the FB is passed through the DLT tracheal lumen, the unobstructed right mainstem bronchus (RMB) should be identified, and the inflated endobronchial cuff should be positioned below the carina without herniation. Next, when the FB is advanced into the RMB, an unobstructed right upper lobe (RUL) bronchus with three segment orifices (apical, anterior, and posterior) should be identified. From there, when the FB is advanced through the endobronchial lumen, an unobstructed left upper lobe and lower lobe (LUL and LLL) bronchus should then be verified. Despite being commonly practiced, these procedures were found to have certain limitations. First, there is a high variation rate of RUL segments (Gonlugur et al., 2005), wherein only 40% of people have the standard three-segment orifices. Moreover, the identification of the right middle lobe (RML) and the lower lobe (RLL) was not clearly mentioned in these reported procedures. Given these limitations, unexperienced practitioners may face difficulty during FB examinations. For example, the RUL bronchus may be mistaken as the RMB when the left DLT distal bronchial end is inserted into the right bronchus intermedius (RBI), leading to a time-consuming reconfirmation procedure. As another example, practitioners may also be confused by the LUL and LLL anatomical landmarks, which may cause DLT distal impaction and LUL occlusion. Although it has been mentioned that the longitudinal elastic bundles (LEDs) extending into the LLL were useful landmarks to distinguish the lower lobe from the upper lobe (Foley and Slinger, 2014), we found that it was not present in all cases during the preliminary observation. Therefore, complete knowledge on the tracheobronchial anatomy and its common variations is the key factor for performing a fast and successful lung isolation device placement (Hosten and Topcu, 2011). Despite acknowledging this need, the tracheobronchial tree anatomical descriptions using an FB by anesthesiologists have not been comprehensively reported.

Therefore, we performed this study to investigate the application of an FB with a camera function in the DLT positioning of patients undergoing thoracic surgery, to examine the tracheobronchial anatomy and its common variations, and to determine the anatomical landmarks that can be easily identified by practitioners for rapid DLT positioning.

2. Materials and methods

This study was approved by the Institutional Review Board of Zhongshan Hospital, Fudan University (B2021-247), Shanghai, China. The trial was registered at http://www.chictr.org.cn/ (registration number: ChiCTR2100045522). Written informed consent was obtained from all patients before the study, and data were collected from April 19, 2021, to June 25, 2021.

Two hundred patients aged 20–75 years were prospectively enrolled in this study. All patients were noted to have American Society of Anesthesiologists (ASA) physical status classes I–II and were scheduled for video-assisted thoracic surgery (VATS) requiring OLV using left-sided DLT. However, patients who met the following conditions were excluded: restrictive lung disease, history of chronic obstructive airway disease, pneumothorax, difficult intubations, major airway anatomical abnormalities, main bronchus narrowing, tracheal deviation, pleural effusion, and dental problems. Additionally, if the left main bronchus (LMB) could not be intubated after three attempts or FB-guided intubation showed failure (switch to β-blockers), that patient would be excluded from the study.

2.1. Study protocol

Monitoring of each patient included electrocardiography, oxygen saturation, invasive blood pressure, and capnography. Before induction, an 18G cannula was inserted into a vein in the forearm, wherein lactated Ringer’s solution was administered. All patients were placed in the left lateral decubitus position, and a thoracic epidural catheter (19G; PaJunk GmbH Medizintechnologie, Germany) was inserted at the thoracic T7 to T8 epidural space by an experienced anesthesiologist. Induction was then performed using propofol target-controlled infusion (TCI) which used a three-compartment population pharmacokinetic model defined by Schneider et al. (1998) (the target plasma concentration was set at 4.0 μg/ml), remifentanil (0.2 μg/kg/min), sufentanil (0.2 μg/kg), and rocuronium bromide (0.6–0.8 mg/kg). During DLT placement, video laryngoscopy (Glidescope, Verathon, Inc., Bothell, WA, USA) was performed in all patients. According to previous studies (Hannahall et al., 1997; Narayanaswamy et al., 2009), DLT size depended on the patient, as measured by chest computed tomography, with the following recommended sizes and the corresponding LMB diameters: 35 Fr for diameters ≤11 mm, 37 Fr for diameters between 11 and 12 mm, and 39 Fr for diameters ≥12 mm. A flexible bronchoscope with camera functions (UESCOPE Flexible VideoScope, Zhejiang UE Medical Corp., China) was used to verify DLT positioning and collect tracheobronchial tree images.

2.2. Data collection

DLT placement was performed by different residents with varied experiences on performing thoracic anesthesia. The DLT was passed through the larynx, with its distal concave curvature oriented anteriorly, and the DLT stylet was removed after the endobronchial cuff had passed through the vocal cords. The tube was rotated 90° to the left and advanced until slight resistance was felt. The FB was then inserted immediately to verify the DLT position from right to left in an FB examination, which was performed by one experienced thoracic anesthesiologist, who had considerable experience using DLT and FB. According to our preliminary study, DLT positioning at initial FB examination was classified into three types: Type I, the DLT bronchial end was in the LMB, and the primary carina could be observed; Type II, the DLT bronchial end was in the RBI; and Type III, an unidentified trachea or bronchus wall was observed from the DLT tracheal lumen.

Moreover, the incidence of each DLT type was recorded. After necessary position correction, the DLT endobronchial cuff was inflated under FB guidance. Afterwards, the main tracheobronchial tree images were collected, mainly including the RUL bronchus and segment bronchus orifices, RML bronchus and segment bronchus orifices, RLL bronchus and segment bronchus orifices, LUL bronchus and segment bronchus orifices, and LLL bronchus and segment bronchus orifices. More specifically, FB examination was suspended when oxygen saturation dropped to 95%, and the remaining procedures were performed after brief mechanical ventilation with 100% oxygen.

2.3. Statistical analysis

Continuous variables were reported as mean and SD. Categorical demographic and clinical data were described as number of subjects and percentage.

3. Results

A total of 200 patients were enrolled between April 19, 2021, and June 25, 2021. From them, a total of five were excluded due to excessive bronchus secretions impacting image collection. Thus, exactly 195 patients were analyzed in this study (Table 1). After DLT placement, FB was used to verify DLT positioning. Our results showed that Type I DLT was detected in 134 (68.7%) patients, Type II in 28 (14.4%) patients, and Type III in the remaining 33 (16.9%). After necessary position correction by FB, and predetermined images were collected. According to the classic classification (Supplemental Table 1) (Gaye et al., 2001), the image of a patient’s tracheobronchial tree is illustrated in Figure 1. For better understanding, we rotated all images in the same direction as the FB screen.
facing the patient's head, clearly illustrating the segment bronchus orifices of the RUL, RML, RLL, LUL, and LLL. The image examples of the Type II and III DLT positions are further illustrated in Figure 2.

As shown in Figure 3, seven types of RUL bronchial division were recorded, and the image examples are illustrated as follows: The most common, Type I, occurred in 74 (37.9%) cases; Type II in 40 (20.5%); Type III in 35 (17.9%); Type IV in 25 (12.8%); Type V in 13 (6.7%); Type VI in 2 (1%); and RUL quadfurcation was seen in 6 (3.1%) cases.

Image examples of the common features of the RML, RLL, LUL, and LLL are shown in Figure 4. RML with two-segment bronchus orifices were detected in 167 (85.6%) cases, whereas RML with three-segment bronchus orifices were detected in 28 (14.4%) cases. With the exception of rare variations, RML with five-segment bronchus orifices were detected in 25 (12.8%) cases. In LUL, the four-segment bronchus orifices of LB1 [LLL anterior basal segment] and LB9 [LLL lateral basal segment] combination, or LB9 with LB10 [LLL posterior basal segment].

Some rare variations detected in the tracheobronchial tree in the present study are shown in Supplemental Figure 1. Tracheal bronchus was detected in two (1%) cases, and an accessory cardiac bronchus (ACB) was detected in only one (0.05%) case. In RLL, the absence of RB7 was detected in three (1.5%) cases, whereas the subsuperior segment was detected in five (2.6%) cases. In LUL, the LB1 from upper lobe division was detected in three (1.5%) cases, and LUL with three segments was detected in 13 (6.7%) cases.

After comprehensive analysis of these images, the "mirror images" of RLL and LLL were verified, and our finding that both superior segment of RLL and LLL were less variable (100% identified). Moreover, in the view of FB, each superior segment orifice was the first appearing segment of the RLL and LLL, which can be easily recognized. However, clear LEDs extension into both RLL and LLL was present only in 116 (59.5%) cases (Figure 5). In addition, a flowchart of suggested DLT position verifying procedures was illustrated (Figure 6).

4. Discussion

In patients requiring lung isolation, DLT is the most commonly used device, and FB is the most reliable tool for verifying DLT positioning. However, the high tracheobronchial tree variation rate and the anesthesiologist’s limited anatomical knowledge may restrict skilled FB application and waste time during DLT positioning. Thus, the present observational study systematically described the tracheobronchial tree and its variations after DLT placement using FB, which can be utilized as a reference or educational material for thoracic anesthesiologists.

It has been found that single-FB examination is sufficient to verify the position of lung isolation devices (Campos et al., 2006; Narayanaswamy et al., 2009; Park et al., 2020). In the present study, the initial DLT positions observed by FB were classified into three types. In Type I, the DLT bronchial end was in the LMB, and the primary carina could be observed, only requiring minor DLT position adjustments (slightly forward or

### Table 1. Demographic characteristics of the study population.

| Variables               | n (%) |
|-------------------------|-------|
| ASA status, n I         | 112 (%)|
| II                      | 83 (%) |
| Age, year               | 55 ± 12|
| Gender (male/female), n | 87/108|
| Body mass index, kg/m²  | 24 ± 3|
| Surgery Type, n (%)     |       |
| Lobectomy               | 82    |
| Segmentectomy           | 71    |
| Wedge resection         | 42    |

![Image of a patient’s tracheobronchial tree. A. RL: right lung; LL: left lung; B. RUL: right upper lobe; RML: right middle lobe; RLL: right lower lobe; D. LUL: left upper lobe; LLL: left lower lobe; RB1: RUL apical segment; RB2: RUL posterior segment; RB3: RUL anterior segment; RB4: RML lateral segment; RB5: RML medial segment; RB6: RLL superior segment; RB7: RLL medial basal segment; RB8: RLL anterior basal segment; RB9: RLL lateral basal segment; RB10: RLL posterior basal segment; LB1 +2: upper lobe apicoposterior segment; LB3: upper lobe anterior segment; LB4: Lingula superior segment; LB5: Lingula inferior segment; LB6: LLL superior segment; LB8: LLL anterior basal segment; LB9: RLL lateral basal segment; RB10: LLL posterior basal segment.](image-url)
backward). More importantly, the Type II DLT position needs to be emphasized, as it is this type wherein unexperienced practitioners may connect the DLT to the ventilator after FB examination or perform auscultation to reconfirm DLT positioning, which is a time-consuming process. Moreover, the Type II DLT position is commonly addressed by pulling the DLT bronchial end backwards to the main trachea and reinserting it under FB guidance from the DLT bronchial lumen. Meanwhile, in Type III, given that an unidentified trachea or bronchus wall was observed by FB from the DLT tracheal lumen, several positions are possible. For example, if it was caused by the DLT bronchial end being placed too deep in the LMB or inserted into the LLL bronchus, it can be addressed by pulling the DLT backward under the guidance of FB from the DLT tracheal lumen. However, if the DLT was rotated greatly or the DLT bronchial end was in the RMB, this can be solved by pulling the DLT bronchial end backwards to the main trachea and reinserting it under FB guidance from the DLT bronchial lumen. Although all type II and III DLT positions were corrected by FB in present study, in rare situation when the DLT bronchial end cannot be inserted into the LMB even under FB guidance from the DLT bronchial lumen, other lung isolation devices should be considered, such as b-blocker. After the patients were turned to the lateral position, the DLT position was reconfirmed and adjusted by FB.

The general tracheobronchial tree anatomy and its variations in the present study are consistent with those described in previous studies (Beder et al., 2008; Gonlugur et al., 2005; Smith et al., 2018). In general, the RUL bronchus divides into three segmental bronchi, which are regarded as important landmarks during DLT positioning — the anterior, posterior, and apical segments (Campos, 2009; Foley and Slinger, 2014).

Figure 2. The image examples of Type II and Type III DLT position. A, Type II: the DLT bronchial end was in right bronchus intermedius (RBI). From the DLT tracheal lumen, the secondary carina (a) and the orifices of RUL were observed (b). From the DLT bronchial lumen, the unidentified bronchus orifices were observed (c). B, Type III: an unidentified trachea or bronchus wall was observed from the DLT tracheal lumen (d). From the DLT bronchial lumen, the unidentified bronchus orifices were observed (e).

Figure 3. The seven types of RUL bronchus division. Type I: all three segmental bronchi branch out independently of each other. Type II: the apical and the anterior segmental bronchi form a common trunk and the posterior segmental bronchus branches independently. Type III: the apical and the posterior segments are combined and the anterior branch is independent. Type IV: the anterior and the posterior segment form a common trunk and apical is independent. Type V: the posterior segment is absent and all subsegments arise from the apical and the anterior segments. Type VI: the apical segment is absent and all the subsegments arise from the other two segments. The quadrifurcation of RUL.
While no cases had a left tracheal bronchus, attributing to its low incidence (Cheng et al., 2020) and study’s small sample size. Moreover, although there is a low ACB incidence (frequency: 0.08%) (Ghaye et al., 2001), we detected one case with this uncommon variation. We also illustrated the typical images of these uncommon variations, including the absence of the RB7, the subsuperior segment, the LBI from the upper lobe division, and the LUL with three segments. The incidences of these variations were slightly different from those reported in previous studies (Beder et al., 2008; Ghaye et al., 2001), which may be attributed to the sample size and population differences. Despite this, we believe that practitioners who are familiar with this knowledge will have more confidence when performing an FB examination.

Data from the present study are also an important anatomic basis for anesthesiologists to perform selective segmental inflation, which can facilitate surgical resection (Beiras-Fernandez et al., 2007; Okada et al., 2007). Novel DLT, such as Viva Sight DLT among others, which is a single-use DLT with an embedded video imaging device, allowing intraoperative confirmation of proper tube positioning and facilitated repositioning when necessary (Schuepbach et al., 2015). However, a systematic review article showed that even after VivaSight DLT use, an FB was still needed. Additionally, VivaSight DLT may cause soft tissue trauma, such as bleeding, hematoma, edema, and erythema, as well as complications of sore throat and dysphonia (Saracoglu and Saracoglu, 2016). While there are also some limitations in present. Firstly, we only selected the left-sided DLT as it was the most commonly used lung isolation device, thus we did not investigate these tracheobronchial anatomies under right-side DLT or b-blocker use. However, it should be noted that the main purpose of the present study was to determine the normal anatomy and common variations of the tracheobronchial tree, wherein practitioners should already be skilled enough during FB examination if they are familiar with these anatomical knowledges, regardless of the lung isolation device applied. Secondly, the DLT position examination by FB was performed by one experienced thoracic anesthetist, and thus the findings were based on only one person’s judgement, which would bias the results. In addition, although DLT placement was performed by different residents with varied experiences on performing thoracic anesthesia, we did not systematically record or

Figure 4. The image examples of common features of RML, RLL, LUL and LLL. A. The segment bronchus orifices of RML. B. The segment bronchus orifices of RLL. C. The segment bronchus orifices of LUL. D. The segment bronchus orifices of LLL.
Figure 5. The image example of the mirror images of RLL and LLL, and the image example of the longitudinal elastic bundles (LEDs) extending into RLL and LLL. A, B: The image example of the mirror images of RLL and LLL of a case with clear LEDs. C, D: The image example of the mirror images of RLL and LLL of a case without clear LEDs.

Figure 6. A flowchart of suggested DLT position verifying procedures.
classify the experiences of each resident, therefore, the correlation between the residents' experiences and DLT position types are lacking. Finally, there was no hypothesis or comparison in this descriptive study; therefore, testing the performance of fresh anesthesiologists in DLT position verification after knowing the tracheobronchial tree anatomy is the goal of our future study.

In conclusion, the tracheobronchial tree and its common variations after DLT placement using FB were described in the present study. It is important that the anesthesiologist be familiar with this anatomical knowledge, which may help to rapidly confirm the accurate position of DLT or other lung isolation devices through the FB. Moreover, the results from this study indicated that the superior segments of the RLL and LLL were less variable and recognizable, and therefore can be assigned as the anatomical landmark for rapid DLT positioning through the FB.

Declarations

Author contribution statement

Chao Liang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ling Jiang: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Yiming Liu: Conceived and designed the experiments; Analyzed and interpreted the data.

Minmin Yao: Analyzed and interpreted the data.

Jing Cang: Changhong Miao: Conceived and designed the experiments; Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interest’s statement

The authors declare no conflict of interest.

Additional information

The clinical trial described in this paper was registered at [http://www.chictr.org.cn/] under the registration number ChiCTR210004-5522.

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References

Beder, S., Kupeli, E., Karnaş, D., Kayasan, O., 2008. Tracheobronchial variations in Turkish population. Clin. Anat. 21, 531–538.

Beiras-Fernandez, A., Kur, F., Kuzmarenk, I., Eifert, S., Oberhoffer, M., Silber, S., Reichart, B., Vicol, C., 2007. Aberrant origin of the left main coronary artery arising from the right coronary artery associated with coronary artery disease: a case report. Heart Surg. Forum 10, E175–E176.

Brodsky, J.B., 2015. Cox: a bronchial blocker is not a substitute for a double-lumen endobronchial tube. J. Cardiothorac. Vasc. Anesth. 29, 237–239.

Brodsky, J.B., Lemmens, H.L., 2003. Left double-lumen tubes: clinical experience with 1,170 patients. J. Cardiothorac. Vasc. Anesth. 17, 289–296.

Campos, J.H., 2009. Update on tracheobronchial anatomy and flexible fiberoptic bronchoscopy in thoracic anesthesia. Curr. Opin. Anaesthesiol. 22, 4–10.

Campos, J.H., Hallam, E.A., Van Natta, T., Kerner, K.H., 2006. Devices for lung isolation used by anesthesiologists with limited thoracic experience: comparison of double-lumen endotraheal tube, Univent torque control blocker, and Arndt wire-guided endobronchial blocker. Anesthesiology 104, 261–266 discussion 265A.

Cheng, L., Liu, S., Qi, W., Dong, Y., 2020. The incidence of tracheal bronchus in thoracic surgery patients and its implication for lung isolation: a retrospective cohort study. J. Cardiothorac. Vasc. Anesth. 34, 3068–3072.

Cohen, E., 2004. Double-lumen tube position should be confirmed by fiberoptic bronchoscopy. Curr. Opin. Anaesthesiol. 17, 1–5.

Foley, K.A., Slinger, P., 2014. Fibreoptic bronchoscopic positioning of double-lumen tubes. Anaesth. Intensive Care Med. 15, 505–508.

Ghayar, B., Szapiro, D., Fanchamps, J.M., Dondelinger, R.F., 2001. Congenital bronchial abnormalities revisited. Radiographics 21, 105–119.

Gonlugur, U., Eroglu, T., Kaptanoglu, M., Akkurt, I., 2005. Major anatomical variations of the tracheobronchial tree: bronchoscopic observation. Anat. Sci. Int. 80, 111–115.

Hannahal, M., Benumof, J.L., Silverman, P.M., Kelly, L.C., Lea, D., 1997. Evaluation of an approach to choosing a left double-lumen tube size based on chest computed tomographic scan measurement of left mainstem bronchial diameter. J. Cardiothorac. Vasc. Anesth. 11, 168–171.

Hosten, T., Topcu, S., 2011. The importance of bronchoscopic anatomy for thoracic surgery patients and its implication for lung isolation: a retrospective study. J. Cardiothorac. Vasc. Anesth. 25, 397–404.

Klein, U., Karzai, W., Bloos, F., Wohlfarth, M., Gottschall, R., Fritz, H., Gugel, M., Klein, C., 2013. The importance of bronchoscopic anatomy for surgical planning of double-lumen intubation. Curr. Opin. Anaesthesiol. 26, 769–772.

Lacroix, M., 2009. Choosing a lung isolation device for thoracic surgery: a comparison of conventional and fiberoptic-guided advance of left-sided double-lumen tubes. J. Cardiothorac. Vasc. Anesth. 23, 762–769.

Oktar, A., Saracoglu, A., Saracoglu, K.T., 2009. VivaSight: a new era in the evolution of tracheal tubes. J. Clin. Anesth. 21, 442–449.

Priebe, H.J., Guttmann, J., 2008. Electrical impedance tomography to confirm correct placement of double-lumen tube: a feasibility study. Br. J. Anaesth. 101, 411–418.

Steinmann, D., Stahl, C.A., Minner, J., Schumann, S., Loop, T., Kirschhaum, A., Priewe, H.J., Guttmann, J., 2008. Electrical impedance tomography to confirm correct placement of double-lumen tube: a feasibility study. Br. J. Anaesth. 101, 411–418.

Zhang, T., Wang, W., Chen, J., Ran, L., Story, D.A., 2009. Sore throat or hoarse voice with bronchial blockers or double-lumen tubes for lung isolation: a randomised, prospective trial. Anaesth. Intensive Care 37, 441–446.