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Review Article

Routine Application of Fiberoptic Bronchoscopy in the Positioning of Double-Lumen Endobronchial Tube

Liu Zhang*, Huiping Li*, and Chaoran Wu

From the Department of Anesthesiology, Laboratory of Anesthesia and Critical Care Medicine, Translational Neuroscience Center, West-China Hospital of Sichuan University, Chengdu, China.

*Contributed equally to this work.

Correspondence to Dr. Chaoran Wu at chaoranwu@126.com.

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ABSTRACT

Aim of review: This review aimed to present an overview of reports and current opinions regarding the application of fiberoptic bronchoscopy (FOB) in the positioning of double-lumen endobronchial tube (DLT), and to compare the respective merits and demerits of FOB and the blind method.

Methods: Related literature was retrieved from the databases, including PubMed, Embase, Ovid Medline, ScienceDirect, Cochrane databases, and SpringerLink using the keywords of “double lumen tube” or “lung separation” or “one lung ventilation” and “auscultation” combined with “fiberoptic bronchoscopy” from inception to April 1, 2018. The retrieved literature was then carefully read by the authors and summarized with caution.

Recent findings: The correct position of DLT was of great importance, since a misplaced or improperly used tube could imperil any operation or even lead to a serious catastrophe. However, the conventional blind way still prevailed in most institutions. By contrast, FOB was superior in correctly positioning a DLT, reducing airway injury, shortening the intubation time and contributing to a rapid diagnosis of abnormal ventilation.

Summary: FOB should be applied as a routine in the positioning of DLT after taking into account the importance of correct DLT positioning in the one-lung ventilation and the potential critical sequelaes induced by the considerable number of malpositions. (Funded by the National Natural Science Foundation of China.)

Fiberoptic bronchoscopy (FOB) is ranked as the gold standard to verify the correct positioning of a double-lumen endobronchial tube (DLT) since its first description by Shinnick in 1982 (1). However, it remains a source of controversy regarding whether FOB should be applied as a routine in the positioning of DLT (2-4). Therefore, a comprehensive understanding of the benefits of FOB would assist in risk-benefit decision-making. Recently, the visualization technology is integrated with traditional double-lumen tube, which renders the emergence of VivaSight double-lumen tube, marking the new update in one-lung ventilation. However, a systematic review by Saracoglu et al. indicated that, the VivaSight double-lumen tube displayed a faster tracheal intubation and a higher success rate at the first attempt, but it manifested no advantage in reducing the necessity of bronchoscopy, since the camera in the VivaSight could not detect and prevent a DLT that was too far in or out the wrong lung (5, 6). Furthermore, severe adverse events have also been reported for the VivaSight, such as melting due to the heat of light source and sudden shutdown without warning (7). Therefore, this review aimed to present an overview of reports and current opinions regarding the application of FOB in DLT positioning in comparison to the blind methods.

Accurate Positioning of a DLT

FOB has long been introduced into DLT positioning; however, the conventional blind way still prevails in most medical institutions. As indicated in numerous studies, auscultation alone is unreliable for the correct positioning of DLT (Table 1). For instance, in one study involving 200 patients, FOB inspection suggested that 38.0% DLTs positioned with auscultation required reposition by at least 0.5 cm. Among them, 40.5% DLTs had the tip occluding the respective upper lobe orifice, and 20.8% had the endobronchial cuff in the wrong mainstem bronchus, while 38.7% at or above the carina (8). In another study enrolling 23 patients assessed with a FOB following intubation with the blind method, 48% of the blindly placed DLTs were mispositioned (9). In addition, a study including 200 patients demonstrated that, 79 of the 172 (45.9%) DLTs thought to be well positioned by clinical examination were subsequently revealed to be mispositioned by FOB, among which 25(14.5%) were critical (those that might influence the surgical procedure or affect patient safety if left unadjusted) (10). Another study recruiting 24 patients suggested that FOB confirmation had resulted in the reposition of 78% left-sided and 83% right-sided DLTs, after satisfactory evaluation by auscultation (11). Such results were consistent with those from recent studies. For example, the study by de Bellis M et al. revealed that FOB inspection had discovered 32% left-sided DLTs that required to be moved for >0.5 cm to correct their positions, along with 5% dislocated DLTs in the right main bronchus, despite the satisfying clinical evaluation with auscultation (12). Furthermore, 46.7% (14 / 30) DLTs were confirmed by FOB to be either too deep or too shallow in the study by Liu Z et al., in which an endobronchial cuff of 0.5 to 1.0 cm below the carina was considered as the optimal position (13). Obviously, the above evidence suggests that auscultation alone seems not so reliable.

Breath sound, which may be influenced by its intensity, the chest wall thickness, and experience of the anesthetic practitioner, accounts for the main reason for the unreliability of auscultation. For example, breath sounds heard at the upper lobe may be transmitted from the ipsilateral lower lobe or from the contralateral lung across the mediastinum. Thus, it can hardly determine whether the minimized or disappeared breath sound is associated with the occlusion of the ipsilateral upper lobe orifice. The same is true for patients with underlying different breath sounds secondary to lung disease or situations when the bronchial cuff is not completely located in the main bronchus or is sufficiently inflated.

A prospective study involving 21 adult patients undergoing elective thoracic surgery suggested no significant differences in PaO2 value between patients with correctly and incorrectly positioned tubes according to FOB (two-lung ventilation: 494 ± 99 vs 454 ± 91 mmHg or one-lung ventilation: 254 ± 125 vs 169 ± 95 mmHg) (14). However, the limited evidence and the small sample size revealed that their effectiveness should be adequately assessed. Moreover, these fine mispositioned tubes would lead to the possibility of inadequate lung separation. Eventually, the contralateral lung may be at risk of contamination of blood, water, or pus from the diseased one during surgery (2).

A National Confidential Enquiry in Britain published in 1998 demonstrated that 30% deaths of British patients undergoing major thoracic surgery were related to DLT malfunctioning, which would induce prolonged duration of hypoxemia and hypoventilation, thus requiring multiple tube repositions (2). Unfortunately, FOB was not employed by them to assess the positioning of DLT (2). Besides, it is important to note that even a small volume of pus aspirated into the dependent lung can lead to severe postoperative pneumonia, which may subsequently give rise to fatal sepsis and multi-organ dysfunction syndrome (15).

On the other hand, occlusion of the left or right upper lobe of bronchus, which can not be detected by auscultation in most cases, may contribute to intraoperative lobar collapse in the dependent lung and add to the risk of postoperative infections (2). Besides, herniation of the bronchial cuff over the carina undetected in clinical assessment may slip out into the trachea or partially occlude the ipsilateral bronchus, resulting in hypoxemic episodes during one-lung ventilation.

Additionally, the correctly positioned tubes may dislocate after position shifting in patients. For example, FOB assessment had disclosed comparable rates of displacement (35.4% vs 34.6%) in polyvinyl chloride and silicone left-sided DLTs after changing patients from supine to lateral position Moreover, 8.3% polyvinyl chloride and 7.9% silicone DLTs had herniated to the right main bronchus (16). Thus, it is essential to determine the DLT positioning immediately after intubation and lateral positioning (10, 17). A tube that is confirmed by FOB to be correctly positioned in the supine position would greatly facilitate the second and further inspection in the lateral position or during operation. Additionally, a mispositioned tube can hardly be accurately repositioned after turning the patient to the lateral position intraoperatively (4).

Solid evidence from randomized controlled trials (RCTs) over the long-term potential adverse effects of fine mispositioned tubes is lacking, such as hypoxemia, failed non-dependent lung collapse, tracheobronchial injury, pulmonary atelectasis, and postoperative pneumonia. Nevertheless, it seems reasonable to routinely employ FOB in DLT positioning, given the catastrophic outcome of failed lung isolation.

Table 1. Clinical Reports for the Use of DLT.

Studies	Study Designs	Malposition Rate	Notes
Lewis et al. (8)	Prospective observational study, n = 200	38.0%	In 40.5% of the patients, the respective upper lobe orifice was occluded by the bronchial tip, in another 38.7%, the endobronchial cuff was at or above the carina and the remaining 20.8% in the wrong mainstem bronchus.
Smith et al. (9)	Prospective observational study, n = 23	48.0%	In 11 of the 23 patients (48%), less than satisfactory. In 4 patients (17%), herniation of the bronchial cuff over the carina. In 6 patients (26%) unable to see the bronchial cuff and the last 1 patient (4%) narrowing of the bronchial lumen.
Klein et al. (10)	Prospective observational study, n = 200	45.9%	Too distal n = 52 (65.8%), too proximal n = 18 (22.8%), overinflated of the bronchial cuff n = 7 (8.9%), underinflated of the bronchial cuff n = 2 (2.5%).
Alliaume et al. (11)	Prospective observational study, n = 24	78% for L-DLT, 83% for R-DLT	Correct DLT positioning was not possible with auscultation in 5 patients (28%) despite several attempts.

DLT, double lumen endobronchial tube; L-DLT, left double-lumen endobronchial tube; R-DLT, right double-lumen endobronchial tube.

Table 2. Intubation Time of DLT.

Studies	Study Designs	Patients	Results
Boucek et al. (27)	Prospective randomized study, n = 58	Patients undergoing thoracic surgery requiring endobronchial intubation	Meantime for fiberoptic-guided method and auscultation is 181 vs 88 seconds.
Cheong et al. (28)	Prospective randomized study, n = 30	Patients undergoing thoracic surgery	Meantime for fiberoptic-guided method and auscultation is 106 vs 347 seconds.

DLT, double lumen endobronchial tube.

Reducing Airway Injury

As proposed in several studies, the largest DLT that can successfully fit the bronchus should be preferentially employed (3, 18). Nevertheless, it should be noted that an over-large DLT may potentially increase the injury to the mucosa of both the airway and the vocal cords. For instance, in a case reported by Hannallah (19), a small left mainstem bronchus (9 mm) was intubated with an over-large DLT. After blind reposition for twice intraoperatively, owing to inadequate non-dependent lung collapse, a 3-4 cm laceration was noticed in the left mainstem bronchus. What' s worse, atelectasis and pneumonia also occurred postoperatively. Similarly, Yuceyar et al. also reported the same problem in their study, in which a large DLT was employed to achieve lung isolation, resulting in a 2 cm longitudinal laceration in the left mainstem bronchus (20).

On the other hand, an over-large DLT would also add to increased resistance during intubation. Furthermore, a large DLT will fit tightly in the mainstem bronchus, and inflation of the bronchial cuff with even 1 ml of air would lead to a remarkable distention of the bronchial wall, thus contributing to bronchial injury (19).

However, an undersized DLT would also lead to increased risk of airway injury. For example, Sivalingam et al. had reported a DLT migrated far into the left lower bronchus, which resulted in tension pneumothorax and pneumomediastinum, since the whole tidal volume was delivered into a single lobe when a small DLT was employed (21). In addition, a laceration in the left mainstem bronchus was also observed in another case, as the undersized DLT went far into the left mainstem bronchus (22).

So far, many methods have been put forward to select the proper size of DLT, such as chest radiograph and CT scan. Nonetheless, there is still possibility of selecting an inappropriate size of DLT. On this account, the application of FOB can greatly reduce airway injury secondary to the inappropriate size of DLT. This is because that, a tube either too big or too small will be easily detected under a direct vision, before the attendant risks of forceful intubation or traumatic blind attempts.

Noticeably, FOB guidance in DLT intubation can also potentially reduce airway rupture. For example, Conti et al. had speculated that the direct laceration from the endotracheal tube tip to the flaccid posterior tracheal membrane during tube insertion was the most possible mechanism of the iatrogenic tracheobronchial rupture (23). Moreover, another study in which a patient with a past medical history of radiotherapy underwent surgery for oesophageal cancer suggested that the tracheobronchial rupture might probably be avoided if a FOB was applied (24).

Another merit of FOB is that the potential overdistention of the cuff can be discovered without causing ischemia to the airway mucosa while offering a sufficient seal to the airway, since overinflation of either the bronchial or tracheal cuff is the most common causative factor of airway rupture (25). Besides, Ceylan et al. had reviewed 18 cases with tracheobronchial rupture after double-lumen tube intubation from January 1999 to October 2010, and discovered that a considerable number of airway rupture would have been avoided if a FOB was employed (26).

Finally, a distally mispositioned DLT may cause a severe injury to the bronchial tree or even a tracheal rupture when turning the patient to the lateral decubitus position (10). In one study conducted by Boucek et al. (27), the FOB guided approach was comparable to the traditional blind method with regard to airway trauma; nevertheless, the airway injury was disastrous. Therefore, the application of FOB in lung separation is imperative considering that the actual incidence of airway damage from DLT is certainly under-reported.

Shortening the Intubation Time

Scarce studies are available to compare the intubation time between the traditional blind and the FOB-guided approaches. After a systematic literature retrieval from Ovid Medline, Embase, Pubmed, and Cochrane Library databases up to April 2017, only two studies comparing the intubation time between the traditional blind and FOB-guided approaches were found, but they had yielded opposite outcomes (27, 28) (Table 2). Specifically, the study by Boucek et al. (27) involving 58 patients published in 1998 suggested that the FOB-guided approach required more time in intubation (88 vs 181 s, $P = 0.029$). Contrarily, Cheong et al. (28) who studied 30 patients in 1999 discovered that, compared with the traditional blind approach, FOB guidance could greatly reduce the time required to correctly place a DLT (mean 347 vs 106 s, $P<0.05$).

It was found after a careful review of the methods used in these two studies that, the FOB-guided approaches described in these two articles were slightly different. Concretely, in the study by Cheong et al. (28), FOB was introduced into DLT positioning when the double-lumen tube had passed the glottic opening and laryngoscopy was removed. However, in the study by Boucek et al. (27), FOB was applied immediately after the tip of DLT had passed through the vocal cord, while the large proximal lumen and cuff remained above the vocal cords. At the same time, the practitioner had to manage the laryngoscope, the DLT and FOB simultaneously, so the proximal lumen and tracheal cuff of DLT were often advanced without a clear vision. Accordingly, it was not surprising to find that the FOB-guided approach took more time in the study by Boucek et al. (27).

In addition, personal experience of FOB also plays a crucial role in reducing the intubation time, and the position of DLT can be confirmed when bronchoscope is employed. Clearly, FOB is a useful tool that every thoracic anesthetic practitioner should master. With the accumulation of the experience in using FOB, the outstanding time-saving superiority of FOB is expected to fully manifest.

New Advances in DLT Positioning

Recently, various methods have been proposed to position a DLT. For instance, Liu Z. (13) had measured the distance between the vocal cord and carina using chest computed tomography (CT) to guide the positioning of DLT, and found that 27 out of 30 patients were in an optimal position after FOB assessment. However, such maneuver was not applicable to patients whose glottis was invisible. In addition, Saporito A et al. (29) had visualized the sliding sign at the costophrenic angles as well as diaphragmatic movements by thoracic ultrasound to confirm adequate lung separation, which had yielded equal sensitivity and specificity. Besides, Alvarez-Diaz N et al. (30) had compared the ultrasound method with the traditional blind method, and discovered a significant difference in sensitivity (98.6% vs 84.5%, P = 0.002) after FOB confirmation. However, thoracic ultrasound is associated with several limitations in confirming lung separation. Firstly, it can be interfered by various diseases in lung parenchyma, such as pneumothorax, pleural adhesion, and pulmonary consolidation. Secondly, lung ultrasound can hardly determine whether the bronchial cuff would partially occlude the opposite bronchus. Thirdly, ultrasound can only confirm whether the right lung is adequately isolated from the left one, but it can not guide the positioning of a DLT for repeated tracheal intubations. On this account, FOB seems to be an indispensable accessory for DLT positioning.

Conclusions

Considering the significance of correct DLT positioning in one-lung ventilation, and the potential severe sequelaes resulted by a considerable number of malpositions, FOB should be applied as a routine in the positioning of DLT. Apart from the benefits in guaranteeing correct positioning and the adequate cuff volume to avoid subsequent complications, FOB also contributes to the rapid diagnosis and management of abnormal ventilation. In view of the potential airway injury during the course of intubation, the FOB-guided approach should be preferred to minimize the potential trauma.

The following key points should be noted to better use a FOB:

Strict sterilization is required; otherwise, cross-infection may follow.

Minimize cervical spine movement to avoid dislodgment (31).

Profound knowledge of the bronchoscopic airway anatomy is necessary to prevent misidentification of the view.

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