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Airway troubles related to the double-lumen endobronchial tube in thoracic surgery

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Abstract

Purpose. Several case reports indicate critical respiratory complications in relation to the double-lumen endobronchial tube (DLT). A prospective survey for the airway problems in using the DLT is presented.

Methods. One hundred adult patients undergoing thoracotomy for lung cancer were investigated. Tube malposition and airway obstruction were searched using a fiber-optic scope. The endobronchial cuff was positioned just below the tracheal carina while the trachea was intubated with a DLT (Rüsch). The distances of displacement, from the tracheal carina to the bronchial cuff, were measured during anesthesia using an epidural catheter, which had marks every 5 mm. The distances for correcting the tube position were measured at both the bronchial cuff and the level of the teeth. PaO_2, $PaCO_2$ and SPO_2 were also measured.

Results. Malposition (displacement over 5 mm from the correct position) was found in 42 patients, and 40 of them were in a withdrawal direction, occurring at the postural change and during one-lung ventilation, especially during manipulation of the lung hilum. Correcting distances at the level of the teeth were 1.5–3-times longer than those at the bronchial cuff. Airway deformities and gradual withdrawal of the bronchial cuff were found in association with surgical manipulation. Obstruction occurred at the tips of the tracheal tube in four patients and the bronchial tube in six patients, and at the tip of both in two patients. Hypoxemia ($PaO_2 < 60$ mmHg) occurred in four patients and hypercapnea ($PaCO_2 > 60$ mmHg) in two patients.

Conclusion. Most of the DLT obstructions were associated with withdrawal malposition. Great attention to DLT displacement and airway deformity is advised.

Key words: Double-lumen tube, Complications, Tube troubles, Airway obstruction, One-lung ventilation

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Introduction

In thoracic surgery, one-lung ventilation is carried out using a double-lumen tube (DLT) to improve the surgical condition [1,2]. Disposable plastic DLTs are widely available, and ventilation techniques have improved owing to an appropriate use of a fiber-optic scope. However, critical respiratory complications such as severe hypoxemia or cardiac arrest have been reported in relation to the DLT [3–5]. Recently, we experienced an airway obstruction, followed by severe hypoxemia, resulting from withdrawal displacement of the DLT. Regarding mechanical airway problems with the DLT, there have been few prospective studies. We therefore investigated airway problems associated with the use of the DLT for one-lung ventilation during lung cancer surgeries to clarify when and how the airway problems occur.

Methods

Patients

One hundred adult patients undergoing thoracotomy for lung cancer were investigated. Their ages were 62 ± 11 (36–84) years (mean ± standard deviation (SD), range), their heights 159 ± 9 (140–180) cm, and their body weights 55 ± 7 (36–71) kg. The study protocol was approved by the Institutional Human Study Committee, and consent was obtained from each patient.

Anesthesia and ventilation procedures

General anesthesia (sevoflurane or isoflurane, nitrous oxide in oxygen) was combined with thoracic epidural anesthesia. Following induction of anesthesia, the trachea and bronchus were intubated with a DLT (Rüsch, Kernen, Germany) under sufficient muscle re-

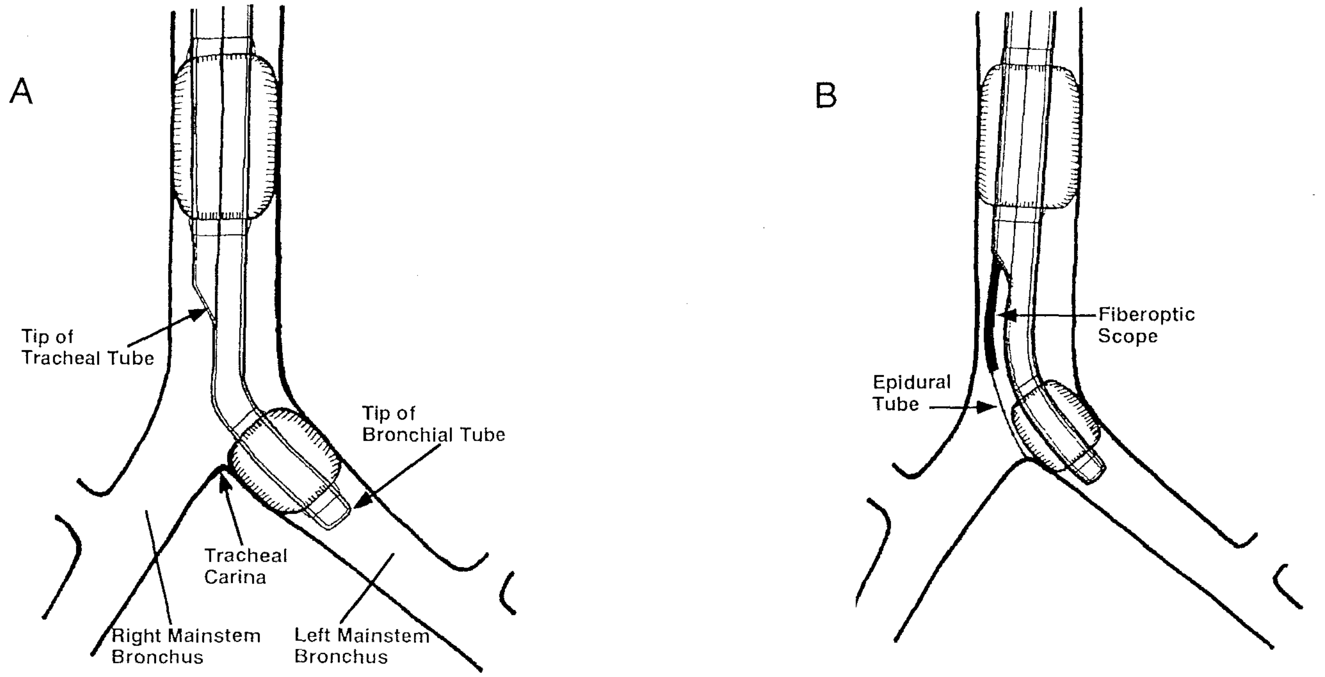


Fig. 1. A Correct position for the left-sided double-lumen tube. The tip of the bronchial tube is in the mainstem bronchus and the proximal end of the bronchial cuff is in contact with the tracheal carina. **B** A typical malposition of the double-lumen tube and the method of measuring displacement. The bronchial cuff has withdrawn into the trachea proximally. An epidural catheter marked every 5mm is inserted through the fiber-optic scope, and the distance of the displacement between the tracheal carina and proximal end of the bronchial cuff is measured

laxation. A left-sided DLT was used if possible except when the operation involved the left mainstem bronchus. Following intubation, correct positioning of the DLT was confirmed using a fiber-optic scope (outer diameter 3.5mm, FP10, Pentax, Tokyo, Japan). In the correct position, the tip of the bronchial tube was placed in the mainstem bronchus and the bronchial cuff, inflated with 0.5–1.0ml of the air, was positioned in contact with the tracheal carina at the proximal end (Fig. 1a). The tube and a bite-block were fixed tightly at the lips with adhesive tape. The patient was then carefully turned to the lateral decubitus position, keeping the relative positions of the head, neck, and trunk constant, and the position of the tube was again observed using the fiber-optic scope. Two-lung ventilation was instituted until the thoracotomy, and one-lung ventilation was then performed while the chest was open. The dependent lung was ventilated with 66%–100% oxygen and a constant flow (2l/min) of oxygen was insufflated through the non-dependent lung. The minute volume and respiratory rate for the dependent lung were set at 80%–100% and 120%–150% of those during two-lung ventilation.

Observation of the DLT and the airway

During anesthesia, the DLT and the tracheo-bronchial tree were frequently observed with a fiber-optic scope for malposition of the tube and airway obstruction. We defined malposition as a displacement of more than 5mm from the correct position. The distance of any displacement between the tracheal carina and the proximal end of the bronchial cuff was measured using an epidural catheter, which was inserted through the fiber-optic scope and marked every 5mm at the tip (Fig. 1b). When the tracheal carina was not visualized because of obstruction around the orifice of the tracheal tube, we advanced the fiber-optic scope forward gently as extending the space between the inner wall of the trachea and the outer wall of the tube. After such a measurement, the DLT was replaced to the correct position as soon as possible in the cases of malposition. The replacing distance at the level of the teeth was then measured. Stenosis of the lumen and obstruction of the orifices on the DLT were looked for during anesthesia by observing the inner lumina of the DLT and the tracheo-bronchial tree. In addition, the shape of the lumina, the resistance passing a fiber-optic scope through the DLT, and increases in maximum airway pressure were also documented. Chest radiography was performed in a supine position just after the operation in several patients to confirm deformity of the DLT. During anesthesia, SPO_2 was continuously monitored using a pulse oximeter (Nellcor N-200 or N-1000, Hayward, CA, USA) and arterial blood gases were measured as required.

Results

The surgical procedures carried out on the patients in the study are shown in Table 1. The sizes of the DLTs used varied from 35 to 41 French size. Left-sided DLTs were used for 86 patients and right-sided DLTs for 14 (Table 2).

Malposition of the DLT (Table 3)

Malposition was observed in 42 patients during anesthesia. This was due to withdrawal in 40 patients and advancement in two. The withdrawal malposition was detected just after turning to the lateral position before surgery in 35 patients and during one-lung ventilation in 15 patients, in eight of whom it was a recurrence after correction of the DLT's position following the postural change. Surgical procedures around the lung hilum induced deformities of the tracheo-bronchial tree and gradually displaced the DLT in a withdrawal direction.

The correcting distances at the level of the teeth were 1.5–3-times longer than those at the cuff (Table 4).

Table 1. Numbers of patients undergoing surgical procedures for lung cancer in this study

	Left lung	Right lung	Total
Pneumonectomy	7	1	8
Lobectomy	37	45	82
Others	4	6	10
Total	48	52	100

Table 2. Sizes and types of double-lumen tube used

Size (Fr.)	Left-Sided	Right-Sided	Total
35	8	1	9
37	36	7	43
39	38	5	43
41	4	1	5
Total	86	14	100

Values are numbers of patients.

Table 3. Distance of displacement of the bronchial cuff from the correct position

Distance (cm)	After postural change	During one-lung ventilation
>+0.5	2	0
+0.4–−0.4 (normal range)	65	85
−0.5–−0.9	28	13
−1.0–−1.4	4	2
−1.5–−1.9	2	0
<−2.0	1	0

Values are numbers of patients.
+, advanced; −, withdrawal.

Stenosis of the lumina (Table 5)

Stenosis of the DLT occurred in nine patients: in the tracheal tube in two, in the bronchial tube in five, and in both tubes in two. In all patients, it occurred at the sharply curved portion of the DLT and especially after advancing the tube to the correct position, but no ventilatory problems were associated.

Obstruction of the orifices (Table 5)

Complete or incomplete obstruction of the orifices at the tips of the DLT were observed in 12 patients: in the tracheal tube in four, in the bronchial tube in six, and in both tubes in two. They were associated with withdrawal malposition. Incomplete obstruction in right-sided DLTs was seen at the lateral window of the bronchial tube in several patients. The patterns of the obstructions are shown in Fig. 2.

Maximum airway pressure

In almost all cases of obstruction at the tube orifices, maximum airway pressure increased. However, we could not record it because we had to cope with the airway obstruction. High airway pressure was found with surgical procedure and accumulation of sputum.

Table 4. Distance of correction of the double-lumen tube's position at the level of the teeth

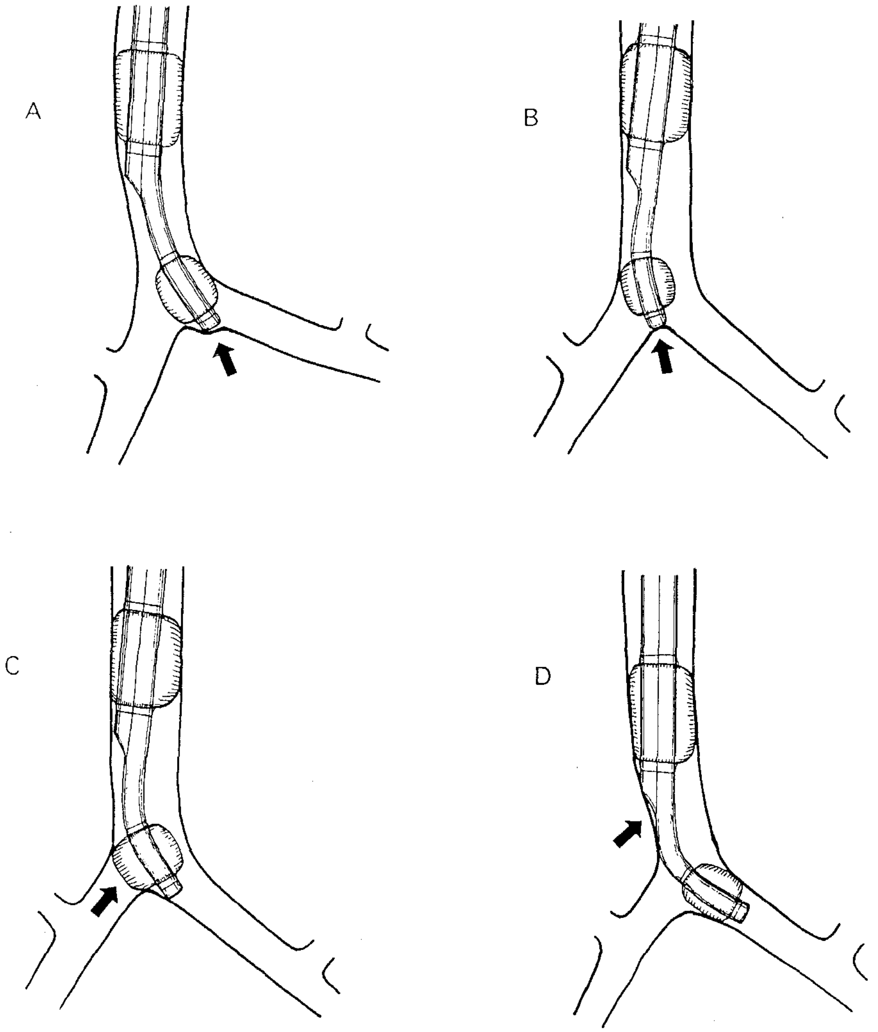
Distance (cm)	After postural change	During one-lung ventilation
+4	2	0
+3	6	0
+2	15	8
+1	10	7
0	67	85
−1	0	0

+, tube advanced for correction; −, tube withdrawn for correction.

Table 5. Incidence of stenosis and obstruction of the double-lumen tube

Sites	Tracheal tube	Bronchial tube	Both tubes	Total
Stenosis of the lumen	2	5	2	9
Obstruction of the orifice	4	6	2	12

Values are numbers of patients.



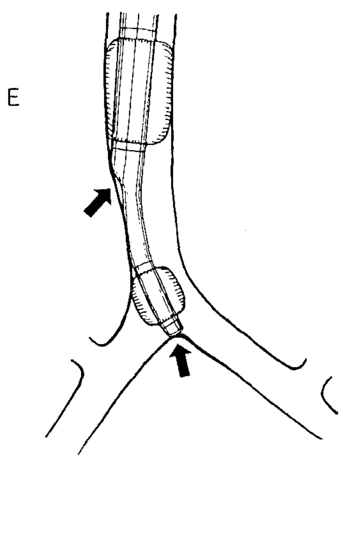


Fig. 2. Patterns of the obstruction of the orifices of the double-lumen tube (*DLT*). **A** Obstruction of the bronchial orifice. The DLT has been withdrawn and the tip of the bronchial tube is in contact with the inner surface of the mainstem bronchus. The soft and flexible tissue of the tracheo-bronchial airway is easily deformed and closes the orifice of the tube. One-lung ventilation through the bronchial tube is disturbed. **B** The bronchial tube has been withdrawn completely into the tracheal lumen and the bronchial orifice is obstructed around the tracheal carina. **C** The bronchial cuff has closed the lumen of the right mainstem bronchus. One-lung ventilation through the tracheal tube is disturbed. **D** The orifice of the tracheal tube is obstructed by the inner surface of the trachea as a result of deformity of the tracheo-bronchial tree. **E** Both orifices of the tracheal and bronchial tubes are obstructed at the same time. This was induced by a withdrawal malposition and tracheo-bronchial deformity that occurred just after the postural change

Table 6. Incidence of hypoxemia and hypercapnea

SPO_2 (%)	≦89	90–95	≧96
	5	26	69
PaO_2 (mmHg)	≦59	60–79	≧80
	4	10	86
$PaCO_2$ (mmHg)	≦49	50–59	≧60
	84	14	2

Values are numbers of patients.

X-ray findings

In A-P view of the chest, deformities of the DLT were not found just after the operation.

Hypoxemia and hypercapnea (Table 6)

SPO_2 was less than 96% in 31 patients, and was less than 90% in 5 of these patients. PaO_2 was less than 80 mmHg in 14 patients, and less than 60 mmHg in 4 of these patients. $PaCO_2$ was over 49 mmHg in 16 patients, and over 59 mmHg in 2 of these patients.

Discussion

The present study revealed a high incidence (42%) of DLT's malposition during anesthesia. The malposition in almost all cases was in the withdrawal direction, and occurred during the postural change and surgical manipulation of the lung hilum. The site of narrowing in the lumen was the sharply benk portion of the tube.

Since the conventional blind placement of the DLT frequently results in an incorrect position of the tube, it is necessary to use a fiber-optic scope for proper placement of the DLT to prevent complications [6–8]. In our study, in spite of correct positioning using a fiber-optic scope and tight fixing of the DLT after the intubation, tube troubles including airway obstruction were found. The high incidence of malposition of the DLT occurred during the postural change. Further, almost all malpositions were in a withdrawal direction and the bronchial cuff migrated into the trachea. It has been reported that flexion and extension of the neck can displace an endotracheal tube [9] and cause the alteration of DLT position [10]. The postural change from a supine to a lateral decubitus position is usually associated with extension, flexion or rotation of the neck, which might elongate the distance from the teeth to the tracheal carina.

The second major occasion of the malposition was during surgical manipulation of the lung hilum. The conductive airway is highly elastic and mobile, and its shape is easily changed by the surrounding tissue. For example, respiratory movement changes the length of the trachea, and pneumothorax, mediastinal tumors, cardiomegaly, and dilated pulmonary vessels change the shape of the tracheo-bronchial tree [11]. It is assumed that the deformity was induced by the gravitational force of the mediastinum, collapse of the non-dependent lung, a high airway pressure in the dependent lung and surgical manipulation around the lung hilum. Although tracheo-bronchial deformity might be related to age, obesity, and location of the cancer, these factors were beyond the scope of the present study.

Malposition of the DLT seems to be related to the shape of the DLT. In contrast to the single-lumen tube, which has a smooth curved shape, the Rusch DLT has a steeply curved shape in its middle part which is positioned in the pharynx. Although this shape has been designed to fit the oral and tracheo-bronchial airway anatomically in a similar way to the red rubber DLT, this design may not be appropriate for Japanese patients, who have smaller physiques than Europeans. Moreover, there is much anatomical variability in the airway from the mouth to the oropharynx among patients, as seen in tracheal intubation [12]. Therefore, a good fit is not likely to be obtained between the DLT and the airway in every case. The sharply curved part of the DLT seems to be susceptible to bend further by compression with the tongue, which also may cause the withdrawal displacement of the tube. Eventually, when the withdrawn tube was advanced to the correct position, the distance advanced at the level of the teeth was longer than at the distal tip, and the lumen of the strongly curved part was constricted after correction. The malposition of the DLT causes serious airway trouble by obstructing the orifice of the tracheal or bronchial tube. Complete obstruction of the orifice of the bronchial tube by the medial wall of the mainstem bronchus has been reported in patients using Mallinckrodt DLT, which had a flatter 63° tapered bronchial tip, even in the correct position during left lateral position [13]. The Rusch DLT with a flatter 90° tapered bronchial tip, which we used, did not induce complete obstruction in the correct position. However, with the withdrawal displacement of the DLT, orifice occlusions of the bronchial and tracheal tubes were noticed in some patients.

It is an important fact that withdrawal malposition of the DLT occurred in 40% of our patients, and was associated with airway obstruction in 30% of these. The high incidence of malposition leads us to reconsider the appropriate position for the DLT. It is recommended that the tip of the DLT is placed at a slightly deeper position than that used in the present study. If the tip of the DLT (left-sided) is placed 1 cm deeper, the incidence of withdrawal malposition and obstruction of the tube orifices would be much lower, judging from the obstruction patterns found in our study. Even if the DLT advanced 1 cm, obstructions of the left upper or lingual lobe bronchi would not occur, because the distances between the tracheal carina and the left upper lobe bronchus are 50 ± 8 mm (mean ± SD) in Japanese males and 45 ± 6 mm in Japanese females [14], and 50 ± 8 mm in American males and 45 ± 7 mm in American females [15]. Provided that there is sufficient distance from the tube to the left upper lobe bronchus, this position should be adopted to avoid the problems caused by withdrawal malposition.

Many of the cases of hypoxemia as well as hypercapnea were found during one-lung ventilation, even in the absence of any airway obstructions. The airway obstruction could be improved before any marked deterioration of PaO_2 or $PaCO_2$ in most of the patients. However, under the condition of low PaO_2 during one-lung ventilation, severe hypoxemia was rapidly induced by complete obstruction of the tube tip in a few patients. Great attention to airway obstruction is needed in patients with low PaO_2 during one-lung ventilation, particularly during manipulation of the lung hilum.

In conclusion, malposition of the DLT occurred mainly during postural change and one-lung ventilation as a result of airway and/or tube deformities. To achieve adequate ventilation using the DLT, the following precautions should be taken. The DLT should be placed so that its bronchial cuff is 1 cm deeper from the tracheal carina, the airways should be observed using a fiberoptic scope at the times when airway problems are most commonly induced, i.e., just after postural change and during manipulation of the lung hilum, and effective treatments should be immediately available.

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