Total Obstruction of the Right Main-stem Bronchus Displayed in Changes of Airway Dynamics during Differential Ventilation with Double-lumen Tube Intubation

Masahiko MIMA, Toshihiro IMANISHI,
Kazunori KUNO and Shinya MASUKO

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Double-lumen tube intubation, using two ventilators to each lung respectively (differential ventilation), facilitates the selective ventilation of the dependent lung with unilateral positive end-expiratory pressure (PEEP), improving vertical matching of ventilation and perfusion, reducing venous admixture, and thus improving the alveoloarterial oxygen tension difference. Reported herein is the use of a computer equipped ventilator capable of consecutive measurement of airway dynamics during differential ventilation for trans-thoracic esophagectomy.

Although the values of airway dynamics have to be carefully interpreted, they were shown to be useful in measuring for early detection of malpositioning of double-lumen tube as well as in endotidal CO_2 analyzation[1] and fiberoptic bronchoscopy[2,3].

Case Report

A 75 year old woman weighing 48 kg was scheduled for trans-thoracic esophagectomy. After induction of general anesthesia, the patient's trachea and the left bronchus were intubated on the first attempt with a 6.0 mm Portex left-endobronchial double-lumen tube. When the patient was ventilated through the bronchial lumen, sounds of ventilation were heard only over the left lung with a stethoscope, and the left side of the chest wall movement seemed to be synchronized with delivery of the inspired volume of oxygen. When ventilated through the tracheal lumen, sounds of ventilation were heard over the right lung alone with the right side of chest wall moving synchronously with the ventilator.

Two ventilators, Engström Erica and Engström ER.300 (Gambro, Sweden), were connected to the tracheal and bronchial lumen of the double-lumen tube, giving approximately half of the calculated tidal volume (250 ml) to each lung with a coarsely synchronized frequency of 14/min in a volume limited and time cycled mode, respectively. Five minutes after intubation, the computer equipped with Erica ventilator revealed compliance (total thoracic) of 33 $ml \cdot cmH_2O^{-1}$ and airway resistance of 16.9 $cmH_2O \cdot l^{-1} \cdot sec$ in the right lung, and compliance of 26 $ml \cdot cmH_2O^{-1}$ and resistance of 19.1 $cmH_2O \cdot l^{-1} \cdot sec$ of the left lung, each value having been averaged from ten consecutive ventilations. The tube was gradually withdrawn 1.5 cm on which compliance of the left lung increased to 30 $ml \cdot cmH_2O^{-1}$,

Department of Anesthesiology, Kansai Medical University, Osaka, Japan

Address reprint requests to Dr. Mima: Department of Anesthesiology, Kansai Medical University, Fumizonocho Moriguchi, Osaka, 570 Japan

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but resistance of the left lung remained unchanged. There were no apparent changes observed in either compliance or resistance of the right lung after the procedure. Sounds of ventilation became more audible than before in the left upper chest. Arterial blood gas analyzed with ABL 3 (Radiometer, Denmark) showed pH 7.49, Pa_{O_2} 155 mmHg, Pa_{CO_2}, 29 mmHg, and B.E = 0 mEq·l^{-1} (FI_{O_2} = 0.4).

PEEP (5 cmH_2O) was applied solely to the left lung, and the patient was turned to the left decubital position for trans-thoracic esophagectomy. Fifteen minutes after the initiation of the surgery, the airway pressure in the right lung became 50 cmH_2O with automatic safety relief of the pressure on each inspiration. Immediately measured airway dynamics of the right lung revealed compliance of 0 $ml \cdot cmH_2O^{-1}$ with an inspiratory tidal volume of 0 ml, and airway resistance of 99.9 $cmH_2O \cdot l^{-1}$·sec. Blood gas analysis showed pH. 7.45, Pa_{O_2} 90.1 mmHg. Pa_{CO_2} 30.5 mmHg and B.E. = 2.0 mEq·l^{-1}. Although the right side (tracheal) cuff was deflated, no changes in those values obtained from the right lung were noted. The left side (bronchial) cuff was then deflated, and almost simultaneously, the inspiratory tidal volume to the right lung was restored to 240 ml, and the resistance became almost nil and compliance changed to about 50 $ml \cdot cmH_2O^{-1}$. Ventilation sounds were well audible in the right upper chest. The double-lumen tube was replaced with a regular single-lumen tube to which one ventilator (ER. 300) was connected, and the surgical procedure was reinstituted. The rest of the intra-operative course was uneventful. Roentogenogram of the patient's chest taken after completion of the operation showed no adverse effects. Both the tracheal and bronchial balloon cuffs of the double-lumen tube were inflated to normal size and shape when exposed to room air after extubation.

Discussion

In regarding to the first incident in which decreased compliance of the left lung was improved by 15% by withdrawing the tube 1.5 cm, the most plausible explanation is that the tip of the tube initially extended beyond the orifice of the upper lobe bronchus, thus preventing the left lung upper lobe from receiving the insufflation gas volume from the ventilator. When a volume of gas present to the left lung fails to ventilate the upper lobe, compliance of the entire left lung decreases since the lung space available for insufflation by the same volume decreases. However, only limited data are available as precise values for the total thoracic compliance of both lungs. The interpretation of the present values for the left lung may be considered acceptable if it may be assumed that left lung compliance is essentially the same as that of the right lung.

An unkinking of the tube was unlikely since airway resistance of the left lung was hardly altered by the maneuver. The usefulness of the evaluation of airway resistance is generally recognized, as in the case of asthmatic patients and others. A capnogram shows a zero carbon dioxide removal pattern with both disconnection of the ventilator tubings and total obstruction of the airway. To obtain an appropriate differential diagnosis, some time may be required.

One factor which led to original extended insertion of the tube may have been the selection of the small, Portex #6 tube used in our patient, which is apparently smaller in external diameter than the bulky Carlens #37[4]. However, the difficulty in introducing a larger tube through the larynx or past the carina often necessitates the use of a smaller tube. With a smaller tube, larger volumes of air are necessary to inflate the cuffs to achieve an airtight seal and maldistension can occur. The malpositioned bronchial cuff overriding the carina with which the value for airway resistance of the right lung became extremely high is shown in figure. In addition to the withdrawal of the tube as a causative factor, the postural change of the patient from supine to lateral decubital position and the inadvertent extension or flexion of the patient's neck, an event by which the tube would move to cephalad direction[5], must also be considered.

Some workers advocate fiberoptic bron-

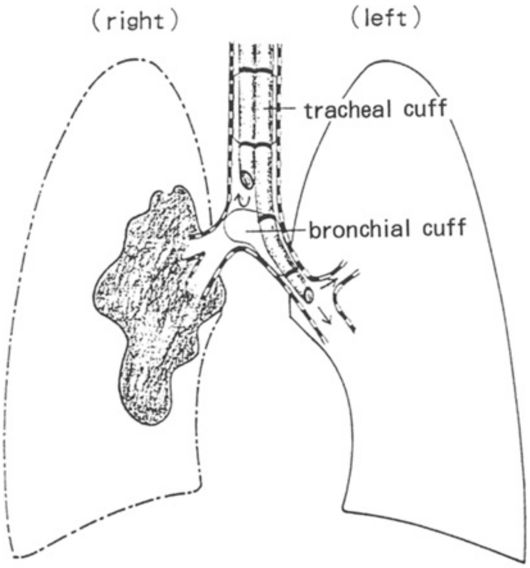

Fig. 1. Withdrawing of the double-lumen tube caused total obstruction of the right mainstem bronchus with bronchial cuff overridden the carina.

choscopes for correct positioning of the double-lumen tube[3]. However, even when using such bronchoscopes with an outer diameter small enough to permit passage through a narrow lumen of Portex #6, ventilation of that side of the lung should be discontinued during the maneuver whereas measurements of airway dynamics can be made without discontinuing ventilation. In this respect, the airway dynamics measurement during controlled ventilation is safe, and, if the values are carefully observed, they may be useful for the early detection of the improper positioning of the double-lumen endobronchial tube.

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