Use of a Left-Sided Double-Lumen Endotracheal Tube in a Patient With a Prior Left Pneumonectomy

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A 77-year-old man, 7 years after left pneumonectomy, was scheduled for a right upper pulmonary lobectomy. The early identification of a newly developing carcinoma on the right upper pulmonary lobe warranted surgical resection. Right exploratory thoracotomy, pleural lysis, partial pleurectomy, and right upper lobe wedge resection were completed, and the patient was discharged without sequelae. This case report describes the intraoperative anesthetic management of a right upper lobe wedge resection and attributes the uneventful intraoperative outcome to a strategically and skillfully placed left double-lumen endotracheal tube.

Keywords: Double-lumen endotracheal tube, pneumonectomy, pulmonary lobe wedge resection.

Lung cancer is the leading cause of death among patients diagnosed with cancer.[1] A pulmonary lung resection for cancer is performed after the following 3 criteria are met. First, the tumor should be nonsmall cell, of which the majority is either squamous cell or adenocarcinoma. Second, the tumor should be considered surgically resectable. The respectability of the lung cancer depends on the absence of substantial mediastinal or distant spread as judged by computed tomography (CT), positron emission tomography (PET), bronchoscopy, and mediastinoscopy. The final criterion includes obtainment of surgical consent.[2] In this case report, the identified prerequisites were met and the patient had a left pneumonectomy for treatment of squamous cell carcinoma in 2001.

This case report describes the airway management of a patient who was scheduled to undergo right upper pulmonary lobectomy 7 years after a left pneumonectomy.

Case Summary

A 77-year-old man, who was 167.6 cm tall and weighed 79.2 kg, was found to have a new lesion in his right upper pulmonary lobe. The lesion measured 1.5 × 1.2 cm on a CT scan of the thorax. This lesion was also seen on PET. A pulmonologist was consulted and pulmonary function tests were performed. The forced vital capacity (FVC) was 1.66 L (56% of predicted for a person with 2 lungs), the forced expiratory volume in the first second of expiration (FEV_1) was 1.17 L (54% of predicted volume for a person with 2 lungs), and the FEV_1/FVC ratio was in the normal range. The pulmonologist excluded the measurement of diffusing capacity of the lung for carbon monoxide. Also, cardiopulmonary exercise testing, which measures maximum oxygen consumption (V_{O_2}max), was not obtained. Dunn et al[3] indicated that a baseline arterial P_{O_2} is probably not an important predictor of postoperative complications or mortality following pulmonary resection. Hypercapnia (arterial P_{CO_2} > 45 mm Hg) has been traditionally considered a major risk factor for pulmonary resection. Other authors[4,5] indicated that hypercapnia is not a contraindication to lung surgery.

The patient had preexisting comorbidities. He had a history of coronary artery disease, but a recent dobutamine stress test had a normal result. There was a history of hepatitis B, diabetes mellitus type 2, and slight chronic renal insufficiency (the calculated glomerular filtration rate was 49). He was a former smoker, having stopped in 2001 at the time of his left pneumonectomy. Laboratory results showed the following values: hemoglobin, 12.1 g/dL; hematocrit, 34.1%; white blood cells, 4,400/µL; platelets, 267,000 mm^3 sodium, 144 mmol/L; potassium, 3.9 mmol/L; chloride, 112 mEq/L; carbon dioxide (CO_2), 23 mmol/L; serum urea nitrogen, 15 mg/dL; creatinine, 1.4 mg/dL; and glucose, 118 mg/dL. Coagulation studies revealed a prothrombin time of 14.4 s, an international normalized ratio of 1.2, and a partial thromboplastin time of 32 s. The chest radiograph showed opacification of the left hemithorax with a shift of the heart and mediastinum to the left. The right lung was clear. The electrocardiogram (ECG) showed a sinus rhythm with a slight first-degree heart block.

We performed a final preanesthetic assessment for the proposed right upper lobectomy. This included a review of the initial assessment, test results, chest radiograph, and CT scan. We believed that the best choice for isolation of the right upper lobe was a 37F left-sided double-lumen tube (Mallinckrodt Broncho-Cath). Also, we thoroughly reviewed the options of inhalational anesthesia vs total intravenous (IV) anesthesia, volume vs pressure-controlled ventilation, and pain control both intraoperatively and postoperatively.

This patient was offered thoracic epidural anesthesia because of the benefits identified in the literature. Also, we were more experienced in the placement of thoracic catheters for a thoracotomy than in performing paravertebral blocks. Insertion of the thoracic epidural catheter was accomplished preoperatively at the T5-T6 level. No blood or cerebral spinal fluid was aspirated through either the epidural needle or the catheter. A 5-mL test dose of 1.5% lidocaine (Xylocaine) with 1:200,000 epinephrine was used to confirm that the catheter was neither intrathecal or intravascular. During the operation, the epidural would be utilized depending on the patient's hemodynamic stability.

On the patient's arrival in the operating room (OR), a pulse oximetry monitor, a blood pressure cuff, and a 5-lead ECG monitor were placed. The patient's room air oxygen saturation as measured by pulse oximetry (Spo_2) was 98%, his blood pressure was 150/72 mm Hg, and his heart rate was 70/min. Before induction, he received preoxygenation and had a Spo_2 of 100%. Also during this time, he received 50 µg of fentanyl and 1 mg of midazolam through his existing 16-g peripheral IV catheter. At induction, he received 140 mg of propofol and 100 mg of succinylcholine. Under direct laryngoscopy, with a Mac 3 blade, the tip of the 37F left double-lumen endotracheal tube was passed through the larynx. Next, a fiberoptic bronchoscope was inserted through the bronchial lumen of the endotracheal tube. The fiberoptic bronchoscope was inserted into the right main bronchus, and the double-lumen endotracheal tube was then advanced over the bronchoscope until the tip was slightly above the opening to the right middle lobe bronchus. The bronchial and tracheal cuffs were inflated, and the patient's lung was ventilated; he had a fraction of inspired oxygen (Fio_2) of 1.0, a tidal volume of 500 mL, and a respiratory rate of 14/min.

Then the fiberoptic bronchoscope was inserted into the tracheal lumen. The entrance to the upper lobe was visualized in order to confirm that the opening was above the bronchial cuff's proximal edge. The optimally placed double-lumen endotracheal tube isolated the right upper lung lobe bronchial opening between the tracheal and bronchial cuffs (Figure). The right upper lung lobe was ventilated through the tracheal lumen. The bronchoscope was also used to verify that the ventilation to the right middle and right lower lobes were unobstructed.

At induction, an additional 14-g IV catheter was placed in an extremity and a 20-g arterial catheter was placed in the left radial artery. After induction, isoflurane was used as the inhalational agent. The patient recovered from the neuromuscular effects of succinylcholine and then received cisatracurium.

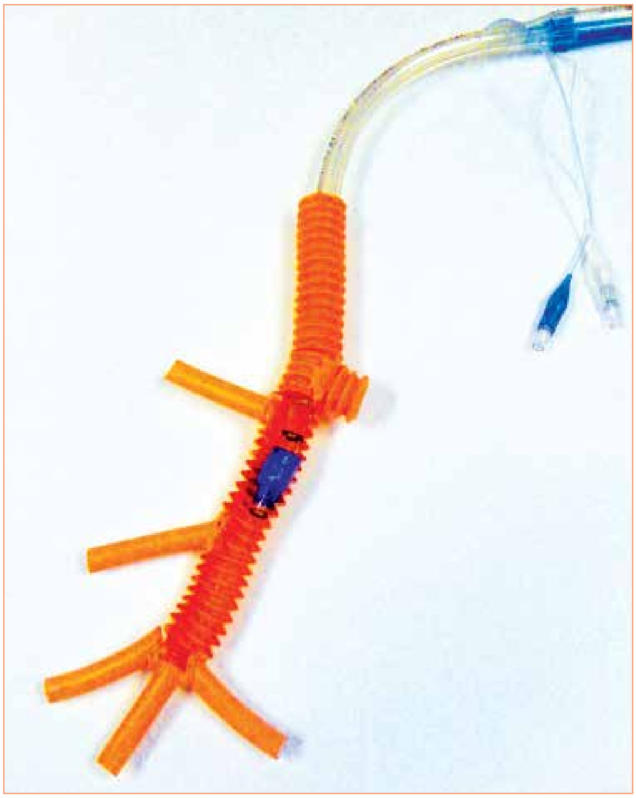

Figure. Corrugated Model of a Bronchotracheal With Strategically Positioned Double-Lumen Endotracheal Tube as Described in This Case

The surgical procedure proceeded uneventfully. The patient's Spo_2 was 100% throughout the case; the end-tidal CO_2 was 40 mmol/L at induction and ranged from 28 to 43 mmol/L throughout the case. The heart rate ranged from 54/min to 85/min. Except for 2 episodes when the systolic blood pressure was in the mid-90s and the heart rate was 54/min to 55/min, the patient was hemodynamically stable. Each time the patient was given ephedrine, 10 mg IV, and had an appropriate response. The total time in the OR was 2 hours 47 minutes, with the actual surgical time being 1 hour 12 minutes. The total time for ventilation with isolation of the right upper lobe was 21 minutes.

When the surgeon asked us to reinflate the right upper lobe, we considered the study by Hansen et al,[6] whose results showed that a targeted lobar recruitment is equally effective as whole lung recruitment. The authors further indicated that, because of restriction of fluid during thoracic surgery, whole lung recruitment tends to cause hypotension.[6] In a patient with two lungs, it may be appropriate to clamp the nonoperative lumen of the double-lumen tube during the vital capacity maneuver to minimize the hypotensive response; however, our patient had only one lung. Therefore, we did not feel a targeted lobar recruitment was necessary in this case.

The total blood loss was 175 mL, the urine output was

500 mL, and a total of 1,600 mL of fluid was given. Via the epidural catheter, the patient received a total of 5 mL of 2% lidocaine, 9 mL of 0.25% bupivacaine, and 100 µg of fentanyl. In addition, he received a total of 650 µg of fentanyl IV for the case. The ECG performed immediately after the surgical procedure was unchanged from the preoperative ECG finding. The planned postoperative epidural infusion was hydromorphone, 15 µg/mL, and 0.125% bupivacaine at a rate of 7 mL/h.

The pulmonologist had requested that the patient remain intubated at the end of the case. Even though Slinger et al[7] showed that the increased flow resistance leading to obstructed expiratory flow or work of breathing is probably not clinically significant with a 37F or larger double-lumen-tube, there is the consideration of ventilator-associated pneumonia. We therefore removed the double-lumen tube and replaced it with an 8.0-mm endotracheal tube with evacuation lumen (Hi-Lo Evac). This tube was chosen because research has shown that the number of ventilator-associated pneumonia cases have been dramatically reduced with the use of this tube.

The patient was extubated the next morning by the pulmonologist after an arterial blood gas analysis at 7:55 AM, with values of 7.32 pH and 50.7 mm Hg $PaCO_2$, 90.6 mm Hg PaO_2, 22.7 mEq/L HCO_3. This was on a FIO_2 of 0.4. The patient had an uneventful postoperative course and appeared comfortable with the thoracic epidural catheter. He was discharged from the hospital on the seventh postoperative day.

Discussion

The reported survival rates of patients who undergo pneumonectomy often vary because of sparse numbers. Alexiou et al[8] reported that 111 patents undergoing a pneumonectomy between 1991 and 2000 had 1-, 3-, and 5-year survival rates of 66%, 47%, and 44%, respectively. Kim et al[9] looked at 94 long-term survivors of nonsmall cell lung cancer between January 1992 and December 2000 and found a 10-year survival rate of 67.3%. Martini et al[10] found that if a patient remained in remission for 5 years that the survival rate for an additional 5 years was 92.4%. Wong and Henteleff[11] reported that 130 patients had a 5-year survival of only 34% and had a 10-year survival rate of only 13%.

The tumor staging system for lung cancer consists of the following: tumor size (T), lymph node involvement (N), and metastasis (M). Also, the lung cancer is classified by stages 1 through 4 depending on the size of the tumor, the node involvement, and the presence of metastasis. Several studies looked at stage 1, T1 (the tumor is ≤ 3 cm) and stage 1, T2 (the tumor is > 3 cm). In comparing stage 1 lung cancer, T1N0 vs T2N0, Al-Kattan et al[12] found that the patients with a T2 lesion having a pneumonectomy had a worse prognosis and a higher incidence of local recurrence. Alexiou et al[8] found that patients who underwent pneumonectomy (n = 111) for stage T1N0 or T2N0 nonsmall cell cancer had a lower survival rate compared with patients who underwent smaller lung resections (n = 312).

Goldstraw[13] reported that patients with adenocarcinoma can have decreased survival rates compared with those with squamous cell carcinoma. Our patient's prior left pneumonectomy was performed because of squamous cell carcinoma. The pathologic finding of our patient's recurrent cancer in the right lung was adenocarcinoma. Martini et al[14] reported an overall incidence of recurrence to be 27%, which encompassed 7% local or regional and 20% systemic. Sugimura et al[15] reported a higher rate of recurrent cancer, 445 of 1,073 patients. It was their experience that treatment of nonsmall-cell cancer, of which surgery was one of the modalities, significantly prolonged survival.[15] Voltolini et al[16] reported a very low recurrence rate of 2.5%, or 27 of 1,059 patients. Twelve patients had a local recurrence, and 15 had a new primary lung cancer that developed at a median interval of 45 months (range, 21-188 months).[16] Grodzki et al[17] believed that the prognosis was poor for patients treated by a second surgical procedure earlier than 12 months after the first procedure.

The following questions may be postulated by an anesthesia provider: If a pneumonectomy has been performed, can a patient undergo surgery on the remaining lung? If a lobectomy has been performed, can a patient have a pneumonectomy of the other lung? Grodzki et al[17] retrospectively analyzed a report of the largest series in Europe from 1981 to 2002, which included 18 patients who underwent additional pulmonary resections after a pneumonectomy. Eleven of the 18 patients survived for 2 years (61%). Eight of the 18 patients survived for 5 years (44%).

Spaggiari et al[18] reported on 13 patients, who had surgical procedures for cancer of the residual lung. The procedures performed were 3 segmentectomies, 7 wedge resections, 2 multiple wedge resections, and 1 exploratory thoracotomy. These 13 patients had a 3-year survival rate of 46%.[18] Terzi et al[19] described a patient who underwent a left pneumonectomy for removal of a second primary tumor after a right upper lobectomy due to a superior sulcus tumor.

Limited pulmonary wedge resection, in a patient with one lung, is an acceptable procedure associated with minimal morbidity and mortality rates. Terzi et al[20] mentioned that patients with a metachronous lung cancer may sustain a good quality of life after limited resection of the residual lung. Barker et al[21] indicated that a right upper lobectomy had been safely performed in a patient 25 years after a left pneumonectomy. These reports indicated that additional surgical lung interventions can be safely performed on patients who had either a prior pneumonectomy or a lobectomy.

We had been apprised of the proposed surgical procedure several days in advance. The surgeon was planning to perform a right upper lobectomy. He requested an anesthesia technique that would isolate the right upper lobe. A review was made of anesthesia lung isolation methods in order to accomplish the request. Dr Peter Slinger[22] reviewed lung isolation techniques at the 1997 Annual Anesthesia Winterlude Symposium offered by the University of Ottawa in Canada. He mentioned that in the middle of the 1930s several different practitioners pioneered the use of endobronchial tubes, bronchial blockers, and double-lumen tubes to achieve lung isolation. Also, he indicated that, despite numerous modifications, these 3 methods have persisted to the present as the basis of modern lung isolation techniques.

When isolating the right upper lobe, the anesthesia provider must be aware of pulmonary anatomy. The right main bronchus is about 5 cm in length. The average angle made by the right main bronchus with the trachea is 25 to 30 degrees. The coronal diameter is approximately 17 mm but can vary 4 mm more or less in a man. The right upper lobe bronchus arises from the right lateral aspect of the parent bronchus about 12 to 20 mm from the carina. It is about 1 cm in length and divides into 3 segmental bronchi, which supply the apical, posterior, and anterior segments of the upper lobe. In less than 1% of cases, the apical segment can be supplied by a tracheal bronchus, which arises from the right lateral aspect of the trachea above the carina. The right middle lobe bronchus arises about 2.5 to 3.0 cm beyond the origin of the right upper lobe bronchus from the anterior aspect of the bronchus. The right lower lobe bronchus is the continuation of the principal stem beyond the origin of the middle lobe bronchus.

Taking into account the anatomy of the right lung, we reviewed all the possibilities for isolation of the right upper lobe. After a thorough review, we concluded the best choice was the 37F Mallinckrodt Broncho-Cath left double-lumen endotracheal tube. The decision was made for the following reasons. The standard endotracheal tube distance from the tip to the top of the balloon is such that placement of the balloon below the opening to the right upper lobe would require the tube to enter either the middle or lower lobe bronchus.[23] Also, placement of a standard endotracheal tube in a manner to adequately ventilate the middle and lower lobes would result in no ventilation to the right upper lobe. A similar problem may occur when considering the use of a right double-lumen endotracheal tube. The position and shape of the bronchial cuff of the right double-lumen endotracheal tube is such that when the proximal edge is below the opening of the right upper lobe bronchus, the tip of the tube must enter either the middle or lower lobe bronchus.

The anesthesia provider should be cognizant of the different bronchial dimensions and variability of the takeoff of the right upper lobe bronchus. Campos[24] indicated that a patient with a history of pneumonectomy required the anesthesia provider to be prepared to encounter pulmonary anatomical alterations during placement of the lung isolation device. Campos[24] recommended that the anesthesia provider integrate the fiberoptic bronchoscope for the insertion of the lung isolation device.

A single-lumen endotracheal tube with a small separate channel for a torque control blocker (Univent, LMA) may isolate the right upper lobe and allow ventilation to the remaining lung. Scheller et al[25] reported that the Univent blocker may migrate into the trachea and require replacement with a double-lumen tube. MacGillivray[26] and Campos and Kernstine[27] indicated that the Univent is more difficult to place compared with a double-lumen tube. Bauer et al[28] compared bronchial blockers with double-lumen tubes during video-assisted thoracoscopic surgery and found with respect to time for placement, rate of placement failure, and satisfactory deflation that the double-lumen tube was superior. In addition, the operative lung deflates more easily when the nonventilating lung lumen of the double-lumen tube is open to atmosphere than with the 2-mm suction channel of a Univent tube.

A 37F Mallinckrodt Broncho-Cath left double-lumen endotracheal tube has a short distance from the top of the bronchial cuff to the tip of the tube. We believed that this permitted us to pass the tube to a point where the tip of the tube would be above the entrances to both the middle and lower lobes and would enable the top of the bronchial cuff to be sufficiently below the right upper lobe bronchial opening. This position permitted the right upper pulmonary lobe to be isolated when needed and ventilated when isolation was not required. Scholten et al[29] used a double-lumen endotracheal tube; however, it was used for drainage of an aspergilloma of the right upper pulmonary lobe.

The anesthesia technique could be any of the following: general with inhalation agents, with or without thoracic epidural anesthesia (TEA), and total IV anesthesia, with or without TEA. There are proponents for each technique. Santambrogio et al[30] found, during one-lung ventilation, that arterial partial pressure of oxygen values with total IV anesthesia were greater than those with balanced anesthesia. They also found that propofol improved oxygenation and pulmonary shunt fraction during one-lung ventilation compared with sevoflurane.[30] Pilotti et al[31] compared total IV anesthesia with inhalational anesthesia in thoracotomies in single-lung ventilation. They concluded that total IV anesthesia offered the following advantages: better oxygenation during one-lung ventilation, good recovery of postoperative consciousness with no psychomotor disturbances, and absence of pollution in the operating theater.[31]

Yondov et al[32] compared the effect of halothane, isoflurane, and propofol on partial oxygen pressure during one-lung ventilation in thoracic surgery and found no significant difference in PaO_2 between the 3 groups during respective regimens of ventilation. Also, Dossow et al,[33] in comparing general anesthesia with TEA and total IV anesthesia with TEA, found the following changes from 2-lung ventilation to one-lung ventilation. There was a significant increase in cardiac output in the total IV anesthesia/TEA group, whereas no change was observed in the general/TEA group.[33] In contrast to the studies mentioned earlier, they found that PaO_2 remained significantly increased in the general/TEA group vs the total IV anesthesia/TEA group.[33]

Hypoxic pulmonary vasoconstriction is a local response of pulmonary artery smooth muscle, which decreases blood flow to the area of the lung where a low alveolar oxygen pressure is sensed. Hypoxic pulmonary vasoconstriction aids in keeping a normal ventilation/perfusion relationship by diversion of blood from underventilated areas. It is has been reported that inhalation agents can blunt the response of hypoxic pulmonary vasoconstriction. Beck et al[34] looked at the effects of sevoflurane and propofol on the pulmonary shunt fraction during one-lung ventilation for thoracic surgery. Regarding the blunting of hypoxic pulmonary vasoconstriction, they found no significant difference in the shunt fraction between the 2 groups. Their conclusion was that much of the overall shunt fraction during one-lung ventilation has other causes.[34]

One-lung ventilation may induce epithelial damage and expression of pro-inflammatory mediators in the alveoli of the ventilated lung. The immune response has been shown to be attenuated by volatile anesthetic agents. De Conno et al[35] assessed the immunomodulatory effects of propofol and sevoflurane during one-lung anesthesia. They found, when compared with propofol, that sevoflurane had a significant reduction of inflammatory mediators and a significantly better clinical outcome, as defined by postoperative adverse effects.[35]

What causes acute lung injury after a pulmonary resection? Licker et al[36] found 4 factors to be significant predictors of primary acute lung injury. These factors were excessive intravascular volume, pneumonectomy, high intraoperative ventilatory pressures, and preoperative alcohol abuse.[36] Licker et al[37] further elaborated on the mechanisms of protective lung strategies, such as the use of low tidal volume with recruitment maneuvers, a goal-directed fluid approach, and prophylactic treatment with inhaled β_2 adrenergic agonists. Shilling et al[38] also illustrated another benefit of reduction of the tidal volume. There was less alveolar release of pro-inflammatory cytokines during one-lung ventilation in the postoperative course.

For ventilation of the patient during one-lung ventilation, consideration is given to pressure-controlled ventilation and volume-controlled ventilation. Numerous reports have indicated that the peak airway pressure is lower in pressure-controlled ventilation compared with volume-controlled ventilation. It was also postulated that a reduction in the intrapulmonary shunt during one-lung ventilation occurred with pressure-controlled ventilation vs volume-controlled ventilation. However, in a recent study, Rozé et al[39] looked at pressure-controlled ventilation and intrabronchial pressure. They measured airway pressure simultaneously in the breathing circuit and the main bronchus of the dependent lung. The conclusion was that the decrease in peak airway pressure is observed mainly in the breathing circuit and is not clinically relevant in the bronchus of the dependent lung. This challenges the common clinical perception that pressure-controlled ventilation offers an advantage over volume-controlled ventilation.[39]

Thoracic epidural anesthesia may provide better preservation of the functional residual volume, efficient mucociliary clearance, and alleviation of the inhibitory reflexes acting on the diaphragm and aid in prevention of atelectasis and secondary infections. Soto et al[40] and Ochroch et al[41] indicate that, in the absence of contraindications, all patients undergoing major open thoracic surgical procedures should have a thoracic epidural catheter placed preoperatively. Gedviliene et al[42] reviewed the literature on the impact of thoracic epidural anesthesia on the functions of organs and systems. They concluded, that during one-lung ventilation, thoracic epidural anesthesia reduces pulmonary blood shunt and improves oxygenation. Because of the postoperative pain relief, there was improved respiratory function and in turn the rate of pulmonary complications was minimized. Sympathetic blockade during thoracic epidural anesthesia reduced the rate of perioperative myocardial ischemia and cardiac mortality. They further indicated it had a positive effect on immune function. For these reasons, they recommended TEA as a standard in pulmonary resection surgery.[42]

Conclusion

We presented a rather unique case regarding anesthetic management. The rationale for the accomplishment of isolation of the right upper lobe was presented. Also, the studies were presented with respect to total IV anesthesia vs general anesthesia, volume vs pressure-controlled ventilation, and methods for intraoperative and postoperative pain control. In this case, we believed that the benefits of general anesthesia with TEA outweighed the benefits of total IV anesthesia with TEA. Regarding ventilation, especially in light of the studies by Rozé et al,[39] we decided that volume-controlled ventilation would be an appropriate choice in this case. Even though the reported incidence of hypoxemia has been as low as 1% of the total cases of one-lung ventilation in some centers, we were still vigilant about this potential problem.

If hypoxemia occurs, one must be prepared to do any or all of the following. The position of the lung isolation device must be confirmed. The ventilated portion of the lung must be recruited. Cardiac output has to be made adequate. Continuous positive airway pressure or high-pressure jet ventilation may need to be applied to the operative lobe. Positive end-expiratory pressure to the ventilated portion of the lung must be optimized. An adequate hemoglobulin has to be maintained. If necessary, total one-lung ventilation must be resumed.

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