A Modified Approach to Intubation and Single-lung Ventilation for Lobectomy in a 2-Year-Old Child: A Case Report

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The subject of this case report is a 2-year-old girl who was admitted to the operating room for treatment of recurrent parapneumonic empyema of the right lung. Because antibiotics and traditional therapies were not effective, surgical management was required. A single-lumen endotracheal tube was the chosen method for intubation. Once tube placement was confirmed and the patient's vital signs were acceptable, guidance of the endotracheal tube into the left mainstem bronchus was initiated via fiberoptic bronchoscope. Advancement of the endotracheal tube was unsuccessful after 2 attempts because of poor visualization through the scope. Successful placement was achieved under fluoroscopy with the use of a C-arm. Current practice suggests that using fluoroscopy is a safe alternative for verifying tube placement in the pediatric population.

Keywords: Parapneumonic empyema, pediatric single-lung ventilation, video-assisted thoracic surgery.

Single-lung intubation (SLI) and single-lung ventilation (SLV) can be challenging tasks for anesthesia providers, especially in the pediatric population. When dealing with pediatric patients, margins of error are diminished, the time to adapt and make decisions lessens, and stress levels increase. When faced with these types of situations, it is imperative that anesthesia providers have a plan of care formulated *and* a backup plan, should the original one fail.

When anticipating SLI and SLV, choosing which technique to use requires a careful examination of the patient. This would include an inquiry into past and current health experiences, such as why the patient is undergoing surgery, any medical problems that might interfere with the anesthetic plan (such as anesthetic reactions or malignant hyperthermia), and a complete physical evaluation entailing an in-depth airway assessment (such as loose teeth, mouth opening, macroglossia). The need for such a meticulous history and physical examination helps guide the anesthetic plan and also facilitates lessening potential problems. Of course, in a case of emergency, a rapid assessment might be all one has time for, and the anesthetic plan could change rapidly.

Traditional methods of SLI include bronchial blockers and single- and double-lumen endotracheal tubes (ETTs). Modes of SLV include jet ventilation, pressure control ventilation, pressure-regulated volume control, and oscillatory ventilation. Risks and benefits must be weighed when selecting a method for SLI and SLV. Knowing the physiological responses and outcomes of the intubation and ventilation method will help guide anesthesia providers in managing patients effectively.

The purpose of this case report is to offer an alternative method for guiding and verifying correct placement for SLI using fluoroscopy in the pediatric patient population. The chosen techniques for intubation and ventilation are discussed.

Case Summary

The patient was an otherwise healthy 2-year-old girl with a weight of 11.88 kg. She had an allergy to amoxicillin (rash). Health problems consisted of a history of asthma (no prior related admissions) and right otitis media, with no surgical history noted. Current home medications included levalbuterol as needed, cetirizine, budesonide, and azithromycin (day 4). She was sent to the emergency department after being seen by her pediatrician for cough, congestion, and fever for 1 week. The patient's vital signs on arrival to the emergency department were as follows: temperature, 99.3°F; blood pressure, 114/78 mm Hg; heart rate, 140/min; respiratory rate, 40/min; and room air oxygen saturation, 91% to 94%. Further workup included a chest radiograph that showed right-sided pneumonia with empyema, a computed tomography scan showing a complete right hemithorax, and pertinent serum laboratory studies with the following results: a white blood cell count, 34,200/µL; neutrophils, 60%; bands, 40%; glucose, 152 mg/dL; and blood cultures, negative. Treatments included oxygen at 1 L via nasal cannula and an albuterol nebulizer 1 time (oxygen saturation improved to 93%-98%); intravenous (IV) fluid, dextrose 5% in 0.5% normal saline with 20 mEq of potassium chloride infusing at 65 mL/h (admission potassium level, 4.4 mEq/L); and IV ceftriaxone, 600 mg. The patient was admitted to the hospital.

After an uneventful course of antibiotics spanning just more than 2 weeks, several previous procedures, including decortication and thoracoscopy, mechanical ventilation (lasting < 96 hours on admission), and a chest tube inserted into the right lung that continued with purulent drainage without improvement, the patient was brought to the operating room holding area. The scheduled procedure was a right-sided lower and partial right middle lobectomy using video-assisted thoracic surgery.

The patient was identified and identification verified. The preoperative interview revealed an active child with stable vital signs and a room air oxygen saturation of 97%. The only complications noted throughout her hospital stay were continued purulent chest tube drainage, an unresolved right upper lobe pneumothorax confirmed by chest radiograph, and diminished breath sounds. An airway assessment revealed no loose teeth, normal mouth opening, normal thyromental distance, and no limits in range of motion. Previous anesthetic records also showed no complications perioperatively. After consents were obtained, the patient was brought to the operating room.

The patient was placed on the operating table by her mother, and noninvasive monitors were then applied. Standard inductions of pediatric patients at this facility usually include mask induction with sevoflurane and oxygen. However, because this patient already had a peripherally inserted central catheter in place, oxygen at 10 L via mask was applied, and a smooth IV induction was instituted. Induction drugs included the following: IV fentanyl, 15 µg; and IV thiopental, 75 mg. When mask ventilation was easily established and confirmed, IV vecuronium, 1 mg, was administered. Once the patient was induced and relaxed, a No. 4.0 uncuffed ETT (chosen by using the "age divided by 4 plus 4" formula to achieve a leak at 20 cm of water pressure) was inserted under direct visualization via direct laryngoscopy with a Miller 2 blade. By using the Cormack-Lehane grading method, a grade 2 view of the vocal cords was obtained. Intubation was atraumatic, end-tidal carbon dioxide was visualized on the monitor, and breath sounds were equal bilaterally via auscultation. The ETT was secured at 13 cm at the lip (chosen by using the "age divided by 2 plus 12" formula). Acetaminophen, 360 mg per rectum, was administered for postoperative pain control.

Maintenance of anesthesia was achieved via a propofol infusion at 200 µg/kg per minute, along with a supplemental 1L/1L oxygen/air mixture at onset, a 7L/3L oxygen/nitrous oxide mixture mid-case, and 5L/0.5L oxygen/air mixture at the end of the case.

Due to the necessity of isolating the left lung, both SLI and SLV were needed. We elected to advance the single-lumen ETT into the left mainstem bronchus via a neonatal fiberoptic bronchoscope (FOB). However, this was unsuccessful after 2 attempts because of poor visualization through the FOB. When the original plan failed, the surgeon suggested using fluoroscopy via C-arm as an alternative method to guide the ETT into the left mainstem bronchus. After a couple of attempts via this suggested method, the ETT was successfully advanced to a distance of 18 cm at the lip. Fluoroscopy then revealed that the ETT was inserted too far, and the ETT was pulled back 3 cm, confirmed at this depth via auscultation, and then taped at 15 cm at the lip. The patient was then placed in the left lateral position, supported by axillary rolls and beanbag, with the head supported by a gel donut. Placement of the ETT was verified once again via auscultation, end-tidal carbon dioxide, and fluoroscopy. The patient was put on the ventilator using pressure control ventilation. Ventilator settings were maintained with a peak inspiratory pressure of 24 cm H_2O, tidal volumes maintained around 60 mL, and a respiratory rate of 24/min. Positive end expiratory pressure was not used. Oxygen saturations remained 100% throughout the entire case. End-tidal carbon dioxide remained in the 30s and 40s during the case and in the lower 60s on extubation.

As planned, a right upper and partial middle lobectomy occurred without complications. At the end of the case, 2 right-sided chest tubes were placed, 1 anterior and 1 posterior. Right lower lobe expansion occurred as expected. A total of 600 mL of crystalloid was administered, and 200 mL of packed red blood cells were transfused (due to preoperative hemoglobin and hematocrit values of 8.6 g/dL and 25.5% 13 days earlier). An estimated blood loss of 100 mL was determined. The patient was repositioned supine, and the ETT was pulled back, until bilateral breath sounds were auscultated and end-tidal carbon dioxide was visualized, to a depth of 13 cm. Before extubation, a chest radiograph confirmed ETT placement, chest tube placement, and adequate lung expansion of both left and right sides. Venous blood gas measurement revealed the following: pH, 7.17; carbon dioxide, 59 mm Hg; PO_2, 54 mm Hg; base excess, –7.7 mEq/L; SaO_2, 79%; hematocrit, 31.1%; hemoglobin, 10.6 g/dL; sodium, 139 mEq/L; and potassium, 3.9 mEq/L.

It was decided to extubate the child fully awake. Anesthetic agents were discontinued, oxygen at 5 L via circuit was instituted, and spontaneous ventilation resumed. Even though the induction dose of vecuronium was administered more than 3 hours before the end of the case, a peripheral nerve stimulator was attached to the arm and verified a train-of-four of 4/4. The child continued moving all extremities and moving her head from side to side. Oxygen saturation values remained at 100% with respiratory rates varying from the mid 20s to low 30s/min. The ETT was removed without incident. On extubation, the patient was crying and continued moving all extremities. She was given oxygen at 5 L via "blow by" and then transported to the postanesthesia recovery unit. She was medicated with 10 µg of IV fentanyl IV. Oxygen saturation remained 99% to 100% throughout the recovery period, and no pulmonary complications were reported.

The postoperative day 0 check that night revealed that the left lung was clear, the right lower lobe was still expanded, and oxygen saturation values remained 97% to 99% on room air. On postoperative day 2, the patient was transferred from the pediatric intensive care unit to a general pediatric floor. During postoperative days 3 and 4, the chest tubes were removed, and oxygen saturation values were maintained at 100% on room air. On postoperative day 6, the child was active and playful. Vital signs were stable, she remained afebrile, and was discharged home; her mother was asked to follow up by scheduling a chest radiograph for the child in 2 weeks.

Discussion

Today, several methods exist for isolating a single lung and implementing SLV. The method chosen will depend on the type of surgery, the patient, and surgeon preference. Reasons for needing isolation include massive hemorrhage, bronchopleural fistula, unilateral pulmonary disease, and control of secretions during the removal of an infected part of lung tissue.[1] Several techniques to isolate a lung include the single-lumen ETT, the double-lumen tube, bronchial blockers, and the Univent ETT (Fuji Systems Corporation, Tokyo, Japan). The simplest means of providing SLV to the desired lung is by using a single-lumen ETT.[2]

When deciding which type of equipment to use in the pediatric population, the choices become limited due to not only facility-specific equipment availability but also factory production. The limitation of using the double-lumen tube in pediatrics in the United States is that sizes are available only for ages 6 or older. A balloon-tipped bronchial blocker can be used safely for SLV in pediatric populations. According to the manufacturer, Univent tubes can accommodate children who can tolerate an internal diameter of 3.5 mm. Because sizes are available that will accommodate children (including neonates) and adults, it was decided to use a single-lumen ETT.

It is important to note that several complications could arise when using SLV, especially in pediatric populations, related to the developing pulmonary mechanics. These include hypoxemia, hemorrhage, hemodynamic instability, bronchial rupture (traditionally, if a double-lumen tube used), and alveolar lesions caused by a high fraction of inspired oxygen of 1.0.[1] Several physiological factors can also be affected. When gas exchange is abnormal, thoracic procedures can be dangerous in small children because of intraoperative and postoperative reductions in oxygen saturation due to alterations in chest and pulmonary compliance.[3] Abnormal gas exchange can be further compounded by the position of the patient during surgery. During SLV, there is also a high incidence of atelectasis in the nonventilated lung.

In the pediatric population, physiological changes become pronounced with changes in patient position. Tidal volumes are redistributed away from the dependent lung. When spontaneous contraction of the diaphragm ceases, there is increased tension on the diaphragm of the dependent lung.[4] This tension seems to impair ventilation rather than make it easier. With improper positioning, lung movement is further limited. All of these issues contribute to the decreased proportion of the tidal volume that is usually distributed to the dependent lung, further leading to an increase in the ventilation-perfusion ratio mismatch. In this case, the main change in perfusion is caused by hypoxic pulmonary vasoconstriction, which is stimulated after the onset of SLV.[4] Hypoxic pulmonary vasoconstriction actually helps decrease the ventilation-perfusion mismatch from SLV by shunting blood flow away from the less oxygenated to the more oxygenated alveoli.

Although SLV facilitates the surgeon's view of the surgical field, it decreases the surface area available for gas exchange. When choosing the optimal method of ventilation, physiological factors and changes are taken into consideration. Because of its unique ability to deliver small tidal volumes at low mean airway pressures via a narrow catheter, high-frequency jet-oscillatory ventilation is a good alternative strategy when using a single-lumen ETT in pediatrics. Pressure control ventilation may also be used with both of the previously described methods of SLV, which was the preferred choice for the present case. The use of volume control ventilation is avoided in pediatrics because of the high risk of barotrauma and inaccurate tidal volumes delivered at so few milliliters per kilogram.

In the present case, the original planned method to obtain SLV was not possible. This emphasizes the need to always have a backup plan, so that if the original plan fails, achieving success will not be time-consuming or detrimental to the patient. It is important to recognize that with each individual pediatric patient there are specific and unique considerations that must be made when choosing a method for SLV. Again, these include the type of surgery, the patient's anatomical and physiological conditions, surgeon preference, the anesthesia provider's comfort level with various techniques, and the equipment available in the institution. In the present case, it was initially decided to help guide the ETT via the use of an FOB. When 2 different FOBs failed on 2 separate occasions, the surgeon suggested the use of fluoroscopy as a tool to help guide advancement. This method turned out to be successful. Current literature states that the use of fluoroscopy can provide an adequate and safe alternative to help guide an ETT into a mainstem bronchus within the pediatric population.[5-7]

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