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# One-Lung Ventilation: A Pediatric Simulation Case for Anesthesiology Residents

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## Abstract

**Introduction:** This activity is designed for midlevel and senior anesthesia trainees to experience the complexities of one-lung ventilation in pediatrics in a high-fidelity simulated environment. With the use of video-assisted thoracoscopic surgery (VATS) becoming increasingly common in pediatrics, we identified this area as an opportunity for the development of a dedicated educational simulation activity. **Methods:** Our simulated patient is a 3-year-old girl with empyema presenting for decortication via VATS who subsequently develops hypoxemia. The main challenges for the trainee include airway selection and insertion, lung isolation with fiber optic confirmation, and management of hypoxemia in the setting of one-lung ventilation. A pediatric medical simulator suitable for practicing resuscitation is required, and a tracheobronchial tree model is highly desirable. Basic knowledge of thoracic and pediatric anesthesia is required, but specific experience with pediatric lung isolation is not. **Results:** Learners who experienced the content of this simulation expressed a strong sentiment of value. All pilot trainees were surveyed and indicated they either agree or strongly agree (4 or 5, respectively, on a 5-point Likert scale) that "This simulation enhanced my understanding of how to select lung isolation devices for pediatric patients" and "This simulation enhanced my understanding of how to manage hypoxia in context in one-lung ventilation." Comments were overall positive, including "I am better prepared to manage pediatric one lung ventilation cases." **Discussion:** At the University of Iowa, this activity is part of a core curriculum of simulation training that resident physicians in anesthesiology experience during their training. It functions as a tool for education, evaluation, and self-identification of weaknesses in the learner's knowledge base as it relates to the perioperative management of pediatric one-lung ventilation, as well as for reinforcing material learned in the classroom and operating room. Numerous anesthesiology residents and faculty have pilot-tested this simulation, and necessary modifications have been made based on their feedback.

## Keywords

Anesthesia, PALS, Airway, Pediatric Anesthesia, Lung Isolation, Hypoxia, Bronchial Blocker, Thoracic Surgery, Fiber Optic

## Educational Objectives

By the end of this simulation, the learner will be able to:

1. Interpret/summarize general history, physical exam, imaging, and labs of a pediatric patient in the context of planned procedure (American Board of Anesthesiology milestone [ABA] Patient Care [PC] 1, Medical Knowledge [MK] 1).
2. Compare/critique the various lung isolation devices, including single lumen endotracheal tube (ETT), balloon-tipped bronchial blockers (BBs) such as Arndt endobronchial blocker, double lumen endobronchial tubes, and Univent tubes such as Fuji BBs (ABA PC1).
3. Plan for general anesthesia with lung isolation (ABA PC2).
4. Select an appropriate airway isolation device (i.e., BB available with appropriately matched single lumen ETT), understanding the unavailability of double lumen endobronchial tubes for this patient population (ABA PC2).

## Appendices

- A. Simulation Case Pediatric OLV.docx
- B. Supplemental Data Pediatric OLV.docx
- C. Critical Actions Checklist Pediatric OLV.docx
- D. Debriefing Summary Pediatric OLV.docx
- E. Evaluation Form Pediatric OLV.docx

*All appendices are peer reviewed as integral parts of the Original Publication.*

5. Plan for anticipated and potential intraoperative needs by having a selection of BBs available with appropriately matched single lumen ETT, backup airway adjuncts, arterial line ready, bronchoscopy tower with small-sized bronchoscope prepared and calibrated, continuous positive airway pressure (ABA PC2).
6. Discuss overall operative plan with surgeon, including need for bronchoscopy and likelihood of ICU postoperatively (ABA PC2, Interpersonal Skills and Communication [ICS] 2).
7. Develop postoperative analgesic and care plan (ABA PC3).
8. Perform mask ventilation (ABA PC8).
9. Optimize patient positioning for intubation and perform basic airway placement (ABA PC8).
10. Successfully place lung isolation device (ABA PC8).
11. Perform fiber optic bronchoscopy and lung isolation device placement (if tracheobronchial tree model available) (ABA PC2, PC8).
12. Identify tracheal and bronchial landmarks using online bronchoscopy simulator, thus inferring correct versus incorrect BB placement (if tracheobronchial tree model not available) (ABA PC2, PC8).
13. Recognize the need for arterial line and baseline blood gas (ABA PC2, PC9).
14. Recognize hypoxemia as one important potential complication and explain risk factors for hypoxemia (ABA PC4).
15. Implement lung recruitment maneuvers before one-lung ventilation to decrease the risk of hypoxemia (ABA PC4).
16. Identify the development of hypoxemia (ABA PC4, PC9).
17. Implement continuous positive airway pressure and/or positive end-expiratory pressure to treat hypoxemia (ABA PC4).
18. Recognize the need to call for help when severe hypoxemia or cardiac arrest occurs (ABA PC5).
19. Manage cardiac arrest following Advanced Cardiovascular Life Support and delegate duties accordingly (ABA PC5, MK1, ICS3).
20. Evaluate/critique areas of strength and areas for improvement discovered during the simulation (ABA Professionalism 4).

*Note:* The objectives above include references to their corresponding anesthesiology milestones as outlined by the Accreditation Council for Graduate Medical Education and the American Board of Anesthesiology in the Anesthesiology Milestone Project.

### Introduction

Video-assisted thoracoscopic surgery (VATS), as compared with open thoracotomy, offers the advantages of a smaller incision, less postoperative pain, and a faster postoperative recovery. Recent advances in video-assisted thoracoscopy have stimulated a more aggressive approach to endoscopic thoracic surgical intervention, even in children.<sup>1</sup> Nevertheless, anesthesia for VATS in small children is challenging because, in addition to sharing many of the complexities of one-lung ventilation in adults, it has unique difficulties related to the pulmonary physiology in this population, as well as the availability of appropriately sized equipment. Therefore, we identified this topic as being an opportunity for the development of a dedicated educational simulation activity.

We performed a literature search but were unable to retrieve any educational publications specifically addressing this topic. Chatterjee<sup>2</sup> published a problem-based learning discussion on esophageal atresia and tracheoesophageal fistula in neonates, briefly touching on the subject of one-lung ventilation, and Hassan, Dorfling, McLarney, and Sloan<sup>3</sup> developed a simulation scenario for one-lung ventilation, but it

was not specific to pediatrics. Thus, to the best of our knowledge, this is the first report of an educational simulation dedicated to one-lung ventilation in pediatrics.

In creating a simulation for anesthesiology trainees, our personal experience was used to assist in the development of the proposed scenario, along with specific literature referring to anesthetic management for pediatric VATS<sup>1,4</sup> and guidelines for pediatric advanced life support.<sup>5</sup>

This simulation was instituted at the University of Iowa for resident physicians within the Department of Anesthesiology on the last 2 years of residency (i.e., the CA-2 and CA-3 years). Thus, all trainees taking this simulation would have been exposed to at least 1 month of pediatric surgery (during the intern year) and 1 month each of pediatric anesthesia and cardiothoracic anesthesia (during the CA-1 year). As a result, all trainees were expected to have a basic understanding of one-lung ventilation, recognition of hypoxia, and the differences between pediatric and adult anesthesia; we consider these to be minimum prerequisites for this simulation. Specific exposure to pediatric thoracic anesthesia on the other hand, although helpful, is not a definite requirement.

## Methods

Simulation is a technique, immersive in nature, that evokes or replicates substantial aspects of the real world in a fully interactive fashion. Ultimately, its goal is to improve patient safety.<sup>6</sup> Simulations are necessary because written examinations measure acquisition of knowledge but fail to predict if trainees can apply knowledge to problem solving.<sup>7</sup>

### Equipment/Environment

The format of this simulation (Appendix A) is designed to be a single 1-hour session in an anesthesia faculty-staffed simulation center using the pediatric SimMan (Laerdal Medical, Stavanger, Norway) medical simulator connected to standard monitors, IV fluid (crystalloid), and arterial line. Vital signs are provided throughout the simulation via the monitors connected to the simulator; laboratory results (Appendix B) are provided to the learner by the instructor. In addition, a pediatric manikin suitable for practicing resuscitation is necessary for the final phase of the simulation. By using the SimMan medical simulator to provide real-time vital signs and procedural guidance, learners are immersed in this experiential learning opportunity rather than simply participating in a question-and-answer session to learn about the topic at hand, which in turn improves the overall learning experience.<sup>8</sup>

If available, a tracheobronchial tree model can be used to simulate fiber optic confirmation of bronchial blocker placement; this is highly desirable but not a definite requirement. Alternatively, an online bronchoscopy simulator can be substituted, such as the one available at <http://www.thoracic-anesthesia.com>.<sup>9</sup>

- Drugs required: propofol, fentanyl, ketamine, ephedrine, rocuronium, succinylcholine, epinephrine, atropine, lidocaine, glycopyrrolate, oral midazolam, and albuterol.
- Monitors required: noninvasive blood pressure cuff, capnograph, temperature probe, nerve stimulator, pulse oximeter, 3 lead (EKG) electrocardiogram, and arterial line.
- Other equipment required: anesthesia machine, endotracheal tube, laryngeal mask airway, laryngoscope, stethoscope, defibrillator/crash cart, Storz video tower, small scope, 4Fr double lumen central line kit, ultrasound, Arndt endobronchial blocker size 5, 7, 26F double lumen endobronchial tubes, Fuji bronchial blockers sizes 4.5, 5.0, single lumen endotracheal tube, 3.5/4.0/4.5mm uncuffed.

### Resource Files

*Appendix A. Simulation Case Pediatric OLV:* This file contains specific details regarding the simulation case, including a brief narrative description of the case, learning objectives to be covered by the simulation, and a summary of critical actions to be performed by the learner during the educational activity. In addition, this document also contains information on the simulated patient's initial presentation, including history of present illness, vital signs, physical exam findings, and laboratory studies, and a guide as to how the case is to progress based on the actions taken by the learner. Finally, the document

concludes with a sample of ideal management of the simulated patient as well as some common pitfalls that were demonstrated by trainees while performing the simulation.

*Appendix B. Supplemental Data Pediatric OLV:* This file contains all of the objective data that can be requested by the learner during the simulation.

*Appendix C. Critical Actions Checklist Pediatric OLV:* This file contains a checklist of actions that would comprise one possible route for optimal management of the simulated patient, which can be used to assess the performance of the trainee during the simulation. The file also contains a tool by which the instructor can rate the learner based on his or her performance on the five primary learning objectives.

*Appendix D. Debriefing Summary Pediatric OLV:* This file contains a written summary of the pathophysiology and treatment guidelines used to govern the simulated case. It is designed to be read both by the instructor prior to the case in order to refresh critical concepts and by the learner after the case to solidify learning points discovered during the simulation. To this end, the document can be printed as a handout to be taken by the trainee following the simulation.

*Appendix E. Evaluation Form Pediatric OLV:* This file contains an evaluation form for the learner in order to provide feedback regarding the simulation. The evaluation form addresses feedback both for the facilitator who led the simulation and for the content of the simulation itself.

#### Personnel

The simulation can be proctored by a single instructor with the help of a technician for the high-fidelity medical simulator.

#### Assessment

Learners during the simulation are to be assessed on items that are critical to quality care; these items include knowledge (e.g., proper selection of airway devices), skills (e.g., fiber optic bronchoscopy), ability to react to circumstances (e.g., recognizing and treating hypoxemia), and attitudes (e.g., calling for help when appropriate). The critical action checklist (Appendix C) was created during evaluation of the step-by-step process of the simulation with the goal of providing a list of the most essential steps in caring for the simulated patient; however, as clinical judgment is more important than any single checklist, this list is meant to be modified based on institutional protocols at the discretion of the instructor.

#### Debriefing

As described in the debriefing summary (Appendix D), we usually start with open-ended, self-reflection questions such as “What do you think went well?”, “What did you have difficulty with?”, and “Is there anything you think you should have done differently?” before proceeding to specific questions about the case. Although debriefing typically focuses on the critical action checklist, the debriefing preparation material in the debriefing summary far exceeds the knowledge base necessary for said critical actions. This is by design, as it allows for appropriate preparation for faculty who may administer the simulation but are not experts in pediatric one-lung ventilation. The debriefing summary can also be presented to the learner as a handout along with the evaluation form (Appendix E).

#### Results

During the 2015-2016 academic year, several eligible anesthesiology resident physicians from varying levels of training (CA-1, CA-2, and CA-3) were able to experience the content of this simulation. The simulation was presented by or with the assistance of the core simulation faculty within the Department of Anesthesiology.

Learners who experienced the content of this simulation expressed a strong sentiment of value. All pilot trainees were surveyed and indicated they either *agree* or *strongly agree* (4 or 5, respectively, on a 5-point Likert scale) that “This simulation enhanced my understanding of how to select lung isolation devices for pediatric patients” and “This simulation enhanced my understanding of how to manage hypoxia in context in one-lung ventilation.” Comments were overall positive, including “I am better prepared to manage pediatric one lung ventilation cases” and “Useful information. Managing hypoxia in this case

translates to many different situations.” Overall, pilot trainees and staff indicated this simulation offered valuable specific information regarding pediatric one-lung ventilation strategies and general physiology education that was a net positive learning experience.

### Discussion

Numerous anesthesiology residents and faculty have pilot-tested this simulation, with necessary modifications made based on their feedback. In our simulation center, it is expected that this simulation will be run approximately 15-20 times annually.

Depending on the trainee’s experience, this scenario can be run with a faculty member at the trainee’s side during induction, much as would occur at many training institutions in the United States. For an advanced trainee, the scenario can be slightly changed so that the he or she exhibits greater autonomy.

The goal of this simulation is to expand upon an anesthesia resident’s one-lung ventilation and thoracic anesthesia knowledge base, improve technical skills for placing lung isolation devices, and optimize management of complications specific to pediatric one-lung ventilation. This simulation can also be adapted, depending on resident performance and experience level, to perioperative management of one-lung ventilation and concomitant complications of thoracic surgery.

With regard to limitations and difficulties, this is a case simulation of a subspecialty population. Given that these cases are not commonly experienced by all anesthesiology residents, a broader introduction of pediatric one-lung ventilation may be required. However, we have included supplemental materials to give a broad lecture for novice learners and more detailed materials to sharpen the skills/knowledge of more advanced learners. Additionally, the equipment needed to learn the tracheal anatomy necessary to secure a one-lung ventilation device is not always available; therefore, we include internet links to a website that specifically addresses this in the debriefing summary.

Overall, we would expect steady progress in terms of technical proficiency, managing intraoperative one-lung ventilation, and thoracic anesthesia from self-study reinforced by this simulation.

The pediatric one-lung ventilation simulation provides a safe and less stressful environment to expose novice practitioners to an unfamiliar and specialized scenario requiring them to employ skills and knowledge that will enrich their educational experience.

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