Postanesthesia Care Unit Simulation

Acute Upper Airway Obstruction Secondary to Laryngospasm

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DEMOGRAPHICS

Case Title: Acute Upper Airway Obstruction Series: Laryngospasm With Resultant Negative-Pressure Pulmonary Edema

Patient Name: Debbie White

Case Description and Diagnosis: An obese, 36-year-old woman who was admitted to the postanesthesia care unit (PACU) 5 minutes ago after undergoing a laparoscopic cholecystectomy under general anesthesia and extubated deeply in the operating room is presented to the participant. The patient is unconscious and initially breathing easily with an oral airway in place. During observation, she exhibits a sudden increase in respiratory effort and noise with ventilation. The diagnosis of laryngospasm is made and treated, only to reveal persistent hypoxemia and negative-pressure pulmonary edema (NPPE).

Target Audience:
- Anesthesiologists in practice
- Anesthesiology residents (PGY2–PGY4)
- Interdepartmental residents rotating through anesthesia
- Medical students (third and fourth year)
- Certified registered nurse anesthetists
- Certified registered nurse anesthetist students

CURRICULAR INFORMATION

Educational Rationale

Upper airway obstruction in the PACU is not uncommon and has multiple etiologies. Recognizing presenting signs and symptoms and understanding the physiology arising from varying causes of obstruction is essential to making the correct diagnosis and correcting the problem. In this case, the learner is exposed to a common airway complication in the PACU, laryngospasm, which is further complicated by NPPE. It is important that the provider is aware of both cardiac and noncardiac causes of acute-onset perioperative pulmonary edema during the diagnostic phase to guide effective treatment and resolution.1 Negative-pressure pulmonary edema is seen as often as 1 in 1000 patients that receive anesthesia, with most cases occurring in the postextubation period secondary to laryngospasm.1 After relief of the upper airway obstruction, roughly 10% of patients develop clinical signs of NPPE.2,3 It is important to understand that certain patients, such as those with obstructive sleep apnea or nasopharyngeal abnormalities, may be at increased risk of forming acute pulmonary edema in the postextubation phase.4–6 As with any airway complication, prompt diagnosis and timely management are required for improved clinical outcomes. Simulation provides an opportunity for trainees to practice real-time analysis of data, formulate and execute a reasonable plan, and optimally use surrounding resources during a potentially stressful and urgent time.

ACGME Core Competencies

(1) Patient care (PC), (2) medical knowledge (MK), (3) practice-based learning and improvement (PLI), (4) interpersonal and communication skills (CS), (5) professionalism (PR), and (6) systems-based practice (SBP).

Learning Objectives

1. Discuss how to ensure a comprehensive handoff of patient care (PC, CS, PR, SBP).
   a. Standardization is useful in providing comprehensive handoff of patient information. One
communication tool with this goal in mind is SBAR, which stands for situation, background, assessment, and recommendation. By using this tool, pertinent information about the patient’s history of present illness, interventions, medical history, physical examination and useful laboratory work can be presented succinctly along with a suggested plan of care.

2. Discuss the differential diagnosis for acute respiratory distress indicative of an airway obstruction in a postoperative patient (PC, MK).
   a. A likely cause of upper airway obstruction in a PACU patient with stridulous breath sounds shortly after extubation is laryngospasm. Other etiologies include trauma (airway burn or hemorrhage), infection (retropharyngeal abscess or epiglottitis), iatrogenic (postextubation), foreign bodies, vocal cord paralysis, tumors (laryngeal tumors), or angioedema (anaphylactic, angiotensin-converting enzyme inhibitors, or Cl inhibitor deficiency).  
   b. This patient presents with stridor and increased work of breathing in the early postextubation period, suggestive of upper airway obstruction.
   c. The nasal cannula may be used up to 6 L/min, at which point, higher flow rates may cause discomfort to the patient because the high flows and relatively low humidity can cause mucosal 
   d. In extreme cases where all of the previously measures are unable to secure an airway, an emergent percutaneous airway via cricothyrotomy is indicated. This approach is through the cricothyroid membrane and can be performed with a needle technique.

3. Describe the diagnosis and treatment of airway obstruction (PC, MK).
   a. Diagnosis of upper airway obstruction is reached based on presenting situation, physical examination findings, and improvement with appropriate treatment.
   b. A common postoperative cause of obstruction is loss of pharyngeal muscle tone, usually related to prolonged neuromuscular blockade, opioids, persistent effects of inhaled/intravenous anesthetics, or patient history of obstructive sleep apnea.  
   c. Hypoventilation  
   d. Supplemental oxygen therapy in the PACU should be administered based on the patient’s medical history, surgery performed, and current condition.

4. Describe the diagnosis and treatment of laryngospasm (PC, MK).
   a. Diagnosis of laryngospasm is reached based on patient risk factors, presenting situation, physical examination findings, and improvement with appropriate treatment.
   b. Risk factors for laryngospasm in this patient include history of asthma, recent extubation, and residual sedation. Other risk factors include smoking or smoke exposure, pediatric patient, ENT surgery, or recent upper respiratory infection. Clues to diagnosis include the acute desaturation with increased work of breathing, high-pitched upper airway sounds, and inadequate or absent breath sounds.
   c. Treatment of laryngospasm is aimed at supporting ventilation. Call for help early. Attempt airway maneuvers such as jaw thrust and nasal airway. Assist the patient’s inspiratory effort with positive-pressure ventilation with 100% oxygen. The next line of therapy would be to administer a low dose of succinylcholine (10–20 mg) to relax the vocal cords. If these maneuvers fail, induction and intubation may be necessary.

5. Describe the differential diagnosis and management of postoperative hypoxemia with oxygen supplementation and with positive-pressure ventilation (PC, MK).
   a. The formal physiologic differential diagnosis for arterial hypoxemia consists of the following:  
   b. Low FIO2—seen in high altitudes where the atmospheric pressure is low and total oxygen inhaled is less than at sea level (21%).  
   c. Participant should be aware of the concept of V/Q mismatch and the difference between shunting and dead space. Generally, supplemental O2 does not improve oxygen saturation in cases of shunting.
   d. Supplemental oxygen therapy in the PACU should be administered based on the patient’s medical history, surgery performed, and current condition. The nasal cannula may be used up to 6 L/min, at which point, higher flow rates may cause discomfort to the patient because the high flows and relatively low humidity can cause mucosal
<table>
<thead>
<tr>
<th>State</th>
<th>Patient Status</th>
<th>Student Learning Outcomes or Actions Desired</th>
<th>Trigger to Move to Next State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Baseline (0:00)</td>
<td>Patient is hemodynamically stable in the PACU 5 minutes postoperatively</td>
<td>Learner actions Operator</td>
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<tr>
<td></td>
<td>HR 85</td>
<td>○ Handoff of care</td>
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<tr>
<td></td>
<td>BP 120/70</td>
<td>○ Patient is on 5-L face mask with increased work of breathing</td>
<td></td>
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<tr>
<td></td>
<td>RR 10</td>
<td>○ Teaching points and objectives</td>
<td></td>
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<tr>
<td></td>
<td>SpO₂ 99% on 5-L face mask oxygen</td>
<td>○ SBR handoff technique</td>
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<td></td>
<td>Temperature 36.7°C</td>
<td>○ Trigger: Handoff completed</td>
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<tr>
<td></td>
<td>Stridor, minimal breath sounds, retractions</td>
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<td>2. Hemodynamics begin to deteriorate (.30)</td>
<td></td>
<td>Learner actions Operator</td>
<td></td>
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<tr>
<td></td>
<td>HR 120</td>
<td>○ Prepare to treat/diagnose tachycardic and hypertensive patient</td>
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<tr>
<td></td>
<td>BP 150/80</td>
<td>○ Nurse states “increased retractions noticed”</td>
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<tr>
<td></td>
<td>SpO₂ 94% on 5-L O₂</td>
<td>○ Teaching points and objectives</td>
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<tr>
<td></td>
<td>RR 15</td>
<td>○ Differential diagnoses of elevated blood pressure and pulse</td>
<td></td>
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<tr>
<td></td>
<td>Temperature 36.7°C</td>
<td>○ Treatment of tachycardia</td>
<td></td>
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<tr>
<td></td>
<td>Increased stridor, retractions, and absent breath sounds</td>
<td>○ Continuous monitoring of the patient</td>
<td>Trigger: Increased work of breathing</td>
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<tr>
<td>3. Marked hypertension and tachycardia (1:00)</td>
<td>Increased work of breathing and desaturation</td>
<td>Learner actions Operator</td>
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<tr>
<td></td>
<td>HR 145</td>
<td>○ Treat hypoxia with oxygen by face mask</td>
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<tr>
<td></td>
<td>BP 170/80</td>
<td>○ BP/HR increases, and O₂ decreases</td>
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<tr>
<td></td>
<td>SpO₂ 90% on 5 L</td>
<td>○ Teaching points and objectives</td>
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<tr>
<td></td>
<td>RR 20</td>
<td>○ Discuss differential diagnosis of increased work of breathing and hypoxia in a postoperative patient</td>
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<tr>
<td></td>
<td>Temperature 36.6°C</td>
<td>Trigger: Appropriate treatment of hypoxia</td>
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<tr>
<td>4. Worsening desaturation (1:30)</td>
<td>Breath sounds decrease and retractions decrease</td>
<td>Learner actions Operator</td>
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<td></td>
<td>HR 80</td>
<td>○ Interpret laboratory results</td>
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<td></td>
<td>BP 130/80</td>
<td>○ If laboratory results are requested, give laboratory values</td>
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<td></td>
<td>SpO₂ 80% on 5-L O₂</td>
<td>○ Teaching points and objectives</td>
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<td></td>
<td>RR 30</td>
<td>○ Management of hypoxic patient</td>
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<tr>
<td></td>
<td>Temperature 36.6°C</td>
<td>○ Order laboratory values including hemoglobin, electrolyte panel, and arterial blood gas</td>
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<td></td>
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<td>Trigger: Appropriate management of hemodynamics/vitals</td>
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<td>5. Premature ventricular contractions (PVCs) begin (2:00)</td>
<td>Respiratory exhaustion with agonal inspiratory efforts</td>
<td>Learner actions Operator</td>
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<td></td>
<td>HR 54</td>
<td>○ Recognize respiratory failure</td>
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<td></td>
<td>BP 80/40</td>
<td>○ Nurse may state the patient has agonal inspiratory efforts</td>
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<tr>
<td></td>
<td>SpO₂ 65% on 5-L O₂</td>
<td>○ Teaching points and objectives</td>
<td></td>
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<tr>
<td></td>
<td>RR 10</td>
<td>○ Pathophysiology of upper airway obstruction</td>
<td></td>
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<tr>
<td></td>
<td>Temperature 36.7°C</td>
<td>○ Trigger: Assess airway</td>
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<tr>
<td></td>
<td>Arterial blood gas reveals respiratory acidosis and hypoxemia 7.2/59/65/26</td>
<td>○ Evaluate for intubation</td>
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</table>

(Continued)
drying. FIO₂ is increased by 0.04 with every additional liter supplemented by nasal cannula. If the patient remains hypoxic with supplemental oxygen, then positive-pressure ventilation should be considered. Continuous positive airway pressure may improve the hypoxemia by recruiting additional alveoli to increase ventilation of blood in the pulmonary circulatory system. In this case, noninvasive positive-pressure support may be used as an alternative to intubation. It would be prudent to ventilate the patient gently to avoid inflating the stomach and increasing risk of aspiration.

6. Describe the treatment of pulmonary edema secondary to airway obstruction (PC, MK).
   a. Treatment of NPPE begins with the resolution of the upper airway obstruction. Often, in a healthy
patient, NPPE will resolve spontaneously. During this time, the patient should receive supportive therapy as necessary including supplemental oxygen and positive-pressure ventilation. It is important to note that this type of edema is different from the typical pulmonary edema seen in other patients (cirrhosis, renal failure, congestive heart failure, volume overloaded patients, etc.). The fluid is being pulled from the intravascular volume, and therefore, the patient may actually be hypovolemic. It is for this reason that diuretics should be reserved for cases of underlying fluid overload from previous medical conditions. Steroids and epinephrine may also be treatment options. Recovery may take 12 to 48 hours if the correct diagnosis and treatment is in place.

7. Discuss how to prioritize tasks and delegate tasks in a time of crisis (PC, CS, PLI, SBP).
   a. The participant should be referred to the principles of crises resource management. Essentially, the participant should be aware of all available resources and call for appropriate help early on in the development of the crisis. During this time, the participant should remain calm, prioritize, and delegate tasks to staff based on their abilities and skill level. Closed loop communication is a key and can help to ensure that tasks are understood and done in a timely fashion.

8. Discuss the evaluation process for intubation versus noninvasive CPAP (MK).
   a. Both the etiology and estimated time to recovery are important in choosing treatment of upper airway obstruction. If the condition will improve in a short period with noninvasive CPAP, then intubation is not necessary. However, if the patient meets intubation criteria by insufficient ventilation or oxygenation, for example, a more invasive approach may be needed.

   a. The participant should acknowledge that although the crisis has resolved, the patient is still in a critical condition. Therefore, the patient should require close observation, and an appropriate discussion of disposition is warranted with the primary team and nursing staff in the PACU. In addition, the event should be clearly and concisely relayed to both groups using the SBAR technique previously described.

4. Recognize hemodynamic instability and premature ventricular contractions with oxygen desaturation and order 100% O₂ via bag valve mask.
5. Establish additional intravenous access and/or central venous access if there is adequate time. Considering the acuity of this situation, it may be necessary to skip this step and administer an intramuscular dose of succinylcholine.
6. Recognize laryngospasm and administer low dose succinylcholine with improved airway resistance and air movement. Evaluate patient for intubation versus CPAP and appropriate airway management.
7. Recognize pink frothy secretions and diagnose acute NPPE secondary to airway obstruction and administer furosemide and noninvasive CPAP.
8. Call for assistance during medical emergency.
9. If cardiac arrest develops, initiate cardiopulmonary resuscitation.
10. Detect stabilizing condition with appropriate airway management.
11. Delegate tasks appropriately using all available personnel.
12. Transfer patient to highly monitored care to ensure adequate resolution of airway obstruction and pulmonary edema.

Guided Study Questions

1. What are the essential elements of effective handoff communication (SBAR—situation, background, assessment, and recommendation—technique)?
   a. The SBAR format should be used during patient handoff between anesthesiologists and nurses in the PACU. The SBAR includes situation, background, assessment, and recommendations. For situation, identify yourself, identify the patient, and the current state of the patient. For background, identify medical history and procedure details. For assessment: evaluate vital signs including respiratory rate (RR), blood pressure (BP), pulse, oxygen saturation, level of pain, consciousness, and input/output of fluids. For recommendation, what you recommend is done next for the patient.

2. What patients are at risk for laryngospasm? Negative-pressure pulmonary edema?
   a. Laryngospasm in the postoperative patient is seen immediately after extubation and may be triggered by extubation during light planes of anesthesia or secretions that have fallen on the vocal cords. Patient-specific risk factors were discussed previously (smoke exposure, reactive airway disease, pediatric population, upper respiratory infection symptoms, etc). Additional risk factors include electrolyte abnormalities, anaphylaxis, tetanus, and retropharyngeal abscess.
   b. Patients with upper airway obstruction are at risk for NPPE. The participant should make sure that this is in fact NPPE and not another cause of

Simulation Performance Objectives

1. Communicate diagnosis to health care team promptly to initiate collaborative action.
2. Recognize increased respiratory effort with retractions, minimal breath sounds, and inspiratory stridor.
3. Order arterial blood gas, chest x-ray, 5 to 8 L/min face mask oxygen.
pulmonary edema such as fluid overload or heart failure. The main cause of NPPE in the early postextubation phase is laryngospasm. However, any obstruction to the airway can cause NPPE including trauma or head and neck tumors.

3. What is the pathophysiology of laryngospasm? Negative-pressure pulmonary edema?
   a. Mechanical stimulation of the intrinsic laryngeal muscles of the true vocal cords can cause them to spasm, occluding the laryngeal opening. Laryngospasm most often occurs in the early postextubation phase while the patient is emerging from general anesthesia. This may occur in the operating room or in the PACU.
   b. Negative-pressure pulmonary edema is caused by the generation of negative intrapleural pressure when the patient inspires against an obstructed airway. This increased pressure leads to increased venous return to the right heart and increased pulmonary blood volume. Increased hydrostatic pressure along with possible increased capillary permeability ultimately results in pulmonary edema. It is important to rule out other causes of pulmonary edema such as congestive heart failure, fluid overload, cirrhosis, renal failure, and acute respiratory distress syndrome.

**REFERENCES USED**


**Didactics**

None.

**Assessment Instruments**

None.

**PREPARATION**

**Monitors Required**

- Noninvasive blood pressure cuff
- Arterial line
- 5-lead electrocardiogram
- Temperature probe
- Pulse oximeter
- Capnograph
- Foley catheter

**Other Equipment Required**

- Anesthesia machine
- Face mask oxygen
- Bag valve mask
- Nasal/oral airway
- Noninvasive CPAP
- Pumps
- Defibrillator
- Nerve stimulator
- Suction
- Labeled syringes—furosemide, succinylcholine, propofol
- Endotracheal tube—7.0 mm
- Laryngoscope—#3 blade
- Isotonic sodium chloride solution

**Supporting Materials**

- Chest x-ray revealing pulmonary edema
- 12-lead electrocardiogram
- Preoperative history and physical
- Anesthesia record
- Pink frothy secretions
- Laboratory values
  
  iStat: pH 7.24; \( PCO_2 \), 59 mm Hg; \( PO_2 \), 65 mm Hg; base excess, −4; Sat, 90%.

  Na, 135 mmol/L; K, 4.2 mmol/L; iCal, 4.3; Glu, 110.6 mmol/L;
  
  Hgb, 13 g/L; Hct, 39.

**Time Duration**

Set-up: 15 min
Preparation: 10 min
Simulation: 15 min
Debrief: 20 min

**SIMULATION EXERCISE**

**Information for Participant**

Case Stem to be Read to Participants

An obese 36-year-old woman was admitted to the PACU 5 minutes ago after undergoing a laparoscopic cholecystectomy under general anesthesia and extubated deeply in a fast-paced operating environment. The patient is 5 ft 4 in. and weighs 215 lb (163 cm, 98 kg), with a history of cholecystitis and obstructive sleep apnea. She is otherwise healthy. You are covering the PACU, and the PACU RN caring for the patient alerts you that a new patient has arrived. The patient is yet unconscious but breathing easily.
Additional Information if Asked

- Intravenous access: 1 peripheral intravenous
- Urine output: 45 mL/h, yellow urine in Foley collection bag
- No intraoperative complications
- Estimated blood loss: 20 mL
- Fluids received: 2 L of crystalloid over 3 hours
- Wound dressing appears dry
- Patient is currently on 4-L oxygen via face mask
- The postsurgical plan was to extubate the patient’s trachea and observe overnight.

Information for Facilitator/Simulator Operator Only

Background and Briefing Information

Participant is handed over the case of a patient that has just undergone a laparoscopic cholecystectomy and is now in the PACU. After handoff of patient care, the patient develops hypoxia, inspiratory stridor, retractions, and later minimal breath sounds.

Discussion of Scenario

In our experience with presenting this simulation scenario at UC Irvine for case discussion and high-fidelity simulation, we have found that this scenario may be easily tailored to participants of varying training levels. Although we may not advance the scenario beyond stable ventricular tachycardia for junior participants, we will progress to cardiac arrest for more senior participants. Topics for debriefing include the differential diagnosis for acute postoperative hypoxia, inspiratory stridor, increased work of breathing, and management of ventricular tachycardia and advanced cardiac life support protocols. We find it imperative that confederates clearly note the change in sound of the patient’s breathing to assist in the development of the scenario. We have also found it useful to use a Yankauer suction with dilute fake mannequin blood and detergent in it to suggest pink frothy secretions from the oropharynx during suctioning to further clue the participant to the possibility of negative pulmonary edema. Laboratory values are available, should the participant request them, but given the acuity of the situation with laryngospasm, prompt action to secure the airway rather than obtain additional information is taught to be the primary focus.

Patient Data Background and Baseline State

Patient History (Should Follow Standard H and P Format)

A 36-year-old woman with obstructive sleep apnea, obesity, and cholecystitis underwent an elective laparoscopic cholecystectomy.

Review of Systems

Central nervous system: Awake, alert, and oriented before general anesthesia
Cardiovascular: Negative
Pulmonary: Obstructive sleep apnea
Renal/hepatic: Negative
Endocrine: Negative
Hematology: Negative

Current Medications and Allergies

Hospital: hydromorphone patient controlled anesthesia, diphenhydramine as needed for insomnia no known drug allergies
Home medications: None

Physical Examination

General: No acute distress
Weight, height: 215 lb, 5 ft 4 in.
VS: 128/90, P90, RR 12, SpO2 100%
Airway: MP1, neck FROM, TM 93F B
Lungs: Clear bilaterally
Heart: Regular rate and rhythm, no murmurs

Laboratory, Radiology, and Other Relevant Studies

CXR: WNL
Electrocardiogram: NSR, rate 90
Pulse oximeter: 100

ERRATA

The Effects of Simulated Patients and Simulated Gynaecological Models on Student Anxiety in Providing IUD Services: Erratum

On page 284 of this article which appears in the 7th volume, 5th issue of Simulation in Healthcare, in the Statistical Analysis section, “Kruskal-Wallis test” should be replaced with “Wilcoxon test”.

REFERENCE