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

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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 C1 inhibitor deficiency).[7]
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.[8]
   c. This patient presents with stridor and increased work of breathing in the early postextubation period, suggestive of upper airway obstruction.
   d. Treatment of airway obstruction begins with supplemental oxygen and a variety of methods starting from lesser to more invasive. Initial efforts to relieve upper airway obstruction include maneuvers to improve positioning like chin lift or jaw thrust. Continuous positive airway pressure (CPAP) of 5 to 15 cm H_2O can also help. If the patient fails to respond appropriately, nasal or oral airways may be attempted, depending on the situation and level of consciousness. If it is suspected that the obstruction is opioid related, naloxone (0.5 μg/kg intravenous) may be administered.[7] It is important to recognize and treat airway obstruction early to decrease morbidity and mortality.
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.
   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.
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:
      i. V/Q mismatch—no ventilation is a shunt. No perfusion is dead space. Seen in acute pulmonary edema, bronchitis, pulmonary embolus, chronic obstructive pulmonary disease. When the pulmonary vessels sense a decrease in alveolar oxygen, there is localized vasoconstriction, essentially shunting the blood flow to other alveoli with a higher oxygen supply.
      ii. Shunt—no improvement with supplemental oxygen. Most commonly due to atelectasis in the postoperative period.[9]
      iii. Low FIO_2—seen in high altitudes where the atmospheric pressure is low and total oxygen inhaled is less than at sea level (21%).
      iv. Hypoventilation—respiratory depression/arrest secondary to opioids, obesity hypoventilation syndrome, and residual neuromuscular blockade.
      v. Diffusion abnormality—seen in chronic obstructive pulmonary disease, interstitial lung disease, and pulmonary edema.
   b. The main course of action initially is to secure the airway because there is impending airway compromise in patients that are unconscious and have difficulty breathing. Ultimately, once airway is secured and adequate oxygenation is provided, the provider must diagnose and treat the underlying cause.
   c. Participant should be aware of the concept of V/Q mismatch and the difference between shunting and dead space. Generally, supplemental O_2 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 1. Simulation Scenario

State	Patient Status	Student Learning Outcomes or Actions Desired and Trigger to Move to Next State	
1. Baseline (0:00)	Patient is hemodynamic ally stable in the PACU 5 minutes postoperatively	Learner actions	Operator
	HR 85	○ Handoff of care	○ Patient is on 5-L face mask with increased work of breathing
	BP 120/70		Teaching points and objectives
	RR 10		○ SBAR handoff technique
	Spo_2 99%		Trigger: Handoff completed
	5-L face mask oxygen		
	Temperature 36.7°C		
	Stridor, minimal breath sounds, retractions		
2. Hemodynamics begin to deteriorate (:30)		Learner actions	Operator
	HR 120	○ Prepare to treat/diagnose tachycardic and hypertensive patient	○ Nurse states "increased retractions noticed"
	BP 150/80		Teaching points and objectives
	Spo_2 94% on 5-L O_2		○ Differential diagnoses of elevated blood pressure and pulse
	RR 15		○ Treatment of tachycardia
	Temperature 36.7°C		○ Continuous monitoring of the patient
	Increased stridor, retractions, and absent breath sounds		Trigger: Increased work of breathing
3. Marked hypertension and tachycardia (1:00)	Increased work of breathing and desaturation	Learner actions	Operator
	HR 145	○ Treat hypoxia with oxygen by face mask	○ BP/HR increases, and O_2 decreases
	BP 170/80	○ Send laboratory tests: blood gas, chest x-ray	Teaching points and objectives
	Spo_2 90% on 5 L		○ Discuss differential diagnosis of increased work of breathing and hypoxia in a postoperative patient
	RR 20		Trigger: Appropriate treatment of hypoxia
4. Worsening desaturation (1:30)	Breath sounds decrease and retractions decrease	Learner actions	Operator
	HR 80	○ Interpret laboratory results	○ If laboratory results are requested, give laboratory values
	BP 130/80	○ Detect impending respiratory failure	Teaching points and objectives
	Spo_2 80% on 5-L O_2		○ Management of hypoxic patient
	RR 30		○ Order laboratory values including hemoglobin, electrolyte panel, and arterial blood gas
	Temperature 36.6°C		Trigger: Appropriate management of hemodynamics/vitals
5. Premature ventricular contractions (PVCs) begin (2:00)	Respiratory exhaustion with agonal inspiratory efforts	Learner actions	Operator
	HR 54	○ Recognize respiratory failure	○ Nurse may state the patient has agonal inspiratory efforts
	BP 80/40	○ Begin airway maneuvers with nasal/oral airway and positive-pressure ventilation with 100% O_2 via bag valve mask	Teaching points and objectives
	Spo_2 65% on 5-L O_2	○ Diagnose laryngospasm	○ Pathophysiology of upper airway obstruction
	RR 10	○ Improved airway resistance with low dose succinylcholine	Trigger: Assess airway
	Temperature 36.7°C	○ Evaluate for intubation	
	Arterial blood gas reveals respiratory acidosis and hypoxemia 7.2/59/65/26		

(Continued)

TABLE 1. *(Continued)*

State	Patient Status	Student Learning Outcomes or Actions Desired and Trigger to Move to Next State	
5. PVCs begin (2:00)	Respiratory exhaustion with agonal inspiratory efforts	Learner actions	Operator
	HR 54	○ Recognize respiratory failure	○ Nurse may state the patient has agonal inspiratory efforts
	BP 80/40	○ Begin airway maneuvers with nasal/oral airway and positive-pressure ventilation with 100% O_2 via bag valve mask	Teaching points and objectives
	Spo_2 65% on 5-L O_2	○ Diagnose laryngospasm	○ Pathophysiology of upper airway obstruction
	RR 10	○ Improved airway resistance with low dose succinylcholine	Trigger: Assess airway
	Temperature 36.7°C	○ Evaluate for intubation	
	Arterial blood gas reveals respiratory acidosis and hypoxemia 7.2/59/65/26		
6. Cardiac arrest (optional segment for experienced participants) (3:00)	Ventricular fibrillation with no pulse and continued desaturation	Learner actions	Operator
	HR 180s	○ Recognize cardiac arrest with ventricular fibrillation	○ "Patient no longer has pulse and is no longer conscious."
	BP no BP read	○ Call for crash cart if not already present	Teaching points and objectives
	Spo_2 40% on 5-L O_2	○ Order chest compressions immediately and run code blue per 2010 advanced cardiac life support guidelines	○ Managing cardiac arrest
	RR 0		
7. Vitals improve (4:00)	HR 100 sinus with occasional PVCs	Learner actions	Operator
	BP 150/90	○ Recognize laryngospasm	○ "Improved chest excursion"
	Spo_2 88% on 100% oxygen via bag mask valve	○ High peak inspiratory pressure noted	○ Suction patient's airway with Yankauer that has pink tinged bubbly fluid in it (can be made from diluted fake blood and detergent or detergent and food coloring) to indicate pink frothy secretions
	Temperature 36.5°C	○ Notify for help	Teaching points and objectives
	Capnogram reveals good CO_2 curve	○ Call for crash cart	7cir; Recognize laryngospasm and treat with positive-pressure ventilation, low dose succinylcholine
	Bilateral coarse breath sounds		Trigger: Pink frothy secretions along with pulmonary edema on CXR
8. Resolution (6:00)	HR 100 sinus with occasional PVCs	Learner actions	Operator
	BP 150/90	○ Continue to treat upper airway obstruction with positive-pressure ventilation	○ "Patient continues to have pink frothy secretions"
	Spo_2 88% on 100% oxygen via bag mask valve	○ Suction airway for frothy pink secretions	Teaching points and objectives
	Temperature 36.5°C	○ Continue to monitor vitals	○ Discuss NPPE
	Capnogram reveals good CO_2 curve	○ Evaluate patient for intubation vs. noninvasive CPAP, await resolution	Trigger: Appropriate management of upper airway obstruction and NPPE
	Bilateral coarse breath sounds	○ Discuss crises resolution care	

drying. FIO_2 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.[10] 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.
9. Describe the management of a patient after crises resolution (PC, MK, PLI, CS, PR, SBP).
   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.

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
4. Recognize hemodynamic instability and premature ventricular contractions with oxygen desaturation and order 100% O_2 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

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.[8]
   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.

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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; P_{CO_2}, 59 mm Hg; P_{O_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, Spo_2 100%

Airway: MP1, neck FROM, TM > 3 FB

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

Khadivzadeh T, Erfanian F. The effects of simulated patients and simulated gynaecological models on student anxiety in providing IUD services. *Simul Healthc.* 2012;7:282–287.